THE

SCIENTIFIC WORKS

OF

C. WILLIAM SIEMENS, KT.

F.R.S., D.C.L., LL.D.

CIVIL ENGINEER.
UNIFORM WITH THE PRESENT WORK.

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CIVIL ENGINEER.

A COLLECTION OF

ADDRESSES, LECTURES, ETC.

EDITED BY

E. F. BAMBER, C.E.

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ETC.
SIR WM. SIEMENS, F.R.S.

SOCIÉTÉ ANONYME CONTINENTALE POUR LES MACHINES À VAPEUR RÉGÉNÉRÉE, SYSTÈME SIEMENS.


Messieurs,—Dans mon rapport de Septembre passé j'ai indiqué comment le principe de notre invention a été reconnu graduellement par les autorités de la science. J'ai indiqué aussi les progrès techniques de l'invention et les difficultés pratiques qui restaient encore à résoudre pour pouvoir lancer cette entreprise sans restreint dans le commerce.

Il est inutile à présent de revenir sur le principe.

Quand au progrès dans la construction mécanique de la machine je peux vous annoncer plusieurs faits bien intéressants pour l'avenir, quoique je doive regretter que les nouvelles machines de 10 et 20 chevaux, qui ont été en train depuis l'été passée ne soient pas encore tout-à-fait achevées, et par conséquent, que je ne suis pas en mesure de pouvoir vous communiquer des résultats décisifs.

Jusqu'à présent nous avons lutté encore contre deux inconvénients mécaniques dans notre système, qui étaient plus ou moins prononcés dans les 5 machines qui ont fonctionnés dans les années passées.

Il s'agissait de trouver une construction de vases de chauffe
telle que la surface échauffée pouvait être augmentée considérablement sans inconvénients, et même sans risque pour leur solidité.

J'ai la satisfaction de vous annoncer que cette difficulté a été effectivement vaincue. Des vases de la nouvelle construction ont été appliqués à la machine de Gateshead qui marche régulièrement à présent dans l'usine de Messieurs Hick et Son à Bolton, avec une force à peu-près au double de celle qu'elle avait avant à Gateshead. Les fourneaux mobiles répondent encore à mes expectatives, et je crois en effet que l'appareil de chauffage est rendu à présent tout-à-fait convenable et pratique. Je me propose de faire faire un rapport spécial de cette machine par des ingénieurs indépendants, et de vous l'envoyer prochainement.

Un second inconvénient grave dans notre système consistait dans une contrepression très forte au piston du cylindre régénérant vers la fin de chaque coup. Cette dernière circonstance est d'une grande importance pour la partie mécanique de la machine, en ce que le frottement produit par cette contrepression, mange une portion considérable de la force totale de la machine même, et par cela il était nécessaire de construire les organes principaux de la machine bien plus forts que la transmission de sa force réelle n'exigeait. Cette contrepression s'augmentait en proportion avec la capacité relative du cylindre régénérant; mais tandis que les considérations mécaniques étaient en faveur d'un petit cylindre régénérant, les considérations de l'économie du système me poussaient à augmenter encore cet organe important. Dans cet état de choses, je pensai de remédier à cette contrepression instantanée, et le premier expédient qui se présentait, consistait dans un levier à poids oscillant. Cet expédient fut essayé à Stettin il y a un an, et l'effet produit sur la machine était tellement avantageux, que je me décidai à l'appliquer partout et d'en profiter encore pour augmenter l'économie, en augmentant la capacité du cylindre régénérant.

Les machines de 10 chevaux maintenant en train d'exécution, étaient dessinées avec cet organe; mais comme c'était une période de transition des constructions hasardées aux constructions assurées, il arriva que je trouvais bientôt un second moyen bien plus parfait, dans la forme d'un quatrième cylindre de distribution, par lequel la force de la machine sera augmentée, et le point mort ôté. Aussi peu de temps après, se présenta à mon idée le remède radical, par
lequel les capacités justes du cylindre régénérateur sont réduites à la moitié, en proportion des cylindres moteurs, le point mort ôté, et le poids (et par conséquent le prix) de la machine réduit de 20 à 25 %. Dans le même temps les cylindres moteurs recevront des pistons ordinaires au lieu des stuffing-box (presse-étoupe).

Les constructions des machines de 10 chevaux étaient trop avancées déjà pour les arrêter, exceptée celle de Seraing. Pourtant on arrêta la construction des poids oscillants partout, et la machine de Paris, chez Monsieur Anjoubaud, étant la plus avancée, je me proposai de l’essayer tout bonnement sans cet organe, pour pouvoir juger mieux le chemin à suivre pour les autres machines. Ces essais provisoires ont été contrariés beaucoup par des fuites accidentales dans la chaudière, et par d’autres défauts matériels dans la construction de la machine, défauts qu’on va enlever bientôt.

Ces expériences m’ont donné la certitude cependant qu’il faut diminuer la grandeur du cylindre régénérateur, en appliquant un des remèdes déjà indiqués. Pour la machine en construction à Gênes on va exécuter un plus petit cylindre régénérateur, et à Berlin on est en train d’appliquer le quatrième cylindre de distribution. Les cylindres moteurs de la dite machine de Paris et surtout les appareils de chauffe fonctionnent à présent très bien.

La machine de 20 chevaux est presque finie et en train d’être montée dans les usines de Messieurs Samuelson pour l’essayer. Elle est fournie de quatre cylindres, et doit fonctionner bien, quoiqu’elle n’est pas construite selon les dernières améliorations.

Je dois ajouter que la propriété de ces améliorations a été assurée à la Société par des brevets en Angleterre, en France, et en Belgique. J’ai aussi fait construire un modèle de la machine perfectionné pour le faire ajouter au brevet des États-Unis.

La machine portative, la première de notre construction renvoyée de Paris, a été nettoyée, et est en état de fonctionner dans un local spécial à Londres (Scotland Yard). Les vases de chauffe et les toiles métalliques se trouvent encore intacts, mais la machine n’est pas perfectionnée pour fonctionner utilement.

Il est à regretter que la machine de Stettin ne marche pas à présent, à cause d’une contestation entre les constructeurs et Messieurs Bertheim sur la cause de l’accident par lequel cette machine fut arrêtée l’année passée. Il paraît qu’un des boulons dans la tête de la bielle s’étant devissé par soi-même, fut cause de
l'accident. On se hâta de faire les réparations nécessaires, mais on se brouilla avant de la rémettre en marche. Messieurs Siemens et Halske espèrent pourtant régler cette affaire bientôt. Bien que le nouveau perfectionnement de la machine soit d'une grande importance pour des machines fixes, il est d'une condition presque essentielle pour l'application de notre système à la navigation, application de la plus grande importance. Dans le bureau de Londres il y a eu beaucoup d'activité pour préparer les dessins complets de plusieurs machines fixes, d'une machine portative de quinze chevaux, d'une machine maritime de 30 chevaux, et une autre de 60 chevaux est commencée.

Ces études nous seront d'une grande utilité au moment que notre affaire prendra son développement, lequel dépendra en Angleterre dans une grande mesure de la réussite de la machine de 20 chevaux.

En attendant il est nécessaire que la Société puisse construire au moins une machine, de 15 chevaux, des plus perfectionnées, et qu'elle s'engage jusqu'à un certain point pour la réussite de la première machine navale.

Je suis d'avis que la Société devrait concentrer ses moyens, bien faibles dans ce moment, autant que possible pour arriver en Angleterre à ce point indiqué, parce qu'il y a ici des constructeurs de premier rang qui s'intéressent vivement à la réussite de notre entreprise, et qui nous donnent plus de garantie pour la bonne exécution, à des meilleures conditions que nous pourrions trouver ailleurs. Outre cela les constructions ici se font sous mes yeux, et mes relations amicales avec les constructeurs anglais, et mon crédit personnel, forment encore des avantages notables pour la Société.

La maison Hick et Son est déjà embarquée avec nous par le traité du 1er Mai 1857. Messieurs Samuelson et Cie. sont décidés à faire les essais de la machine de vingt chevaux à leur frais pour avoir l'occasion d'étudier mieux le nouveau système dans l'idée de l'appliquer à la marine.

En résumé je n'ai pas aucune hésitation à dire que notre entreprise se trouve maintenant dans un état de progrès rationnel et solide.

Il est probable que cette espèce de progrès ne reponde pas aux expectations impatientes et purement spéculatives d'une fraction de nos actionnaires ; mais je dirai qu'il n'est pas raisonable de
S’attendre l’accomplissement d’un but aussi vaste que le nôtre par des moyens tellement limités, sans des délais et des contrariétés de différents genres. L’histoire de toutes les inventions importantes est l’histoire d’un progrès graduel et d’une persévérance éclairée de la part des entrepreneurs. Pour ma part j’ai dévoué à cette affaire non seulement la plus grande partie de mon temps (et mon temps est un capital dans la position où je me trouve), mais j’ai dévoué encore tout l’argent que j’ai tiré de la Société et celui de mes moyens particuliers. Je crois qu’il m’est permis de faire valoir cette circonstance, plutôt personnelle, mêlée à un rapport officiel parceque je la regarde comme un titre à votre confiance, et comme une assurance pour la réussite complète de notre entreprise.

Londres, 4 Mai, 1857.

(Signé) C. W. Siemens.

DEEP SEA TELEGRAPHS.

By C. W. Siemens.*

On coming forward to address you on the subject of deep-sea telegraphs, it is necessary for me, in the first place, to define my subject by drawing the distinction between deep-sea lines and submarine telegraphs in general.

The characteristics of a shallow sea-line are, firstly, that the iron sheathing usually applied has abundant strength to support the cable during the operation of submersion, as also for raising the same again to the surface for the purposes of repairs; secondly, that it admits of being divided into sections of convenient lengths for the transmission of messages; and lastly, that it lies within reach of abrasion from currents, or even ship’s anchors, and has to be made strong enough to resist these mechanical agencies.

The deep sea lines, on the contrary, lie virtually beyond the reach of accident, and in perfect calm at the bottom of the sea; they require, therefore, less absolute strength, but a greater amount of relative strength, to support their own weight in sea.

water. They generally do not admit of being subdivided into sections, and, therefore, a difficulty arises in regard to them which does not exist in the case of shallow sea cables, respecting the transmission of messages through them at a sufficient rate. Another consideration is that deep-sea cables have to bear a great amount of hydrostatic pressure, and we have to consider what the effect of that pressure is upon the cable. Commercially speaking, we may say that there is this difference between the two cables—that shallow sea cables, or cables which lie in water from 50 to 200 or 300 fathoms deep, have generally proved commercially successful, whereas deep-sea cables, properly speaking, have not done so. In fact, I may say, that at this moment there is not a single deep-sea line which has proved permanently successful.

Within a few weeks the great experiment of a second Atlantic cable will be repeated, and, it is to be hoped, in the interest of progress and science, as also for the sake of those who have invested so largely in the undertaking, that it may be attended with success. It may, indeed, be safely affirmed that the utmost care has been bestowed upon the manufacture of this cable, and that the chances of its success are infinitely greater than they were on the last occasion, although there may be some reasonable grounds for criticism, particularly as regards the mechanical structure and durability of the outer sheathing. The short space of an hour would not nearly suffice to treat this subject in anything like an exhaustive manner, but I shall, at any rate, endeavour to point out the principal points of interest involved in the construction and treatment of deep-sea cables.

First let me allude to the conductor. This consists generally of a strand of three or seven copper wires, which are twisted together so as to form a metallic rope. Deep-sea cables contain generally only one conductor, as this is sufficient for the purpose of establishing a communication; but multiple deep-sea cables have also been laid with temporary success. The conductor of a submarine cable is the medium of the transmission of the electric current; it also acts as the internal lining of a Leyden arrangement of great length, in which the gutta-percha or other insulating material employed acts the part of the glass jar, and the sheathing of the cable the part of the external tinfoil covering. Considering the extraordinary aggregate surface of long submarine
lines, the effects of the change produced by that surface are very considerable. The amount of charge varies according to the surface of the conductors, and is inversely proportionate to the thickness of the insulating material. Therefore if we could by some means or other double the conductivity of a conductor of a given size, the rate of transmission through the same would exactly be doubled; from which it at once appears how important it is to make a conductor of the least possible size for a given amount of conductivity. The best conductor to answer this requirement would be a single cylindrical wire of silver, which is known to be the best conductor; but a single wire would in the first place be objectionable, because a break or flaw in it would destroy the efficiency of the whole line, and the employment of silver would not be warranted, because a cheaper metal, copper, in its pure state, has very nearly the same conductivity.

The following table shews the conductivities of various metals:

Table of the Conducting Powers of Metals.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Conductivity</th>
<th>Matthiessen</th>
<th>Siemens</th>
<th>Arndtzen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver</td>
<td>100</td>
<td>58.2</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>Copper, pure</td>
<td>99.9</td>
<td>58.1</td>
<td>Matthiessen</td>
<td>Siemens</td>
</tr>
<tr>
<td>&quot; telegraph</td>
<td>85</td>
<td>49.4</td>
<td>Matthiessen</td>
<td>Siemens</td>
</tr>
<tr>
<td>&quot; Rio Tinto</td>
<td>14.2</td>
<td>8.3</td>
<td>Matthiessen</td>
<td>Arndtzen</td>
</tr>
<tr>
<td>Magnesium</td>
<td>42.3</td>
<td>24.6</td>
<td>Siemens</td>
<td></td>
</tr>
<tr>
<td>Iron, pure</td>
<td>16.8</td>
<td>9.8</td>
<td>Matthiessen</td>
<td></td>
</tr>
<tr>
<td>Platinum</td>
<td>14.2</td>
<td>8.3</td>
<td>Arndtzen</td>
<td></td>
</tr>
<tr>
<td>German silver</td>
<td>7.12</td>
<td>4.14</td>
<td>Siemens</td>
<td></td>
</tr>
<tr>
<td>Mercury</td>
<td>1.72</td>
<td>1</td>
<td>do.</td>
<td></td>
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</tbody>
</table>

Taking silver at 100, pure copper is 99.9, or virtually the same. But the best commercial copper we can get at present for the construction of telegraphs has a conductivity of 85. The Burra Burra copper, a good copper of commerce, has only a conductivity equal to 14, owing to a small percentage of foreign matter. From this it appears how important it is to get copper of the highest conductive quality. Since it would not be safe to use a single wire, owing to the risk of a break occurring, we must use a rope of copper wires of the highest conductivity, and it is important that this rope of wires should be as densely united together as possible. Generally seven wires are twisted together, which arrangement, however, might be improved in conductivity for the
same diameter, if six smaller wires were laid in between the interstices of the larger ones, the object being to get within a given diameter a maximum amount of conductivity.

We come next to the insulating coating, which may be considered as the vital part of a submarine cable, especially the deep-sea cable. The insulating covering of the conductor is that portion of a submarine cable which requires the greatest amount of care. The insulating substances to be found in nature far exceed in number and amount those which are remarkable for their conductivity, and comprise all the earths, silica, glass, porcelain, sulphur, besides bituminous and resinous substances; yet, notwithstanding this vast field for selection, we have as yet found only two substances fulfilling the collateral conditions of admitting to be moulded upon the conductor into a homogeneous and pliable covering, capable of excluding sea water entirely under great hydrostatic pressure. These substances are india-rubber and gutta-percha.

The substance which was used in the first instance for insulating wire, was india-rubber. It has great flexibility, and its insulating power is very remarkable, but it is a substance which is at no time in a plastic state, therefore considerable difficulties are encountered in dealing with it. Gutta-percha was next tried, and from the time when it was first laid in the harbour of Kiel, in 1848, until the present day, it has been the material used in preference to all others for insulating telegraph wires. The circumstance that gutta-percha, at a temperature of 150° Fahr., becomes semi-fluid, is a great point in favour of its application. It can be put upon wire by a process analogous to the making of macaroni or of lead tubes, and by putting several coatings of gutta-percha one upon the other, and combining them by intervening thin layers of a fusible compound known as Chatterton's mixture, the most perfect workmanship is produced, the chances of any flaw or leakage in such a coating being exceedingly small.

As regards insulation, pure india-rubber has an insulating power 40 times greater than that of gutta-percha; but notwithstanding this great superiority, the difficulty of putting it upon wire, and certain other drawbacks to which I shall presently allude, have hitherto prevented its application upon a large scale. Gutta-
percha has a changeable amount of conductivity, that is to say, its conductivity increases with increase of temperature; the temperature at which it is 40 times more conductive than india-rubber is 75° Fahr. The diagram, Fig. 1, Plate 1, shows this remarkable change; the abscissæ represent temperature, and the ordinates relative resistance to the galvanic current.

With regard to the inductive capacity, india-rubber has also the advantage of being superior to gutta-percha in the ratio of 10 to 7.

With regard to fusibility by heat, india-rubber has also a decided advantage over gutta-percha, being capable of resisting the heat of boiling water perfectly, whereas gutta-percha softens at a temperature of 120° Fahr., and melts at 130° or 140°. Great care had, therefore, to be used not to expose gutta-percha covered conductors to the direct radiation of the sun or other sources of heat. With regard to hydrostatic pressure, it has been proved that neither india-rubber nor gutta-percha are in the least altered by great pressure; it may, therefore, be safely assumed that they will remain at the bottom of the deepest ocean perfectly unchanged. No doubt there is compression, and this compression has a remarkable effect upon gutta-percha, as I shall presently show. On the occasion of making a line of telegraph for the French Government, which was put into very deep water, I tested gutta-percha and india-rubber also, in a tank, under a pressure of 300 atmospheres; a remarkable result was produced, shown by diagram Fig. 2, Plate 1. The insulation at freezing-point and at atmospheric pressure is measured by the ordinate at the starting-point of the curve (on the left), and the succeeding ordinates represent the varying electrical resistances due to increase of hydrostatic pressure. It will be observed that under 300 atmospheric pressures the resistance of gutta-percha was nearly three times as great as under atmospheric pressure. I had expected that india-rubber would follow very nearly the same law, but to my surprise, in the case of india-rubber coated wire, the insulation decreased visibly with increase of pressure, returning, however, always to the original high electrical resistance when the pressure was relieved. I then thought that this decrease might possibly be due to the infiltration of water through the pores of the india-rubber; accordingly, I submitted to the test a wire that had been first coated with india-
rubber and then with gutta-percha, the gutta-percha making a complete tube round the india-rubber. This wire followed a law of increase represented by a line between the two, thus clearly showing that we have to deal with a specific quality of the material itself, the precise nature of which has not yet been assigned to any general physical law. For further particulars see Report of the British Association for 1863, page 688.

An important question to be asked in reference to our subject is the following:—Are these substances which we employ for insulating submarine conductors subject to decay? If exposed to air and light they are both very subject to gradual decay, but there is this difference, that gutta-percha becomes brittle by exposure to light and air, whereas india-rubber, at least when put upon copper wire, turns into a viscid liquid and thereby becomes unserviceable; but if submerged, neither of these results takes place; and we may safely affirm that both materials are imperishable when submerged in sea water to any considerable depth. They, nevertheless, undergo a gradual change by absorption of water, unless they are protected by an outer sheathing. Gutta-percha absorbs sea water to a very moderate extent, and in doing so, its conductivity does not sensibly increase. India-rubber, on the other hand, absorbs water at a somewhat greater ratio, and after a full exposure for 100 days to sea water it absolutely begins to dissolve superficially. An experiment, which was continued over 300 days, clearly establishes this result, and goes to prove, moreover, that the rate of absorption is independent of external pressure. For particulars see Proceedings of Institution of Civil Engineers, vol. xxi., page 523. This action may, however, be prevented by the application of an impervious coating, say of tape, saturated with paraffin.

An important advantage in favour of gutta-percha is that joints can be made very perfectly, in fact, joints are now made which are quite equal in insulation to the uniform covering of the wire, whereas, with regard to india-rubber, there is still some degree of difficulty, though I do not mean to say that that difficulty cannot be overcome. There are other substances suitable for insulation which are mostly compounds of india-rubber. A compound of india-rubber and paraffin has been proposed, and its insulation is certainly very remarkable. The compound of india-rubber and
sulphur has also a great insulating property, and has the advantage of being capable of being worked in a plastic state before it is hardened upon the wire by application of heat. It must, however, be admitted that gutta-percha answers every purpose of submarine telegraphy if only care is taken not to expose the cable to heat before it is submerged.

We next come to consider the sheathing, and this also is a very important part of the submarine cable. The protecting sheathing is necessary in order to give strength and protection to the delicate insulated core. The sheathing usually adopted consists of one or two layers of tarred hemp or jute, and a helical covering of iron wires, in the form of a rope. These wires are generally galvanised, in order to prevent, or rather delay, the oxidation of the iron. In the case of the Persian Gulf cable, the iron sheathing is again covered with jute, impregnated with bitumen mixed with sand, which was applied in the molten state, under the direction of Messrs. Bright and Clark.

In the case of the Toulon and Algiers cable, each wire was previously and separately covered with tarred hemp, and then formed into a rope as usual. This mode of covering did not answer well in that instance, the hemp was eaten rapidly away by the marine insect, xylophaga, and there remained only a loose filigree work of wires surrounding the insulated core, offering no protection to the same, and hastening, on the contrary, its failure. A similar sheathing has, I think, unfortunately been adopted for the new Atlantic cable; but it is said, in defence of the same, that the marine animal in question does not exist in the Atlantic; I hope sincerely this may be the case, and also that the great strain which must be brought upon the cable in submerging the same, may not injure the core through the partial unwinding and consequent elongation of the helical sheathing, which must take place, and which constitutes, in my opinion, a very serious objection to the application of such a sheathing for deep-sea lines. Other sheatings for deep-sea cables have been proposed. In one proposed by myself, the core is covered with a double layer of best hemp, laid on with moderate twist running in opposite directions, under considerable tension. The hemp is covered, while under tension, by a sheathing of copper strips, which, tightly grasping the hemp, prevent its contraction, and it then forms a complete
flexible tubing. The copper is mixed with a certain portion of phosphorus, which, according to Dr. Percy's experiments, corroborated by my own experience, is remarkably durable in sea water. A cable of this description has been laid in the Mediterranean, where it now forms one of the links between Algeria and Europe. Small cables of this description have been adopted by the Prussian, Italian, and other Governments, for military purposes, owing to their lightness and strength, combined with remarkable flexibility. The conductor of these cables consists of three steel wires, and its outside diameter does not exceed the eighth part of an inch. In making permanent shallow sea cables on this principle, I apply first an iron sheathing, consisting of comparatively thin wires, and upon that, the sheathing just described in which zinc takes the place of the phosphoretted copper. Another covering which has been proposed consists of reeds joined up end to end, and put on like iron wire, producing a rope of very small specific gravity. Different from all these is the cable proposed by Mr. Allen, which has no sheathing whatever, the conductor itself being made strong by being compounded of copper and steel wires. Steel being a very inferior conductor, it is evident that Mr. Allen's cable would not compare favourably for great lengths with others, as regards power of transmission; and for my own part, I should not think it safe to lay down a cable without any external sheathing, which I consider necessary, not only to give strength, but also to protect the insulating material against animals and against abrasion.

We come next to the subject of testing. One of the principal conditions to insure the success of telegraphs, and particularly of deep-sea lines, consists in the application of a complete system of electrical testing at every stage of progress of manufacture and submersion. In the early history of submarine telegraphs this important work was very imperfectly accomplished, and consisted chiefly in methods for the determination of faults, instead of their prevention, and by insisting upon a certain standard of perfection at the different stages of manufacture. For instance, the insulation of the first Atlantic cable was so exceedingly defective before it was coiled on board ship, that it should never have been laid at all, as will be seen from comparison with subsequent cables, shown in the following table:—
The first Atlantic cable is represented by 12, that is to say, the electrical resistance of the insulating coating of a mile of the cable was equal to 12 millions of Siemens units; the Red Sea, by 30; the Toulon and Algiers, by 60; the Malta and Alexandria, by 120; the Bona and Marsala, by 350; and the new Atlantic, by 400, the latter being, however, more thickly covered; so that you see enormous strides have been made without any change of material, simply by increased perfection in the manufacture. But it must also be attributed to the application of proper tests during every portion of the manufacture—tests applied by the engineer who is responsible for the work, and who insists upon a certain standard. In the list to which I have referred, we see that there is a very marked improvement in the case of the Malta and Alexandria line. It may, indeed, be said that this was the first line that was ever made under a proper system of tests. The system then adopted and carried out under my immediate charge (by order of the British Government), has since been applied to other cables with only some modifications of details; and with your permission, I will give you a short account of what those tests were.

It was determined in the first place that all tests should be referred to a single standard of comparison, this being the resistance of a column of mercury of 1 millimetre sectional area, and 1 metre length at freezing point, which standard is now generally known as Siemens unit, having been first proposed by my brother, Dr. Werner Siemens, of Berlin. Instead of estimating the insulation of the gutta-percha covering by the deflection of a galvanometer, as had previously been done, its conductivity per knot of length was expressed in these units, and values were obtained which were independent of the galvanometer and other testing instruments employed, and admitted of direct comparison between
all the results obtained. But the conductivity of gutta-percha varies in an extraordinary ratio with change of temperature, as will be seen by the diagram, Fig. 1, Plate 1, in which the abscissæ represent temperatures, and the ordinates the corresponding electrical resistance; it also varies by electrification of the covering, according to the length of time the current has been active, in the ratio represented in diagram, Fig. 3, Plate 1. In order to obtain standard tests, it was necessary to have them all taken at a uniform temperature, which was fixed at 75° Fahr., being the highest temperature to which the cable was likely to be exposed when laid in a tropical sea.

For this purpose the core to be tested was immersed for twenty-four hours in water-cisterns, which were kept at the standard temperature, when each coil of a mile in length was required to show a gutta-percha resistance of not less than 90 millions of units. The coils of core were then transferred to Reid's pressure tanks, and again tested at the standard temperature, and under a pressure of 600 pounds per square inch. I stated before that increase of pressure ought to increase the electrical resistance of gutta-percha, and accordingly it was found that there was an increase of something like 20 per cent. each time when the pressure was applied, and unless that increase took place, it was inferred that the gutta-percha coating was not as perfect as it ought to be. Each coil was tested separately, and those that did not fulfil the conditions insisted upon, were put aside. The actual resistance obtained in each coil carrying a distinctive number was marked against it, and it was then sent to the cable works. There the cable was tested as each coil was added to its length, and it was required that the total resistance of the whole should be equal to the calculated total resistance of all the parts of which it was composed. There correction had to be made for temperature, because it was not found possible to heat the tanks into which the finished cable was received, to the standard temperature. A very perfect core was thus obtained, and the result has proved that though the external covering may be faulty, being an ordinary iron sheathing, the insulation has never given any trouble, and I believe it is now as good as it was at the beginning. The principal instruments used were Professor Wheatstone's bridge arrangement, suitably modified, and Dubois' galvanometer, which is so delicate as to
detect exceedingly small traces of electric current; but since then Professor Thomson has brought out a reflecting galvanometer of still greater delicacy, which is now used in preference. In testing the Marsala cable we have introduced another instrument, which combines the functions of the galvanometer and of the bridge. It is a differential galvanometer, one coil of which is mounted upon a carriage, and is moved by a micrometer screw to such a point that the effect of the two currents balance each other. The resistance to be measured forms part of the fixed coil circuit, and as this resistance increases, the second coil must be moved back to diminish its influence also upon the needle. The moveable coil is acted upon by a constant battery, and the extent of motion imparted to it, as read off upon a scale, is the measure of the unknown resistance. It is a very convenient instrument, especially for taking great ranges of resistance.

We now come to the subject of coiling on board ship. The cable on leaving the sheathing-machine, passes into a circular or oval tank, where it is kept covered with water for the convenience of testing, because it is only when under water that it can be well tested. It is next coiled into circular iron tanks on board ship, from the outside to the centre, then passing sharply from the smaller circle to the larger, then back again in a complete spiral, and so on. Formerly cables were coiled into dry ships' holds, but in the case of the Malta and Alexandria cable, water-tight tanks were first suggested. These were not adopted, however, until it had been proved by means of some special electrical tests, which I had provided, that a spontaneous generation of heat was taking place within the mass of the cable, which threatened to melt its insulating covering. The cable had then to be coiled over into a ship, which was provided with water-tight tanks, and ever since, such tanks have been specially provided.

The Chairman. Is it so in the Great Eastern?

Mr. Siemens. Yes, the Great Eastern has been provided with enormous iron tanks to receive the cable. The special means devised to tell the temperature at different points within the mass of the cable, consisted of small coils of insulated copper or platinum wire, encased in iron tubes, which were deposited here and there between the layers of cable, with leading wires from them into the testing-room. The resistance of each coil at standard temperature
being fixed at 100 units, and the law of increase of resistance by rise of temperature of these metals being also known, the tempera-
ture of each coil could be easily determined at any time in
measuring its electrical resistance. These resistance thermometers
might be applied with advantage in many cases where it is de-
sirable to ascertain the temperature of inaccessible places, as for
instance, in warehouses and on board ship, where hemp, coals, and
other self-inflammable goods are stored.

One of the most important preparatory operations in the laying
of cables is that of ascertaining the nature of the ground upon
which the cable is to rest, for, however perfect the cable may be,
if it is laid upon unknown ground it may very soon come to grief.
With regard to shallow seas, there is no difficulty in ascertaining
the nature of the ground on which the cable is to rest, whereas in
a depth of 2,000 fathoms I have known a single sounding occupy
five or six hours. Another drawback as regards deep sea sound-
ings consists in the difficulty of identifying the place again, no
landmarks being visible. It must always, therefore, be to a certain
extent a matter of uncertainty what is the depth below the ship in
the open sea. In going across the Atlantic the depths do not vary
materially, as there appears to exist a great plateau on which the
cable may be laid; but in deep seas formed by volcanic action,
such as the Mediterranean, the depths are very uncertain. It is
not impossible, however, that an instrument may be brought to
perfection by which the depth below the ship’s keel may be indi-
cated in the cabin. Such an instrument would be of material
service in warning the telegraphic engineer of changes in the
depth of water in paying out deep-sea cables. The few trials
which have been made have amply proved the principle of the
instrument, and given promise of ultimate success.

The patient care and unremitting attention which the prepara-
tion of a deep-sea cable necessitates, in order to avoid the chance
of a single flaw or error in the arrangements, contrasts singularly
with the exciting operation of submerging the same. A well pro-
portioned cable of ample strength, and a good paying-out appa-
ratus, do much to assure the acting engineer that the cable will
sink without being unduly strained either during its descent or
after it has reached the bottom; but an entanglement in the cable
tank, the breakage of a single wire in the spiral sheathing of the
cable, an accident in the machinery employed, or an unknown chasm at the bottom, may at any moment cause the entire destruction of the cherished work.

The machinery employed in paying out cables consists of two principal parts—the guide apparatus and the brake apparatus. The guide apparatus consists of a solid cone or cylinder in the eye of the cable, and of a series of iron rings fastened above the cable in crinoline fashion, this being the apparatus first introduced by Newall and Co., and generally employed. The cable, on rising from its coil, is confined in its motion between the cone and the guide rings, and is thereby prevented from twisting round itself and forming kinks. The cable passes through troughs and over pulleys, which should always be well housed, from the hold along the deck, over the brake wheel and a dynamometer wheel, over the stern-pulley into the sea.

A variety of opinions exists with regard to the apparatus which ought to be employed for the paying out of cables, and the amount of retaining force which should be applied, depending in its turn upon the curve which the cable assumes in sinking to the bottom. To my mind it appears perfectly clear that, supposing the vessel to proceed at a uniform rate through the ocean, the line which the cable assumes at any one time during its progress must be a straight line. Suppose you have a cable of the specific gravity of 2, this will descend say 40 feet per minute through the water, falling laterally; and if the ship moves forward 40 feet during that time, the result will be that the cable will assume an inclined direction from the ship to the bottom of the sea without any curvature, forming an angle of 45° with the horizon.

(The Chairman: To a certain distance, till the terminal velocity is arrived at, there will be a curvature.)

I suppose that the cable assumes its maximum velocity from the moment it touches the water, its acceleration having been accomplished in descending through the air to the water level; in fact, the time for accelerating the speed must be proportionately exceedingly small, considering that a cable may be an hour and a half, or two or three hours, before it reaches the bottom, and that the maximum velocity which the resistance in the water permits it to acquire would be attained by a free fall through 5 feet of space.

The cable is acted upon by two forces, one force tending to
drive it down, which is its own absolute weight in sea-water, and is balanced by the resistance to lateral displacement offered by the water; and the second force tending to make the cable slide, by virtue of its own weight in sea-water, down the inclined plane which is produced by its position in the water, and which has to be balanced by a retaining force applied to the brake-wheel on board ship. If this cable was left at any one moment to itself, it would slide, as you may observe in the case of a stick which is a little heavier than the water in which it descends in a slanting direction. The strain to be applied at the ship must be equal to the tendency of the cable to sliding, and this force can be accurately determined if the depth and the specific gravity of the cable are known. This question has been ably treated in a paper read by Messrs. Longridge and Brooke before the Institution of Civil Engineers. The amount of retarding force to be applied to a cable in paying it out has to be equal to the weight in sea water of the cable in question, reaching from the ship down to the bottom of the ocean, in order to prevent sliding in either direction, but this amount of retarding force has to be varied according to the amount of slack which it is intended to give to the cable when laid. If, for instance, you have a cable of double the specific gravity of water, weighing in water one ton per mile, and pay it out into a depth of two miles, you will have to apply a brake-force equal to two tons, or the cable will begin to run overboard with a velocity exceeding that of the vessel through the water.

*The Chairman:* Do you know the strength of the Atlantic cable?

*Mr. Siemens:* I do not know exactly the weight in tons. I believe it is equal to supporting 9 or 10 miles of its own weight in water, which is amply sufficient for all purposes.

The angle of descent of a cable is simply the result of the two velocities to which I have referred. If the rate of progress of the ship is four times as great as the rate of descent, there will be an angle of 1 in 4, or 22\(^\frac{1}{2}\)°; but if the rates are equal, there will be an angle of 1 in 1, or 45°; or if the ship's velocity is constant, it will be determined wholly by the specific gravity of the cable itself, and the nature of its surface, which will determine its rate of descent laterally through the water. If a cable is simply covered with hemp, its resistance is excessive, as may be easily proved by
drawing a hemp rope quickly through water. Such a cable it is difficult to submerge in deep seas with a sufficient amount of slack; it will run out with an inclination of perhaps 10° with the horizon, and although the brake may be entirely loosened, it will not slide backward through the water, but will reach the bottom in a straight line, and if there be any irregularities in the bottom, it will have to span them, and be destroyed before long in consequence of a constant strain and complete exposure to corrosive action. Again, if the cable is too heavy, the retaining force would be too great, and serious difficulties would arise. If you suppose a 5-ton cable to be laid to a depth of 2,000 fathoms, a resistance would be required equal to nearly 7 tons. No doubt a sufficiently powerful brake might be constructed, but not even the "Great Eastern" would be able to make headway with such a retarding force behind it, steamers would have to be used to drag the ship forward; but if any accident should occur, if one of the heavy wires should break, become entangled, the signal "stop" would have to be given, the tug steamers would veer round before the wind, the cable vessel would be dragged backward by the strain of the cable, and collisions and great mischief might arise. A deep-sea cable, then, must neither be very heavy, nor very light, or it will fail. Experience tends to prove that a cable of from one and a half to twice the gravity of water answers the purpose best. In this respect, the new Atlantic cable is very perfect; it has a specific gravity of about 1·6, combined with great strength; but on the other hand, it is liable to the accidents through broken wires to which all spiral cables are subject, and, moreover, its durability when laid is not likely to exceed that of the Toulon and Algiers cable, which was of the same construction. The cable to which I referred before, sheathed with copper, has about the same specific gravity as the new Atlantic cable, but is free certainly from the above-named objections. I ought not to proceed, however, without alluding to a failure which took place in submerging a cable of this description between Oran and Carthagena last year. Passing over an accident of a purely mechanical nature which occurred in the first attempt, the cable was laid successfully from Oran to Carthagena, a distance of 116 miles, but broke a few hours afterwards, 10 miles distant from Carthagena. According to the soundings which had been previously taken by the French Ad-
miralty in the usual way, the ground presented a moderate incline (shown by the dotted lines on the diagram Fig. 4, Plate 1), but which afterwards turned out to be a great chasm. A cable being laid over a chasm like that, has a poor chance of being taken to the bottom, because whatever slack you may give, and there was 28 per cent. given in this instance, it all slides down in a straight line, and accumulates at the bottom. Supposing the cable suddenly to touch upon a promontory, it will at once be arrested there and remain suspended in a straight line, because the tenacious mud or ooze which covers the bottom of the ocean, prevents the loose or spare cable on both ends of the suspended piece from sliding towards it to allow of its sinking to the bottom, and the piece of cable thus suspended, under great strain in a catenary curve of perhaps two miles length, must break sooner or later. This cable was, however, partially recovered from a great depth, and has since been submerged between Marsala and Bona, forming a link in the chain of telegraphs which unite France with its African dependency.

It may here be reasonably objected that a cable ought never to have been laid upon such ground, and, further, that if the ground could not be avoided, the soundings ought to have revealed the chasm across which the cable fell, in order that special precautionary measures might have been adopted to meet the case. The answer is, that a line of soundings which had been taken carefully by the French Admiralty showed no such chasm, but that unfortunately the pilot vessel mistook its course during the laying of the cable, and approached Carthagena in a line deviating by about two miles towards Cape Pallos from the line of sounding. The coast about Carthagena, being of a decidedly volcanic formation, might certainly have been avoided altogether, and a much safer landing place might have been found near Cape de Gate; but although this had been strongly urged, it had been refused to the contractors owing to some previous international arrangement which was not to be disturbed. This accident proves, however, the great necessity for careful and more extensive soundings than those which have hitherto preceded the establishment of deep-sea cables; it also goes to prove, that in passing over very irregular ground, it is not sufficient to allow considerably more cable to run overboard than to cover the distance passed over by the cable-ship. The
only effective method of laying the cable to the bottom of a chasm would be to stop the vessel over it until the cable assumes a vertical position, and then to proceed slowly onward.

It is desirable that a deep-sea cable should be very flexible, so as to accommodate itself thoroughly to the irregularities of the ground, and in this respect the copper or zinc-sheathed cable leaves little to be desired.

Time does not permit me to enter upon the consideration of untried modes of constructing and submerging cables. The electrical tests applied during the operation of paying-out, and for determining the position of faults in existing cables, is a most interesting branch of the science of telegraphic engineering, which I shall also have to pass over on this occasion, referring those interested to the Government Blue Book of 1861, and other sources of information. Nor does time permit me to describe the particular arrangements of instruments for working long submarine lines. Enough I hope has been said to justify the following conclusions:

1. That the insulating materials now used in the construction of deep-sea cables, are efficient and likely to endure until the protecting sheathing gives way.

2. That for shores and shallow seas, heavy iron-clad cables of from 5 to 10 tons weight per mile have proved practically successful, but that a further protection of the iron wires is desirable to increase their durability.

3. That for deep seas, durability cannot be obtained by weight of iron sheathing, but that a sheathing of moderate weight, which is capable of resisting both the chemical action of sea water and the teeth of marine animals, is requisite.

4. That a hemp covered cable, or a bare insulated conductor, without a metallic sheathing of some sort, is highly objectionable.

5. That the present mode of paying out is safe and efficient under proper management, although capable of further improvement.
FEST-REDE ZUR KINKEL-ABSCHIEDSFEIER,

am 27 September, 1866,

VON C. W. SIEMENS.

MEINE DAMEN UND HERREN,—Es ist jetzt meine ehrenhafte Pflicht die Gesundheit unseres geschätzten Gastes auszubringen und ihm bei dieser Gelegenheit die schönen Ehrengeschenke zu überreichen, welche aus Ihrer freien Zusammenwirkung hervorgegangen sind.

unzart erscheinen, eine solche Mittheilung in seiner Gegenwart zu machen, aber es liegt andererseits eine gewisse Notwendigkeit vor, und müssen sich die Himmelskörper selbst der zerglie-
dernden Critik heutzutage unterwerfen, so wird auch er sich willig dem Unvermeidlichen fügen.

Was nun seine allgemeinen Eigenschaften anbelangt, so habe ich zu berichten, dass er kein Weltnebel ist, denn sein Spectrum zeigt sehr entschiedene Linien eigenen Characters. Auch er kein Comet, Planet, oder Trabant, welche nur reflectirtes Licht wiedergeben und deshalb für meine Untersuchung untauglich sind, sondern er gehört recht eigentlich der Familie der Fixsterne an, welche das ihnen eigenthümliche Licht bis zu späten Zeiten hin zu strahlen im Stande sind. Unser Stern wird in Folge cosmischer Gesetze nächstens auf grössere Ferne von uns rücken. Wir werden ihm aber dennoch von hier aus in seinem Laufe beobachten können, auch wird sein Glanz eher noch zunehmen, indem er aus dem verdunkelnden Gedrange der hiesigen Milchstrasse entfernt sein wird. Er gehört endlich den sogenannten "Burning Stars" an, welche periodisch besonders helles Licht um sich verbreiten, welches in unserem Falle bis an den äussersten Horizont der deutschen Sprache und deutschen Sinns fühlbar sein wird. Was nun seine eigentlichen Bestandtheile anbetrifft, so habe ich, mit Ausnahme des festen Eisens, keins von den so-
genannten unedlen Metallen in ihm entdecken können. Aber ich werde davon abstehen die Analyse der gefundenen Stoffe ihnen hier mitzutheilen, da Sie am Ende gar Zweifel in die Richtigkeit meiner Methode setzen könnten. Ich ziehe es deshalb vor, auf historische Grundlage überzugehen, um unser heutiges Fest vor uns selbst, sowie auch in den Augen unseres Ehrengastes zu begründen.

Vor zwanzig Jahren lebte an der Universität zu Bonn ein Professor der Kunst- und Literatur-Geschichte, welcher schon damals in gebildeten Kreisen ein hohes Ansehen wegen seiner streng wissenschaftlichen und dabei dennoch ansprechenden Herleitungsweise genoss. Er war vordem Doctor der Theologie gewesen, hatte aber zwischen den engen Mauern eines kirchlichen Systems keine genügende Nahrung für seinen forschenden Geist finden können. Sein Uebergang wurde vom grossen Publicum mit Freuden begrüsst, aber auch die extra guten Leute seiner früheren
THE ADDRESSES, LECTURES, ETC., OF

Facultät waren zufrieden darüber, denn man hatte den Doctorem theologae mit gelehrt den dogmatischen Abhandlungen unterm Arm an der Heerstrasse vor Bonn im Winter schurren sehen! Nun, das war "shocking," und hätte das theologische Schurren so fortgedauert, wie leicht hätten die gelehrt den Dogmen sammt dem Doctor zum Falle kommen können!?


bedrängten Patrioten stets eine gesicherte Stätte darbietet. Lassen Sie uns deshalb die Gastfreundschaft Englands stets rühmlichst anerkennen!

THE ADDRESSES, LECTURES, ETC., OF

Verlust höher achten wollten als den Gewinn, welcher unserm Ehrengaste durch seine Uebersiedelung nach der Schweiz erwachsen wird.

Lassen Sie uns vielmehr versuchen, durch eigene Anstrengung die Scharten einigermassen auszuwetzen. Aber auch vom selbst-stüchtigen Standpunkte ausgesprochen ist seine Uebersiedelung nicht ohne Interesse für uns; trotz ausserordentlicher Vitalität würde es Dr. Kinkel nicht möglich gewesen sein, viele Jahre hindurch so fort zu wirken, wie er es hier im Drängen des Londoner Geschäftslebens thun musste, während er in der würdigen Zurückgezogenheit eines akademischen Lehrstuhles seinen Freunden, seiner Familie und dem deutschen Publicum noch viele Jahre in Fülle seiner geistigen Kräfte erhalten zu werden verspricht. Seine literarischen Arbeiten mussten namentlich hier in’s Stocken gerathen und werden wir seiner grösseren Ruhe gewiss noch manche erfrischende Schöpfung zu verdanken haben.

Sollte, wie wir es Alle sehnlichst hoffen, deutsches Heldenblut nicht umsonst geflossen sein, so werden wir ihn gewiss auch noch in seiner politischen Laufbahn als Vertreter des Volkes in einem deutschen Reichs-Parlamente eine bedeutende Rolle spielen sehen. Seine vielseitige Erfahrung wird ihm dabei von ausserordentlichem Nutzen sein. Hat er nicht uns neuerdings erst gezeigt, dass er nicht Parteimann, sondern patriotischer Staatsmann ist, indem er, früheren Widerspruch und Unglimpf vergessend, die Fahne seiner politischen Gegner zu der seinigen machte, sobald er erkannte, dass dadurch der Weg zur Einigung des Vaterlands aufs neue angebahnt sein mochte. Es ist diese Selbstverleugnung um so höher anzuerkennen, als es der deutschen Natur so schwer fällt, die eigenen Wege und Ansichten der Erreichung des grossen Ziels unterzuordnen, und mögen alle unsere politischen Parteimänner dieses Beispiel sich zum Muster dienen lassen.

Indem Kinkel England verlässt, wird er doch von den Seinigen unter uns zurücklassen. Seine beiden erwachsenen Kinder werden in unserer Mitte bleiben,—und ausserdem giebt es hier für ihn eine dreifach geheiligte Stätte, welche ewig frisch in seiner Erinnerung bleiben wird. Der heutige Abend und unser Ehrengeschenk werden ihm die Ueberzeugung schaffen, dass er hier viele Herzen zurücklässt, die fortfahren werden warm für ihn zu schlagen.
Herr Dr. Gottfried Kinkel, es bleibt mir jetzt nur noch die angenehme Pflicht im Namen der anwesenden zahlreichen Versammlung von Verehrern und Freunden, sowie auch im Namen vieler anderer Landsleute, welche durch Umstände verhindert worden, am heutigen Fest Theil zu nehmen, dieses gediegene Kunstwerk und jene silbernen Geräthe förmlich zu überreichen.

Möge der Lenker der Geschicke Ihnen, Ihrer verehrten Frau und Familie Gesundheit, Friede und Freude im reichen Masse ertheilen und möge der heutige Abend Ihnen als Beweis dienen, dass Sie sich den höchsten Preis eines recht denkenden Mannes, die Achtung, die Anerkennung und das Wohlwollen Ihrer Mitbürger erworben haben!

[Hier folgte der Toast selbst, welcher von den 300 Anwesenden mit Begeisterung getrunken wurde.

Der Camberweller Gesangverein, unter Leitung des Herrn Pirschel, trug darauf "geistliches Abendlied" von Kinkel, componirt von Methfessel, vor.]

TESTING ELECTRIC CABLES.

By C. WILLIAM SIEMENS.*

INTRODUCTION.—On a former occasion, when I delivered a lecture in this Institution, on "Electric Telegraphs," I found that it was impossible, in the course of an hour, to go into the whole of the subject; and this evening I propose to confine your attention to "The Testing of Electric Cables."

Notwithstanding this limitation, I find that I should not nearly be able to exhaust my subject or to give you the proofs of the different problems involved. I shall, however, endeavour to give a general outline of the principles involved in testing electric cables; and also show you the *modus operandi* by which the more

important of these tests are carried into effect. It is unnecessary for me to enlarge on the importance of electrical tests; I would only call to your mind that in the case of an Atlantic cable, a single flaw—a microscopic defect—would vitiate the whole undertaking. But I also hope to be able to prove to you that by a proper system of electrical testing, the chances of such a flaw remaining unobserved are infinitely small.

**General Laws.**—In dealing with the subject, we have to operate chiefly with one of the forces in nature, that is the "electromotive force." We are taught, however, that the forces of nature, such as heat, light, electricity, and chemical action, are reducible to one and the same fundamental principle—that is, "mass in motion." If I take any weight, say one pound, and raise it one foot high, I cause a tension between this substance and the table, or the earth beneath it, which tension will call this weight back to the table through the space of one foot, with a force of one pound, and the power here represented is the foot-pound or unit of force. In electrical science we have another kind of tension, which is not gravity, but electro-motive force. We have in each of these glass jars a porous jar containing proto-sulphate of mercury. This proto-sulphate of mercury is composed of sulphuric acid and oxide of mercury, and the oxide of mercury of oxygen and metallic mercury. Inside this pot amidst proto-sulphate of mercury is carbon, and outside the porous pot is zinc. Now, zinc has a great affinity for oxygen, whereas carbon has, at low temperatures, a very slight affinity for oxygen. The consequence is that the zinc wants to combine with the oxygen and set the mercury free. The sulphuric acid present is quite ready to take up the oxide of zinc as soon as it is formed, and aids the tendency of the zinc to separate the oxygen from the salt. A tension is produced which results in chemical action and in motion of the particles acted upon, which latter manifests itself either as heat or, if the conditions admit of it, as electricity. The chief condition necessary to produce the electric current consists of a metallic connection between the carbon and the zinc, and it is within this metallic connecting wire that the electromotive force becomes manifest and applicable for our purposes.

But it is quite permissible to represent electromotive force by gravitation. I have here a diagram (Plate 2, Fig. 1) in which
the height of the liquid in a tube is to represent electromotive force or the height of this column represents the attraction of the zinc for the oxygen. If to one element I add a second similar element, I produce the same effect as adding to one column another similar column; I superadd one tension to another, or I double my electromotive force.

Now, the liquid-column, shown in the diagram representing the electromotive force, would discharge itself through a narrow pipe, with a velocity depending upon the height of column, on the one hand, and upon the frictional resistance or obstruction offered to the discharge of liquid on the other hand. The analogous obstruction offered to the electric current within a conductor we call electrical resistance. If the pipe is of a certain length, say one metre, and of a certain size, say of one square millimetre sectional area, we may call the obstruction which it offers to the flow of liquid a unit measure. If we were to double the length of the pipe, we should have exactly double the resistance; and if we neglected the influence of inertia, only half the amount of liquid would flow in a given time. By increasing the length of pipe indefinitely, we shall be able to ascertain its length in measuring the delivery at the outlet. This is accomplished in dealing with electrical resistances by means of the electrical balance which I shall describe presently.

Another important point for us to fix, before entering upon the real subject of the evening, is that of charge, or electrical induction. If the liquid, represented in the diagram, was suddenly let loose upon the pipe, it would not flow from it until the pipe itself was filled; and if the sides of the pipe were composed of a porous substance, then its pores must also be filled beforehand; but if we suppose that this substance, besides being porous, is elastic, that is to say, composed of cells containing air, then the amount of liquid that would have to be absorbed into the walls of the pipe would be proportionate to the height of liquid, or to the electromotive force, as we should call it.

In these illustrations, analogous laws are involved to those which we have to deal with in electricity. I must mention, however, another. If the porous substance composing the pipe allowed of a certain amount of liquid to ooze out on all sides, we should then, not only have to deal with the liquid flowing out at the other end,
but also with this leakage, which leakage we may regard as a separate discharge, bearing a certain proportion of the principal discharge, or as offering a certain proportionate resistance to the flow of the liquid. By increasing the length of the tube, the leakage will increase or its resistance to leakage will diminish in the same proportion.

Now, if at the outlet end we had a water-wheel, and made that water-wheel turn by the flow of the liquid, we should then have a case analogous to working an electrical instrument at the end of our line, and it is at once apparent that we should endeavour to lose as little of our current on the road as possible, either by conduction, or by induction, or by absorption into the material composing the pipe, in order that we may obtain the greatest possible effect from a given source of power and a given size of conductor. This illustration serves to bring home to our minds the nature of the forces and resisting influences which we have to deal with in submarine telegraphy.

At the root of all electrical measurement is what is called Ohm’s law, which says that the current, or the amount of the flow, is equal to the electromotive force divided by the resistance. That is a law which applies not only to electricity, but also to heat and other forces. It stands to reason that the amount of electricity flowing through a conductor is as the electromotive force (or the height of the column), and, inversely, as the resistance. All substances do not, however, offer the same resistance to the electric current. If this pipe was rough in the inside it would offer greater resistance to the flow of water than it would if it was smooth. So, also, if we have a conductor of one metal, such as iron, we find greater resistance than when we have the same length, and the same area of conductor of another metal, such as copper.

That brings us to the measurement of electrical resistances. There is a table here showing the conductivity of different metals, which vary in an extraordinary ratio. Thus, pure copper conducts fifty-five times better than mercury ; whereas, the copper of commerce very often conducts only about five or six times more than mercury.

**Measure of Electrical Resistance.**—In order to measure resistance, we must have a measure or unit of resistance, just as
much as, in order to weigh a substance, we must have a unit weight, such as the pound or kilogramme. Several units have from time to time been proposed. Formerly the mile of iron or copper wire, or, in France, the kilometre of iron wire, of a certain section, was taken to represent the unit of resistance, but it is evident from what I have just stated that these are very vague measures. A slight variation in the constitution of the metal, or in its admixtures, would vary the value of a mile of wire between very wide limits. It was at the time when electrical tests assumed a practical and serious shape that my brother, Dr. Werner Siemens, proposed his mercury unit; that is, the resistance offered by one metre length of mercury enclosed in a tube of one square millimetre sectional area at the freezing-point of water. This unit has been generally used in cable-testing up to this time. But, at present, another unit is proposed, the British Association unit, which is derived from Weber's absolute unit of electrical force. It is difficult to explain correctly what that means; but the following may serve to convey the general idea:—If I have a loop of wire of a certain length, and turn it suddenly, with respect to the magnetic axis of the earth through 90°, I develop in this wire a certain current which, if it is made to act upon the needle of a galvanometer, produces a certain deflection. The force thus set up by this motion, Weber calls the absolute unit of electrical magnitude; and the resistance which is set up in the loop of wire of given quality and dimensions he calls the unit of resistance. Now, ten millions of these units of resistance would form the unit of resistance proposed by the British Association Committee. This unit would have certain ulterior advantages, being referable to a unit of force; but its production is attended with considerable difficulty, which leaves reasonable room for doubt, whether future determinations may not materially modify its value. At present the material unit of a certain amount of mercury, which being a liquid is not subject to differences of temper, contained in a certain tube appears to be more certain, it differs only about 4\% per cent. from the British Association unit, and it has this advantage—it is largely used.

Measure of Charge.—In addition to the unit of resistance, we have to determine the unit of charge, or unit capacity for static electricity, which may be defined as follows: If I have one
round plate of metal of any given size, and oppose to it another plate of metal of the same size, approaching them to the distance equal to their own diameter, I have a unit measure of capacity for electricity. I may take these plates as large as I like, or as small as I like; so long as I make the distance equal to the diameter, the amount of electrical charge contained by such arrangement is always the same, taking atmospheric air to be the intervening medium in every case.

Effect of Temperature.—We have next to consider the effect of temperature upon a conductor. We have hitherto assumed that a wire of a certain length, of a certain diameter, of a given material, produced a given resistance. That is only true as long as the temperature remains the same; but with change of temperature, the resistance also changes in a fixed ratio, which is perfectly well ascertained as regards metallic conductors. Therefore, if we want to compare electrical tests, we must either make the actual measurement at a fixed temperature, or we must introduce a calculation by which we reduce the values to a standard temperature. With regard to metals, the ratio in which temperature affects conductivity, or electrical resistance, is a very simple one; but it is very different with the substances which we call dielectrics, or insulators. There are no such things as absolute insulators; but the insulator which we mostly apply, namely, gutta percha, increases in its conductivity with increase of temperature in a very rapid ratio, which may be represented by an ascending hyperbolic curve, see Fig. 2, Plate 2 (whereas the ratio applicable to the metals is represented by a straight, descending line). A precise knowledge of these ratios is of great importance to the art of testing cables.

Wheatstone's Balance.—In measuring the resistance of metal-conductors, we generally employ a method which is based upon the Wheatstone's diagram or balance. We weigh one resistance against another known resistance, and thereby determine its value. I have Wheatstone's diagram here, which is also represented by a diagram (Fig. 3, Plate 2), and may be seen in actual operation. If we send the current of the battery, B, into this point of juncture, a, the current must flow in the two directions, constituting the branches of the diagram, which branches re-unite at the point b, whence the current is brought
back to the battery at the opposite pole from whence it proceeded. The current will, according to Ohm's law, divide itself between two conductors, inversely as their conductivity. If the arms, $a c$ and $a d$, are equal in resistance, and the two branches $b c$, and $b d$, are also made equal, then there would be as much current pass the one way as the other; and no current will pass through a channel which connects the two points, $c$ and $d$. In this cross channel there is a delicate galvanometer, the needle of which would deflect with any passage of current crossways. But suppose I were to make this resistance, $b d$, very great as compared with the resistance, $b c$, then the current flowing through the branch, $a d$, could not all of it proceed through $a b$, but would divide itself again, part of it passing through the cross branch, $c d$, and the inferior resistance; $b c$, deflecting the galvanic needle. If we now increase the resistance of $b c$ until it equals $b d$, then the two branches will again pass an equal amount of current, and no deflection of the needle will occur.

If $b c$ be an unknown resistance, and $b d$ is one which we can alter ad libitum by putting in or taking out stoppers, representing each a known resistance, we can so adjust the latter that upon the application of current no deflection takes place, in which case the one must be the exact measure of the other. That is one method of testing which we employ. I have here, on this table, a complete testing board, which has been taken out of actual use only to-day, in order to be reinstated to-morrow morning, which we employ for testing our cables, and in which as many as twelve different methods of testing are contained. By simply altering these stoppers, we can use the one method or the other. I may here state that this apparatus, in order to be efficient, must be constructed with extreme care; it is a matter involving considerable mechanical skill to make a coil representing an exact amount of resistance; and it also requires considerable skill to make these connections so that there are no false currents or loss, in order to get natural and correct readings.

These different methods I shall endeavour to pass in review.

There is the direct method which I have just alluded to. Now, in order to measure with the greatest amount of accuracy, it is natural that the two channels through which the electricity flows into the balance should be about equal. If you wanted to weigh
fairly, you would make the two beams of the balance about equal, for if one arm of the balance were short, and the other long, you would not weigh at this short end with the same degree of nicety. In the case of electricity another evil arises, that the current, dividing itself unequally between the long arm and the short arm, would heat the short arm; therefore, we are limited in the use of Wheatstone's diagram to a certain range of resistance. We can produce, artificially, the resistance of a thousand units; and, therefore, can compare directly as though I was weighing by equal arms, resistance to that amount. If a greater amount of resistance is to be measured, I can help myself by altering the first two branches of the resistance, which represent the arms of the balance. If, by means of stoppers, I make the resistance of one arm one hundred times greater than the resistance of the other arm, then the resistance I am seeking will be one hundred times greater than the other, which I shall have to establish by stoppering. On the other hand, if we want to measure very accurately a small resistance, we alter the comparative resistances in the other sense, making the stoppered value represent ten or a hundred times the resistance to be measured. When we come, however, to measure the leakage through a mile of cable, we should find not ten thousand units, or one hundred thousand units, we should find one hundred millions, or even as much as five hundred million units of resistance.

SINE METHOD.—In such a case we must resort to a totally different method, which we call the sine method. Here is an instrument which is used for that purpose, being a very delicate sine galvanometer. If a current flows through the coils of this instrument, deflection of the needle takes place; and this deflection increases with the current in the ratio of the sine of the angle, provided you turn the instrument upon its vertical axis through the angle of deflection. This needle being suspended by a silk thread, and being made very astatic, an exceedingly small amount of electricity flowing through, will produce notable deflection. I have to connect my wire in this way, that I bring my battery to one end of the copper conductor enclosed in the insulating tube of gutta-percha or india-rubber, the other end being sealed, and the external covering, or the water in which
the conductor is immersed, in connection with the other pole of the battery, including the galvanometer coil into the circuit. We then get a deflection, and from this deflection we calculate the resistance by the simple formula of the resistance being equal to the sine of the angle, divided by the sine of the angle of deflection, which would be produced by an unit of electromotive force, or by one element upon the same needle, multiplied by the number of elements employed, or \[ R = n \frac{\sin \alpha}{\sin \beta}. \] The deflection which is produced by an element upon the needle has to be determined frequently in testing by this method, and is called the constant of the instrument.

This method is not so simple as the Wheatstone method, where we compare simply one resistance with another; it has, however, the advantage of greater sensitiveness, being much improved in this respect by the application of Professor Thomson's reflecting galvanometer, which with its mirror attached to an extremely delicate needle, reflects a ray of light upon a large scale, and enables us to read with clearness very small angles. For very small angles, as you are aware, the sine may be taken for the angle itself, and therefore, in measuring with this instrument, instead of taking the sines of the angle, we take the simple deflection, and thus save calculation.

**Differential Method.**—Within the last twelvemonth, we have devised and introduced into practice at the Charlton works, another method of measuring resistances, in which neither artificial resistances nor a sine galvanometer are used, and which recommends itself by its extreme facility of operation. The instrument employed consists of a very delicate galvanometer, and of a coil put separately upon a screw carriage, which latter acts upon the same needle under the influence of a constant current. The resistance to be measured is put into the galvanometer circuit with a battery of fifty cells, to produce the current. We connect a second battery to the balancing coil, which is mounted on a slide, that admits of being moved to and fro. It is evident that if I know the effect that would be produced by one cell on the moveable coil, and of a hundred cells on the stationary or galvanometer coil in balancing each other upon the instrument itself, I shall be able to judge the effect also of a larger resistance in the circuit of
the latter. For instance, if I have in the galvanometer circuit a resistance of one million units, I know that in order to balance the needle on the galvanometer, I must screw the moveable coil to a certain point on the scale; then, by increasing that resistance, I must diminish the relative effect of the moveable coil, in order to maintain the needle in balance by moving to a point which can be fixed beforehand by calculation, or which may easily be tabulated from a series of observations in dealing with known resistances. In working with this instrument the unknown resistance is put into the galvanometer circuit, and the screw of the moveable resistance is worked to and fro, until the needle has assumed its zero position, when in reading upon the scale the divisions, I find at once in my table the amount of resistance in units which I wish to measure. Such an instrument is particularly useful where you want to operate quickly, as you do on board ship. In paying out cable, it is of the utmost importance that, when a fault goes overboard, you should at once be able to determine the magnitude of that fault; and this can be accomplished in much shorter time with this instrument than with the instruments we have formerly employed.

Discharge Method.—Another method of measuring a very high resistance is by natural discharge. If we have only a short and highly insulated wire, and charge the same with electricity, the external surface being connected to earth, we shall find that a natural discharge takes place in time, which latter varies according to the insulating property of the covering. This diminution will go on at a very uniform rate. If I employ a very high electro-motive force, say one hundred cells, I produce a high state of tension; this tension produces a comparatively rapid discharge, and at the end of a given time—say in one minute, it will have descended to half that charge. If, on the other hand, we employ a weak current or electro-motive force, we shall have only a small quantity of electricity to discharge, and it will be found that this charge will be reduced to one-half in precisely the same time. In employing this method we are perfectly independent of the amount of battery power employed, but in taking the charge we must note the time; in connecting now the wire with an electrometer, we shall have to watch this electrometer in order to note when this charge has dropped down to half charge. The time of discharge
gives us a direct comparison between insulators, although it does not give us their resistance in units. Therefore, this method only serves to determine the general quality of an insulating material, but is inapplicable for measuring submarine cables.

**Charge in Cables.**—We have now gone through the different methods of testing, and of determining resistances. We come to another branch of the subject—that of determining the charge or lateral induction. If a current flows into an insulated wire, the current does not pass through it without electrifying the insulating substance surrounding it. Part of the current leaks through the insulating material; but a larger amount of it is found there remaining, as it is in a Leyden jar, and forms what is called static electricity. It is evident that before a current can pass through the cable from one end to another, it must charge the whole length of its insulating covering; in fact, the gutta-percha surrounding this wire acts the same as the glass of a Leyden jar. We may consider a long submarine cable like an infinite succession of Leyden jars, which have to be charged one after the other before the electricity can flow out and produce its effect at the extreme end. It is evident that this retardation or this absorption of current should be made as small as possible, in order that each current may as soon as possible arrive at the other end; but we find that different substances absorb different amounts of electricity in charge. Thus india-rubber absorbs only three-fourths of what gutta-percha would absorb, and is in this respect the preferable material to use. But, independently of this consideration, we sometimes want to know the amount of charge which a cable will take, in order to determine by it, its length. If, for instance, we know our insulating material, the size of our conductor, and of the insulated wire, we can tell beforehand what will be the amount of charge in a given length of cable. We measure the charge by the deflection of a galvanometer, and in this way by reading the angle of a single deflection, in putting the battery to the cable, we find the charge $K$ to be equal to the sine of half the angle of deflection divided by the electro-motive force, or the number of cells employed, or, in mathematical language, we have $K = \frac{\sin \frac{\alpha}{2}}{n}$ which formula represents the capacity of a cable for the unit of electro-motive force.
This is one method of determining the charge, or rather the capacity, of a cable.

Another method is by the employment of an instrument which we call the "wippe." It being very difficult to read the sudden deflection of a needle when connection is made with the battery, we substitute by this improved method the constant deflection of that needle. The instrument by which we accomplish this object, and which is placed upon the table, consists of an electrical appliance for producing uniform rotation of a spindle, by means of which connection is made, at rapid intervals, alternately between the cable to be measured and the battery, on the one hand, and the earth on the other hand, producing a regulated succession of charges and discharges. Suppose I make one hundred, or say twenty, charges in a second, and twenty discharges. All these charges go through my instrument in rapid succession, and the needle has not time between impulse and impulse to return to zero, but it will subside into a medium position, which we can examine at our leisure. The charge in this case is not proportionate to the sine of half the angle, but to the sine of the angle of deflection itself. In like manner the instrument enables us to measure the discharges of the cable to earth, allowing the charges to go into the cable direct. We have thus a ready means of carefully examining the capacity of any given cable. Though I could put this instrument now to work, it could only be seen by two or three gentlemen, and even those would require more leisure than we could afford them at present, in order to satisfy themselves of the result; these are, indeed, not experiments for a lecture-room, but for the study.

Order of Tests.—I think I have passed through all the principal modes of measuring resistance and charge. I should say a few words now about their application in practice. We have to test the cable in all its stages of progress, in order to guard against the possibility of a fault. Commencing at the insulating works, or say at the gutta-percha works, we have first to examine the wire which is proposed to be covered. As I have shown at the beginning of the lecture, the conductivity of copper wire varies between wide limits; and unless great care is used, unless every portion of the wire is carefully examined, we might lose enormously in conductivity. It will be seen at once of what importance conductivity
is, if we consider that the charge, say of the Atlantic cable, is a fixed quantity which has to be furnished before the current can make its appearance at the further end; and that, in filling this large jar, we are limited only by the conductivity of the insulated wire, which allows the electric current to flow in. If the conductivity of that wire could be doubled from what it is at present, we should, in exactly half the time, accomplish our end, or, in other words, we should double our rate of speaking. If, on the other hand, we should allow ordinary copper of commerce to be employed which had a conductivity under twenty-five times that of mercury, whereas we can practically obtain wire conducting fifty times better, we should speak with only half the velocity which we ought to have attained to. Therefore, as the conductivity increases, so the velocity of transmission will also increase, hence the importance of using the very best copper for the purpose.

Having satisfied ourselves upon that point, the wire is handed over to the manufacturer to be covered. It is thereupon tested for insulation. But the electrical resistance of gutta-percha varies with temperature, and in order to get proper comparative tests, we must know the exact temperature of the wire. For this purpose cisterns were arranged, at my suggestion, in testing the Malta-Alexandria core, in which each coil of wire, as it is covered, is soaked for twenty-four hours, the water being maintained at a standard temperature of 75°. The resistance of the insulator, which we obtain at the standard temperature, may be directly compared with the resistance which we have observed in another coil to determine their relative perfection. The coil is next put under great hydrostatic pressure in Reid's pressure-tank. Under this pressure a curious phenomenon appears, namely, the electrical resistance of gutta-percha increases in a fixed ratio. Experiments which I had occasion to make, and which went up to a pressure of 300 atmospheres, showed that the increase due to that amount of pressure, three-folds the electrical resistance. That is to say, if we had electrical resistance of one hundred million of units at atmospheric pressure, by increasing the pressure to 300 atmospheres, we increase the resistance to three hundred millions of units. The moment the pressure is released, the resistance falls rapidly to its original amount. At the bottom of the Atlantic there is a pressure of nearly 300 atmospheres; it will therefore be
found that when a good cable is submerged, the electrical resistance or its insulator must increase permanently three-fold; it must further increase on account of the lowness of the temperature at the bottom. For this double reason the insulating conductor is under the most favourable circumstances that could be imagined, when submerged in a deep ocean. This increase of insulation under great hydrostatic pressure does not affect all materials alike. India-rubber-covered wire, when subjected to the same pressure of 300 atmospheres, decreased in insulation, although it immediately resumed its original high degree when the pressure was released. The change of conductivity by pressure is therefore not reducible to any general law, but applies to each individual substance differently, but it is very important to know in dealing with cables, what changes we may have to expect in submerging them.

Having tested the conductor at the insulating works, it is transferred to the sheathing works, where it is again tested, both during the time of its being covered, and afterwards when it is put into tanks. The usual way of testing it while it is being covered, is to put the conductor into circuit with a battery and an alarum, which latter is made to ring the moment the continuity is broken. Mr. Schwendler, an electrician connected with me, has lately devised a plan by which a continued test for insulation may be applied, and by which an alarum is made to sound the moment the insulation is injured. This is of more importance than the mere continuity test, inasmuch as in the process of covering a cable with iron the soft gutta-percha, or india-rubber, is far more likely to be injured than the conductor itself.

I may also mention here another investigation which has lately been made by Mr. Schwendler, which is to determine the best resistance, or the resistance producing the maximum of magnetic moment in the galvanometer employed in testing with the Wheatstone diagram. I have in the early part of the lecture said that in order to weigh accurately with Wheatstone's diagram, the branches of the system should be as nearly as possible equal. But no rule has as yet been established to determine, if you have to deal with resistances of a certain average value, what resistance on the galvanometer would produce the maximum effect. Mr. Schwendler finds that the resistance of the galvanometer should
be the same as that of each of the branches of the Wheatstone diagram, to produce the most delicate reading.

Testing Joints.—We next come to a branch of testing which we have not referred to as yet; that is, testing the joints. The insulated conductor is sent from the insulating works in lengths of one knot; these have to be joined together before the cable is sheathed, and in making these joints, extreme care has to be used to prevent flaws. The old way of testing joints was to put the freshly made joint into water, to see whether, by doing so, the general insulation of the cable was decreased. But if the cable is very long, then the general decrease of insulation upon it, by even a defective joint is but small. In joining two ends of a cable together, of one mile each, presenting each the enormous resistance of say two hundred millions of units, the total resistance would be seriously affected by a joint which was slightly defective, offering a resistance of say four hundred millions of units; but as the length of the cable increases, its total insulation-resistance must go down; when its length reaches one hundred miles, the insulation would be measured by two millions of units, in which case the fault of four hundred millions would be inappreciable by the instrument. I think Mr. Whitehouse first suggested to measure the leakage separately, by putting the joint into an insulating trough of water, which was connected with one pole of a powerful battery, the second pole of which was connected to the cable with a galvanometer in the circuit to detect leakage. Mr. Latimer Clark has very much improved upon that method, in connecting the insulated bath with a condenser, which condenser charges itself gradually with the leakage through the joint, and is discharged at a certain interval through the measuring instrument. There is only one objection to the latter method, which is, that the condenser itself leaks. It is indeed exceedingly difficult to get a condenser which is as perfectly insulated as the copper wire within a cable. Therefore the charge you get in the condenser is not absolutely the expression of the amount of electricity that leaks through the joint.

It is true that the charge accumulating in even an imperfect condenser must always be proportionate to the electricity flowing into it, the leakage itself being proportionate to the accumulation. Still, this would be supposing that the condenser itself did not
vary in its condition by changes of temperature or by moisture. Considering the difficulty of obtaining a permanent condenser, I prefer to employ another method, which is represented in Fig. 4, Plate 2.

Between the two permanent branches of a Wheatstone diagram a delicate galvanometer is placed, and the cable is inserted between the open end of these resistances or branches. The cable, being in a water-tank, is connected on its outside with the battery, the second pole of which is joined to the resistance-coils. Now, if the cable is mechanically perfect, the insulation-resistance must be everywhere the same along its whole length, and this being the case, there must be as much electricity flowing from the battery through the two resistances, and through every portion of the covering of the cable to earth; the leakage from the cable would, in fact, produce the same effect as one collective leakage at the exact middle of that cable. If there should not be that perfect balance, but if there was a faulty joint at a point near one end of the cable, then the discharge of the battery current to earth would gravitate to this point, and that branch of the balanced resistances near at hand would pass more current than the other branch. The result would be that the needle, in the connecting link or bridge, would be deflected. Now, if an artificial resistance were inserted at the end of the balanced resistance, nearest the fault, this could be so regulated as to re-establish the balance of currents on the galvanometer; and we should get an indication of the importance of that fault. This method is exceedingly sensitive, and a simple means of furnishing a continued verification of the normal condition of a cable in course of manufacture. The slightest inequality between the sides will tip the needle over to one side or the other, as may be illustrated by the diagram before us, in which hydrostatic pressure is again substituted for electrical force. If we take a flat bar of wood, accurately balanced upon pivots in the middle, and bring it under a general rain, then the rain falling down equally upon it, will keep it perfectly in balance, because it will fall everywhere alike. But if at a point near one end there should be an extra amount of rain-fall, this would immediately cause the bar to tip, for the same reason that the electrical balance tips under the influence of the extra leakage of a faulty joint.
Testing on board ship.—Having tested the cable at the insulating and at the sheathing works, we have now to coil it on board ship into tanks filled with water, where it is again subjected to daily electrical tests until it is finally submerged. It has occurred frequently that the cable in running overboard has suddenly shown a fault, and it is the duty of the electrician instantly to arrest the operation. The paying out apparatus used on board ship must be so arranged, that with the least delay of time, the cable may be hauled back in order that the fault, which in the meantime should be accurately determined by the electrician, may be seen to, the moment it comes on board, and the operation continued with the least possible delay. Formerly, no tanks were used on board ship; the cable was dry on board, and it was impossible to know whether it was defective or not, until it was submerged. Since the manufacture of the Malta and Alexandria cable, when I had it in my power to apply water-tight tanks for the first time, these tanks have been invariably adopted, and the operation of paying out rendered more safe in consequence; the chance of any fault going overboard should indeed be exceedingly small. Before the water-tight tanks were used, the method of testing a cable during submergence consisted of putting on the land station a clock, which made certain electric connection, at given intervals of time, in the course of an hour; it made connection of the cable with the earth, with the receiving instrument and for insulation at preconcerted intervals. On board ship, the electrician would, during these intervals, be prepared to test for insulation or for continuity, or to give the necessary instructions to land. It is desirable to test during the paying out as much as possible for insulation, because the important point is to have insulation perfect, the land clock was therefore so arranged, that about three-fourths of the whole time was reserved for insulation tests. At present, when a cable passes from the water in the tank into the sea, it is not so necessary to introduce these various tests. A method has lately been suggested by Mr. Willoughby Smith, which is very promising, of superseding the former ship tests. This consists in having always insulation tests upon the cable; and to connect at the land end a length of insulated wire or condenser to the cable, which is in connection with a very delicate galvanometer, such as a Thom-
son's galvanometer. If now the cable, which remains always charged, is put to battery on board ship, an extra charge will flow in at the condenser, and affect the galvanometer at the land end, enabling him to speak to land while the insulation test continues—not through instruments, it is true, but through a delicate galvanometer, which may, however, suffice for conveying the necessary instructions. I am not quite satisfied in my own mind whether this method would work with sufficient distinctness to be practicable in paying out a very long cable; but for a short cable I am quite certain that it would work well. It is one of those methods which, although not yet practically tested, I have thought right to mention.

Testing for Faults.—If, in paying out, a fault appears within a short distance of the ship, then we could pull back and remedy the fault, and go on. But, unfortunately, it happens sometimes that a fault appears after the cable is laid. If it appears immediately after the cable is laid, it must be a rupture, or the cable has been very badly manufactured; but in course of time, when the cable has been exposed to chafing near shore, or to an accident, faults will appear, and we must be prepared with methods to determine the position of such faults, with a view to their repair. This is one of the most important and most beautiful branches of electrical testing. There are different conditions and circumstances to be observed. If we have, first of all, a fault in a cable of which both ends are accessible, as would be the case if the cable contained two conductors, and in uniting the two conductors into one enabling us to operate upon both sides from the fault, we would be in the condition represented by diagram Fig. 5, Plate 2. We then get the determination of the position of the fault by finding two equations, the one giving the resistance of the whole conductor \( l = x + y \) and the other giving the proportion between \( x \) and \( y \), namely \( a : b = x : y \), and in developing \( x \) and \( y \) from these, we have \( x = \frac{a l}{a + b} \) and \( y = \frac{b l}{a + b} \). This method is the best, being the only one in which the resistance of the fault is wholly eliminated.

Another condition is, in dealing with a single cable, when the fault still permits us to speak through from end to end. In that
case we shall have to measure the insulation resistance, and get our correspondent at the other end to do the same, and communicate the result through the cable. We embody these results in two formulas as before, from which we eliminate the resistance of the fault, and establish the numerical relation between \( x \) and \( y \), representing the resistances on both sides of the fault, for which we may put lengths of cable, supposing the conductor to be uniform.

Another description of fault where it is more difficult to operate is, when the cable is ruptured altogether, and you can consequently no longer speak through it. In that case we have to deal with the resistance of the cable and the resistance of the fault, or place of contact between the conductor and the sea, which you cannot eliminate. We can, however, approximately determine the resistance due to the fault in observing the amount of polarisation produced by a current of a certain duration. If there is much copper exposed, there will be much polarisation, and, therefore, little resistance in the fault itself, and \textit{vice versa}. And thus by careful comparison and analysis we can approximately determine the resistance of the fault and of the remaining resistance which determines the position of the fault.

Another case arises if a cable is ruptured, but the gutta-percha completely overlaps, and insulates partially the end of the broken wire. In that case we operate by measuring the capacity for charge of the cable, in connecting the cable with a powerful battery for a moment, and suddenly disconnecting it and making connection to earth through a galvanometer, when the needle is bent over to a certain angle; and from that angle of deflection we can calculate, as before described, the importance or capacity of the Leyden jar formed by the cable to the point of discontinuity. It is true that there is leakage; but by measuring the charges, and also the discharges, we find, in the difference, an expression for this leakage, and we can, by taking the mean between the two, determine the exact capacity of the cable remaining, and, therefore, also its length, having determined its specific capacity beforehand.

Another case, an analogous one, which occurs sometimes, is that the copper wire alone is separated, but the gutta-percha or other insulating covering remains intact. There we have the jar
THE ADDRESSES, LECTURES, ETC., OF

without any leakage at the end, and we can by our formula determine the importance of this jar as compared with the jar of unit capacity. Having thus determined the position of a fault in a cable under different circumstances, the vessel proceeds to the spot, takes it up, repairs it, and puts the cable back in its normal condition.

CONCLUSION.—Having now conducted you somewhat hurriedly over the field of electrical tests, I hope I have succeeded in satisfying your minds that the application of a well arranged system of tests is not only most desirable, but absolutely essential for the success of submarine cables. I would go further, and assert that a fault should never occur during the laying of a cable, for, however microscopic a fault may be, it ought to be detected before it goes overboard, and a good sheathing should secure the core against mechanical injury. When I addressed you before on the subject of deep-sea telegraphs, the Great Eastern was on the point of leaving these shores. I then expressed my confidence in the insulation of the cable, but some doubt as regards the efficiency of the outer covering. The failure which has since unfortunately occurred has not diminished my confidence in the insulated conductor, and in the eventual success of the undertaking, if only the outer covering and the arrangements for putting the cable to the bottom are more carefully attended to. It is to be hoped that those interested in that great undertaking may have profited by the experience they have gained, and that we may next summer hear of a complete success of that great undertaking, which, as far as electrical science is concerned, ought certainly to be a success.*

The Chairman: I am sure you will all join me in returning our best thanks to Mr. Siemens for the able manner in which he has brought the subject before us.

* This paper was read in the early spring of 1866. Since then this complete success has been achieved.—Editor of the R. U. S. I. Journal.
SIR WILLIAM SIEMENS, F.R.S.

TELEGRAPH TO INDIA.

To the Editor of "The Times" (Saturday, December 5th, 1868).

Sir,—In The Times of to-day I observe a letter from Sir James Anderson, in which he makes the most of the imperfections of land line telegraphs, and inveighs against the support given to them by the Government. No doubt he would be better pleased if the Government were to embark in a gigantic enterprise for the establishment of submarine cables over the coral bottom of the Red Sea and the Indian Ocean.

I agree with Sir James Anderson respecting the bad condition of land lines as they exist in many civilised countries, where they have been erected on the "cheap and nasty" principle, and consist of little more than sticks of wood and of pieces of pottery ware (dignified by the name of insulators) carrying flimsy wire; but I maintain that a land line properly constructed and worked is most reliable, even when carried through countries like Persia.

When Sir James Anderson speaks with disparagement of the different routes for messages to India which are now supposed to exist, according to the list of tariffs published by Colonel Goldsmid, I fully agree with him in regarding them as imperfect and unsatisfactory; but he omits to mention the substantial through-line which is now in course of construction by the Indo-European Telegraph Company, and which will be opened for traffic in less than a twelvemonth, under the guarantee of international conventions, and will, I am confident, give every satisfaction to the public.

Sir James Anderson also complains that the Government are about to squander public money in erecting a third wire between Teheran and Bushire, but he does not seem to be aware of the fact that this third wire will be paid for by the Indo-European Company at the termination of the Anglo-Persian telegraph treaty, and that the company in question is prepared to extend their lines hereafter from Shiraz to Bunder Abbass, whereby, with the line now being constructed along the Mekran coast, a double...
communication by sea and by land will be completed between Europe and India.

Requesting the favour of a short space for these explanatory remarks,

I am, Sir, your obedient servant,

C. W. Siemens.

3, Great George Street, Westminster, S.W., Dec. 4.

To the Editor of "The Times" (Tuesday, December 8th, 1868).

Sir,—The letters in The Times of this day from Sir James Anderson and Mr. Alfred Seymour, in answer to my letter of the 4th instant, on the subject of telegraphs to India, oblige me to again intrude myself upon your space.

Sir James Anderson wishes for a fair investigation of the merits of the case, and I agree with him thoroughly in this respect; but his intimate connexion with submarine enterprise leads him in spite of himself to see only the possible disadvantages of land lines and the possible advantages connected with the laying of submarine lines. His remarks imply that the government in completing the extension of the Indian Telegraph system to the Persian Gulf and Teheran bestows special advantages upon the Indo-European Telegraph Company, which is, however, not the case, inasmuch as these lines are equally necessary for the three routes—via Teheran and Russia, via Constantinople, and via Alexandria, through the Anglo-Mediterranean Telegraph, with which Sir James Anderson himself is so prominently connected. His estimate of the British expenditure upon these lines is, I believe, greatly exaggerated, and, so far from their being a dead charge upon the government, I gather from official statements that they are a source of considerable annual gain, notwithstanding the wretched condition of the lines now existing between the Persian Gulf and this country. The British Government is surely bound either to maintain their lines in good working condition, or to hand them over to others who may be willing to do so.

I have to thank Sir James Anderson for his good opinion of my
ability to construct a good land line; but in accepting the position he is kind enough to give me, I wish to state distinctly that I have no fear of serious interruptions to land lines by lightning, icicles, or cobwebs, against which enemies I place lightning dischargers at each post, good insulators, and disciplined superintendents of the line, who, instead of passing their time in idleness, as is too frequently the case till an actual stoppage of messages has occurred, are made to inspect the line at regular intervals and wipe out the insulators with a simple wet brush at the end of a long handle, and thus prevent the accumulation of hurtful matter.

Mr. Seymour charges me with leaving the chief argument of Sir James Anderson and of "An Englishman" untouched, viz., "that, do what you will, you cannot destroy the great fact that from one end to the other of his line the wires must always be accessible to those who may be hostile, are barbarous or ignorant, and would be on the first appearance of cholera either frightened away from their duties, or buried at the foot of the nearest telegraph post." I am sorry for the omission, and I admit the first part of the proposition thus clearly put, but maintain that neither submarine nor land lines are safe against destruction by a national enemy, or by the evilly disposed; but there is this much to be said in favour of a substantial land line,—that an interruption is easily traced to its source and easily set right, whereas any coral or other fisherman might be hired to raise and cut a submarine line (except in very deep water), and thereby cause a lengthened interruption of through communication. I protest, however, against the second part of Mr. Seymour's proposition, and against what Sir James Anderson says respecting the social and topographical condition of Persia. My experience of that country extends over several years, and I know for certain that of the 50 English telegraph officials who have resided there during five years, only one death, and that from natural causes, has occurred, and no case of personal injury from violence. These facts show more strongly than anything else I could add that the Parliamentary report Mr. Seymour had in his mind had reference to some other country.

I may add that at this moment a large staff of superintending engineers, including two members of my own family, are engaged
in Persia on the erection of the line for the Indo-European Telegraph Company, and that all reports, both official and private, which I have received, speak of a willingness, both on the part of the Persian government, and of the inhabitants, to facilitate our operations.

In the districts along the Mekran coast it may be necessary to subsidize certain chiefs, but British experience in the wild country between Bagdad and Fao proves that the demands of those chiefs are very moderate, and that they discharge their obligations as protectors most faithfully, inasmuch as no line in Asiatic Turkey has been less subject to interruption than that between Bagdad and Fao. Moreover, the Mekran coast line is only a necessary alternative to the submarine line from the Persian Gulf in case of the latter being interrupted.

In conclusion, I wish to state that I am not here to disparage the construction of submarine telegraphs either in the Red Sea or elsewhere; but what I maintain is that they should stand on their own commercial merits in the same manner as the Atlantic Cable or the lines of the Indo-European Telegraph Company do, and that it would certainly be unjustifiable that the government should subsidize one without subsidizing every line to India.

I am, Sir, your obedient servant,

C. W. SIEMENS.

3, GREAT GEORGE STREET, WESTMINSTER, S.W., Dec. 7.

ADDRESS

Of C. WILLIAM SIEMENS, F.R.S.*

President of Section G (the Mechanical Section) of the British Association, delivered on the 19th August, 1869.

In addressing you from this chair, I feel that I have accepted a task, which, however flattering, I should have hesitated to undertake, had I not every reason to rely on your forbearance, and upon

* Excerpt Journal of the British Association for the Advancement of Science, 1869, pp. 200–206.
the friendly support of those senior members of our profession who by their attendance at these annual gatherings give weight and importance to our proceedings. I also greatly depend on the co-operation of those members of the British Association who, although devoted chiefly to the cultivation of pure science, are nevertheless ever ready to assist us in our endeavours to apply that science to practical ends.

It is by submitting such subjects as will be brought before us to the double touchstone of science and of practical experience that we shall be able to appreciate real merit, and at the same time assist the authors of the several papers, by a confirmation or rectification of their views; thus redeeming our proceedings from the adherent disadvantage of lack of time to give that full and patient attention which the authors might meet with in bringing their subjects before the purely professional institutions of Civil Engineers, Mechanical Engineers, or Naval Architects.

In prefacing our proceedings with a few remarks on the leading subjects of the day of special interest to our section, I can scarcely pass over the popular question of technical education.

The Great International Exhibitions proved that, although England still holds her ground as the leading manufacturing country, the nations of the Continent have made great strides to dispute her pre-eminence in several branches, a result which is generally ascribed to their superior system of technical education. Those desirous of attaining a clear insight into that system, and the vast scale upon which it is being carried out under Government supervision, cannot do better than read Mr. John Scott Russell’s very able volume on this subject: they will no doubt agree with the author in the necessity of energetic steps being taken in this country to promote the work of universal education, although I for one think that objection may fairly be made against the plan of merely imitating the example of our neighbours.

The polytechnic schools of the Continent, not satisfied to impart to the technical student a good knowledge of mathematics and of natural sciences, pretend also to superadd the practical information necessary to constitute them engineers or manufacturers.

This practical information is conveyed to them by professors themselves lacking practical experience, and tends to engender in the students a dogmatical conceit which is likely to stand in the
way of originality in the adaptation of new means to new ends in their future career. On this account I should prefer to see a sound "fundamental" education, comprising mathematics, dynamics, chemistry, geology and physical science, with a sketch only of the technical arts, followed up by professional training such as can only be obtained in the workshop, the office, or the field.

The universal interest evinced throughout the country in the work of education, by parliamentary enquiries, by the erection of colleges and professorships, and by the munificence of a leading member of our section in endowing a hundred scholarships, are proofs that England intends to hold her place also in this question of education amongst the civilised nations; and I am confident that she will accomplish this object in a manner in unison with her practical tendencies and independence of character.

Closely allied to the question of education is that of the system of letters patent. A patent is, according to modern views, a contract between the commonwealth and an individual who has discovered a method peculiar to himself of accomplishing a result of general utility. The State, being interested to secure the information and to induce the inventor to put his discovery into execution, grants him the exclusive right of practising it or of authorising others to do so for a limited number of years, in consideration of his making a full and sufficient description of the same. Unfortunately this simple and equitable theory of the patent system is very imperfectly carried out, and is beset with various objectionable practices which render a patent sometimes an impediment to, rather than a furtherance of, applied science, and sometimes involve the author of an invention in endless legal contentions and disaster, instead of procuring for him the intended reward. These evils are so great and palpable that many persons, including men of undoubted sincerity and sound judgment on most subjects, advocate the entire abolition of the Patent Laws. They argue that the desire to publish the results of our mental labour suffices to ensure to the commonwealth the possession of all new discoveries or inventions, and that justice might be done to meritorious inventors by giving them national rewards.

This argument may hold good as regards a scientific discovery where the labour bestowed is purely mental, and carries with it the pleasurable excitement peculiar to the exercise and advancement
of science on the part of the devotee; but a practical invention has to be regarded as the result of a first conception elaborated by experiments, and their application to existing processes in the face of practical difficulties, of prejudice, and of various discouragements, involving also great expenditure of time and money, which no man can well afford to give away; nor can men of merit be expected to advocate their cause before the national tribunal of rewards where at best only very narrow and imperfect views of the ultimate importance of a new invention would be taken, not to speak of the favouritism to which the doors would be thrown open. Practical men would undoubtedly prefer either to exercise their inventions in secret, where that is possible, or to desist from following up their ideas to the point of their practical realization. If we review the progress of the technical arts of our time, we may trace important practical inventions almost without exception to the Patent Office. In cases where the inventor of a machine, or process, happened to belong to a nation without an efficient patent law, we find that he readily transferred the scene of his activity to the country offering him the greatest encouragement, there to swell the ranks of intelligent workers. Whether we look upon the powerful appliances that fashion shapeless masses of iron and steel into railway wheels or axles, or into the more delicate parts of machinery, whether we look upon the complex machinery in our cotton factories, our print works, and paper mills, or into a Birmingham manufactury, where steel pens, buttons, pins, buckles, screws, pencil-cases, and other objects of general utility are produced by carefully elaborated machinery at an extremely low cost, or whether we look upon our agricultural machinery by which England is enabled to compete without protection against the Russian or Danubian agriculturist, with cheap labour and cheap land to back him, in nearly all cases we find that the machine has been designed and elaborated in its details by a patentee who did not rest satisfied till he had persuaded the manufacturers to adopt the same, and had removed all their real or imaginary objections to the innovation. We also find that the knowledge of its construction reaches the public directly or indirectly through the Patent Office, thus enlarging the basis for further inventive progress.

The greatest illustration of the beneficial working of the Patent
Laws was supplied in my opinion by James Watt when, just 100 years ago, he patented his invention of a hot working cylinder and separate steam-engine condenser. After years of contest against those adverse circumstances that beset every important innovation, James Watt, with failing health and scanty means, was only upheld in his struggle by the deep conviction of the ultimate triumph of his cause. This conviction gave him confidence to enlist the co-operation of, a second capitalist after the first had failed him, and of asking for an extension of his declining patent.

Without this opportune help Watt could not have succeeded to mature his invention. He would in all probability have relapsed into the mere instrument maker, with broken health and broken heart, and the introduction of the steam-engine would not only have been retarded for a generation or two, but its final progress would have been based probably upon the coarser conceptions of Papin, Savory, and Newcomen.

It can easily be shown that the perfect conception of the physical nature of steam, which dwelt, like a Heaven-born inspiration, in Watt’s mind, was neither understood by his contemporaries nor by his followers up to very recent times, nor can it be gathered from Watt’s imperfect specification. James Watt was not satisfied to exclude the condensing water from his working cylinder, and to surround the same by non-conducting substances, but he placed between the cylinder and the non-conducting envelope a source of heat in the form of a steam-jacket, filled with steam at a pressure somewhat superior to that of the working steam. His immediate successors not only discarded the steam-jacket, and even condemned it on the superficial plea that the jacket presented a larger and hotter surface for loss by radiation than the cylinder, but expansive working was actually rejected by some of them on the ground that no practical advantage could be obtained by it.

The modern engine, notwithstanding our perfected means of construction, had in fact degenerated in many instances into a virtual steam-meter, constructed apparently with a view of emptying the boiler in the shortest possible space of time.

It is only during the last twenty or thirty years that the subtile action of saturated steam, in condensing upon the sides of the cylinder when under pressure, and of evaporating when the
pressure is relieved towards the end of each stroke, has been again recognised and insisted upon by Le Chatelier and others who have shown the necessity of a slightly superheated cylinder, in order to realise the expansive force of steam.

The result has been a reduction in the consumption of fuel in our best marine engines from 6 or 8 to below 3 lbs. per gross indicated horse power.

It is a hopeful circumstance, that during the next Session of Parliament the whole question of the Patent Laws is likely to be inquired into by a Special Committee, who, it is to be hoped, will act decidedly in the general interest, without being influenced by special or professional claims. They will have it in their power to render the Patent Office an educational institution of the highest order.

In viewing the latest achievements of engineering science, two works strike the imagination chiefly by their exceeding magnitude, and by the influence they are likely to exercise upon the traffic of the world. The first of these is the Great Pacific Railway, which, in passing through vast regions hitherto inaccessible to civilized man, and over formidable mountain chains, joins California with the Atlantic States of the Great American Republic. The second is the Suez Shipping Canal, which, notwithstanding adverse prognostications and serious difficulties, will be opened very shortly to the commerce of the world. These works must greatly extend the range of commercial enterprise in the North Pacific and Indian Seas. The new waterway to India will, owing to the difficult navigation of the Red Sea, be in effect only available for ships propelled by steam, and will give a stimulus to that branch of engineering.

Telegraph communication with America has been rendered more secure against interruption by the successful submersion of the French Transatlantic Cable. On the other hand, telegraphic communication with India still remains in a very unsatisfactory condition, owing to imperfect lines and divided administration. To supply a remedy for this public evil, the Indo-European Telegraph Company will shortly open its special lines for Indian correspondence. In Northern Russia the construction of a land line is far advanced to connect St. Petersburgh with the mouth of the Amour River, on completion of which only a submarine link
between the Amour and San Francisco will be wanting, to complete the telegraphic girdle round the earth.

With these great highways of speech once established, a network of submarine and aërial wires will soon follow to bind all inhabited portions of our globe together into a closer community of interests, which, if followed up by steam communication by land and by sea, will open out a great and meritorious field for the activity of the civil and the mechanical engineer.

But while great works have to be carried out in distant parts, still more remains to be accomplished nearer home. The Railway of to-day has not only taken the place of high roads and canals, for the transmission of goods and passengers between our great centres of industry and population, but is already superseding by-roads leading to places of inferior importance; it competes with the mule in carrying minerals over mountain passes, and with the omnibus in our great cities. If a river cannot be spanned by a bridge without hindering navigation, a tunnel is forthwith in contemplation; or, if that should not be practicable, the transit of trains is yet accomplished by the establishment of a large steam ferry.

It is one of the questions of the day to decide by which plan the British Channel should be crossed, to relieve the unfortunate traveller to the Continent of the exceeding discomfort and delay inseparable from the existing most imperfect arrangements. Considering that this question has now been taken up by some of our leading engineers and is also entertained by the two interested Governments, we may look forward to its speedy and satisfactory solution.

So long as the attention of railway engineers was confined to the construction of main lines, it was necessary for them to provide for a heavy traffic and high speeds, and these desiderata are best met by a level permanent way, by easy curves and heavy rails of the strongest possible materials, namely, cast steel; but in extending the system to the corners of the earth, cheapness of construction and maintenance, for a moderate speed and a moderate amount of traffic, became a matter of necessity.

Instead of plunging through hill and mountain, and of crossing and re-crossing rivers by a series of monumental works, the modern railway passes in zigzag up the steep incline and conforms
to the windings of the narrow gorge; it can only be worked by light rolling stock of flexible construction, furnished with increased power of adhesion and great brake-power. Nevertheless, by the aid of the electric telegraph, in regulating the progress of each train, the number of trains may be so increased as to produce a large aggregate of traffic, and it is held by some that even our trunk lines would be worked more advantageously by light rolling stock.

The brake-power on several of the French and Spanish railways has been greatly increased by an ingenious arrangement conceived by Monsieur Le Chatelier, of applying what has been termed "Contre vapeur" to the engine, converting it for the time being into a pump forcing steam and water into its own boiler.

While the extension of communication occupies the attention of perhaps the greater number of our engineers, others are engaged upon weapons of offensive and defensive warfare. We have scarcely recovered our wonder at the terrific destruction dealt by the Armstrong gun, the Whitworth bolt or the steel barrel consolidated under Krupp's gigantic steam hammer, when we hear of a shield of such solidity and toughness as to bid defiance to them all. A larger gun or a harder bolt by Palliser or Gröson is the successful answer to this challenge, when again defensive plating, or greater tenacity to absorb the power residing in the shot, or of such imposing weight and hardness combined as to resist the projectile absolutely (causing it to be broken up by the force residing within itself) is brought forward.

The ram of war with heavy iron sides, which a few years since was thought the most formidable, as it certainly was the most costly weapon ever devised, is already being superseded by vessels of the "Captain type" as designed by Captain Coles, and ably carried out by Messrs. Laird Brothers, with turrets (armed with guns by Armstrong of gigantic power) that resist the heaviest firing, both on account of their extraordinary thickness, and of the angular direction in which the shot is likely to strike.

By an ingenious device Captain Moncrieff lowers his gun upon its rocking carriage after firing, and thereby does away with embrasures (the weak places in protecting works) while at the same time he gains the advantage of re-loading his gun in comparative safety.
It is presumed that in thus raising formidable engines of offensive and defensive warfare the civilised nations of the earth will pause before putting them into earnest operation; but, if they should do so, it is consolatory to think that they could not work them for long without effecting the total exhaustion of their treasuries, already drained to the utmost in their construction.

While science and mechanical skill combine to produce these wondrous results, the germs of further and still greater achievements are matured in our mechanical workshops, in our forges, and in our metallurgical smelting works; it is there that the materials of construction are prepared, refined, and put into such forms as to render greater and still greater ends attainable. Here a great revolution of our constructive art has been prepared by the production, in large quantities and at moderate cost, of a material of more than twice the strength of iron, which, instead of being fibrous, has its full strength in every direction, and which can be modulated to every degree of ductility, approaching the hardness of the diamond on the one hand, and the proverbial toughness of leather on the other. To call this material cast steel seems to attribute to it brittleness and uncertainty of temper, which, however, are by no means its necessary characteristics. This new material, as prepared for constructive purposes, may indeed be both hard and tough, as is illustrated by the hard steel rope that has so materially contributed to the practical success of steam ploughing.

Machinery steel has gradually come into use since about 1850, when Krupp of Essen commenced to supply large ingots that were shaped into railway tyres, axles, cannon, &c., by melting steel in halls containing hundreds of melting crucibles.

The Bessemer process, in dispensing with the process of puddling, and in utilising the carbon contained in the pig iron to effect the fusion of the final metal, has given a vast extension to the application of cast steel for railway bars, &c.

This process is limited however in its application to superior brands of pig iron, containing much carbon and no sulphur or phosphorus, which latter impurities are so destructive to the quality of steel. The puddling process will still have to be resorted to, unless the process of decarburisation proposed by Mr. Heaton should be able to compete with it, to purify these inferior
pig irons which constitute the bulk of our productions, and the puddled iron cannot be brought to the condition of cast steel except through the process of fusion. This fusion is accomplished successfully in masses of from three to five tons on the open bed of a regenerative gas furnace at the Landore Siemens-Steel Works and at other places. At the same works cast steel is also produced, to a limited extent as yet, from iron ore which, being operated upon in large masses, is reduced to the metallic state and liquified by the aid of a certain proportion of pig metal. The regenerative gas furnace, the application of which to glass houses, to forges, &c., has made considerable progress, is unquestionably well suited for these operations, because it combines an intensity of heat limited only by the point of fusion of the most refractory material, with extreme mildness of draught and chemical neutrality of flame.

These and other processes of recent origin tend towards the production at a comparatively cheap rate of a very high class material that must shortly supersede iron for almost all structural purposes. As yet engineers hesitate, and very properly so, to construct their bridges, their vessels, and their rolling stock of the material produced by these processes, because no exhaustive experiments have been published as yet fixing the limit to which they may safely be loaded in extension, in compression, and in torsion, and because no sufficient information has been obtained regarding the tests by which their quality can best be ascertained.

This great want is in a fair way of being supplied by the experimental researches that have been carried on for some time at Her Majesty’s Dockyard at Woolwich under a committee appointed for that purpose by the Institution of Civil Engineers. In the meantime excellent service has been rendered by Mr. Kirkaldy in giving us, in a perfectly reliable manner, the resisting power and ductility of any sample of material which we wish to submit to his tests.

The results of Mr. Whitworth’s experiments, tending to render the hammer and the rolls partly unnecessary, by consolidating cast steel while in a semi-fluid state, in strong iron moulds, by hydraulic pressure, are looked upon with general interest.

But, assuming that the new material has been reduced to the utmost degree of uniformity and cheapness, and that its limits of strength are fully ascertained, there remains still the task for the
civil and mechanical engineer to prepare designs suitable for the
development of its peculiar qualities. If, in constructing a girder
for example, a design were to be adopted that had been worked
out for iron, and if all the scantlings were simply reduced in the
inverse proportion of the absolute and relative strength of
the new material as compared with iron, such a girder would
assuredly collapse when the test-weight was applied, for the simple
reason that the reduced sectional area of each part, in proportion
to its length, would be insufficient to give stiffness. You might as
well almost take a design for a wooden structure and carry it out
in iron by simply reducing the section of each part. The ad-
vantages of using the stronger material become most apparent if
applied for instance to large bridges where the principal strain
upon each part is produced by the weight of the structure itself,
for, supposing that the new material can be safely weighted to
double the bearing strain of iron, and that the weight of the
structure were reduced by one-half accordingly, there would
still remain a large excess of available strength, in consequence of
the reduced total weight, and this would justify a further re-
duction of the amount of the material employed. In constructing
works in foreign parts, the reduced cost of carriage furnishes also
a powerful argument in favour of the stronger material, although
its first cost per ton might largely exceed that of iron.

The inquiries of the Royal Coal Commission into the extent and
management of our coal fields appear to be re-assuring as regards
the danger of their becoming soon exhausted; nevertheless, the
importance of economising these precious deposits in the production
of steam power in metallurgical operations and in domestic use can
hardly be over-estimated. The calorific power residing in a pound
of coal of a given analysis can now be accurately expressed in units
of heat, which again are represented by equivalent units of force
or of chemical action; therefore, if we ascertain the consumption
of coal of a steam engine or of a furnace employed in metallurgical
operations, we are able to tell, by the light of physical science,
what proportion of the heat of combustion is utilised and what
proportion is lost. Having arrived at this point we can also trace
the channels through which loss takes place, and in diminishing
these, by judicious improvement, we shall more and more approach
those standards of ultimate perfection which we can never reach,
but which we should nevertheless keep steadfastly before our eyes. Thus a pound of ordinary coal is capable of producing 12,000 Fahr. units of heat, which equal 9,240,000 foot lbs. or units of force, whereas the very best performances of our pumping engines do not exceed the limit of 1,000,000 foot lbs. of force per pound of coal condensed. In like manner one pound of coal should be capable of heating 33 pounds of iron to the welding point (of say 3000° Fahr.), whereas, in an ordinary furnace, not two pounds of iron are so heated with one pound of coal. These figures serve to show the great field for further improvement that lies yet before us.

Although heat may be said to be the moving principle by which all things in nature are accomplished, an excess of it is not only hurtful to some of our processes, such as brewing, and destructive to our nutriments, but to those living in hot climates, or sitting in crowded rooms, an excess of temperature is fully as great a source of discomfort as excessive cold can be. Why then, may I ask, should we not resort to refrigeration in summer as well as to calorification in winter, if it can be shown that the one can be done at nearly the same cost as the other? So long as we rely for refrigeration upon our ice-cellers, or upon importation of ice from distant parts, we shall have to look upon it as a costly luxury only; but by the use of properly constructed machines, it will be possible, I believe, to produce refrigeration at an extremely moderate expenditure of fuel and labour. A machine has already been constructed capable of producing 9 lbs. of ice (or its equivalent) for 1 lb. of coal, whereas the equivalent values of positive heat developed in the combustion of 1 lb. of coal and of negative heat residing in 1 lb. of ice is about as 12,000 to 170, or as 1 to 70. This result already justifies the employment of refrigerating machines upon a large scale; but it is hard to say what practical results may yet be reached with an improved machine on strictly dynamical principles, because such a machine seems not to be tied in its results to any definite theoretical limits. In changing, for example, a pound of water from the liquid into the gaseous state, a given number of units of heat are required, that may be produced by combustion of coal or by the expenditure of force, but in changing the same pound of water into ice, heat is not lost but gained in the operation, which heat must
be traceable to another part of the machine, either as sensible heat or as developed force. It would lead me too far to enter here into particulars on this question, which is one not without interest for the physicist and the mechanical engineer.

There are several other subjects I should have gladly mentioned were I not afraid of encroaching unduly upon our time; some of these will, however, be brought before the section in the form of distinct papers, and will, I trust, lead to interesting discussions.

INAUGURAL ADDRESS

Of C. William Siemens, D.C.L., F.R.S.,*

President of the Society of Telegraph Engineers,

Delivered on February 28, 1872.

Gentlemen,—In addressing you at this, the first General Meeting of the Society of Telegraph Engineers, I have, above all things, to express to you my sincere thanks for the great honour you have bestowed upon me in electing me your President. It is not for me to question the wisdom of your choice, although I must confess that it took me completely by surprise; I must rather endeavour to justify your confidence by doing my best to promote the interests of the infant society. Some years must necessarily elapse before our Society can have given substantial proof of its useful action, and by that time this chair will have been filled by other members of your body, but our future prosperity will be influenced in a great measure by the direction in which we shall start upon our pilgrimage. Let us hope, therefore, that our joint efforts may lead us in the direction of true scientific and practical advancement.

But before we set out upon our labours it behoves us fairly to consider whether there is need or scope for a Society of Telegraph

Engineers? Is telegraph engineering not a branch of civil engineering, and do not all our proceedings therefore fall within the legitimate sphere of action of the Institution of Civil Engineers? Or if we meet with difficult questions in physical or mathematical science, is not the Royal Society or Section A of the British Association open for us to discuss them, or may we not go before the Institution of Mechanical Engineers with any purely mechanical question? Is it desirable, indeed, it may be urged, to take a branch from the parent stem and to cultivate it separately; shall we not degenerate thereby into "specialists," or what may be called "fractional quantities of scientific men," and this in the face of the patent fact that the further we advance in scientific knowledge (whether pure or applied) the more clearly we perceive the intimate connection between its different branches, and the impossibility of cultivating one without constantly reverting to the others.

In answer to such allegations we may fairly assert that we do not intend to become "specialists" in the narrow sense of wishing to confine the range of our knowledge to the phenomena and appliances which have an immediate application to our professional objects. We are, on the contrary, sensible to the fact that in order to master those special branches of knowledge thoroughly we shall have to travel into adjacent fields and build our practice upon the wildest possible scientific foundation. But our time is limited, and, although the great principles of nature may be understood generally by one person, their applications are infinite, and all we may hope to do is to attain to a general scientific basis, and with it to devote our energies vigorously to the details of one or two branches of applied science.

If it is impossible for one man to master the special knowledge accumulated in different branches of engineering science, it would be equally impossible for one society to cultivate all those branches in detail; thus the Royal Society can only entertain questions involving general principles of science, and is obliged to leave questions of exhaustive research to special societies; questions of minute chemical investigation are assigned to the Chemical Society; questions regarding the orbits of celestial bodies to the Astronomical Society; and by the same rule of limitation the Royal Society would refuse to receive for instance a paper on
testing the joints of insulated wire, which would be a subject peculiarly suited for our society. The Institution of Civil Engineers has, on the other hand, received, at certain intervals of time (varying from two to three years) a general paper on the progress of telegraph engineering; but it is self-evident that such an occasional paper must be quite inadequate to constitute a record of the progress of a branch of engineering which gives daily proof of its public importance, which is distinguished for its rapid development, and which comprises within itself a wide range of scientific inquiry. Nor would there be time, on such rare occasions, to discuss questions of detail which are of special interest to the telegraph engineer.

We may, therefore, safely conclude that a Society of Telegraph Engineers is necessary for the more rapid development of a new and important branch of applied science; I further maintain that such an institution is desirable in order to afford telegraph engineers frequent opportunities of meeting each other in friendly intercourse, and of impressing them with the conviction that their united action will be advantageous to the material interests of all.

The measure of usefulness of the new society must depend, however, in the first place, upon its constitution and upon the amount of support which it is likely to receive, and in the second place upon the well-directed and continued exertions of its members, particularly of those members and associates who have accepted posts of trust in the council, or as members of the publishing committee. As regards the constitution of the society, a code of rules has been prepared by the committee appointed by the preliminary meeting of the original members, which have been placed in your hands. These rules do not differ materially from those of other societies having similar objects in view. The election of the President and members of council of the society takes place annually according to certain rules which have been framed with a view of combining efficiency of action with a gradual renewal from year to year of the governing body. The society is open to all persons above 23 years of age, who are interested in telegraphy without being necessarily telegraph engineers by profession—they may be physicists, engineers, administrators, or operators in the telegraphic service. They have to be proposed
by several members or associates, and if the council sees no grounds for disqualification the candidates so proposed will be balloted for at the first ordinary meeting of the society. It is the duty of the council to transfer those associates who are duly qualified, according to the provisions of paragraph 2, into the class of members.

As regards accession of members, we have every reason to be satisfied with the first fruits of our labour. Our actual list of members contains already 110 names, without counting the class of foreign members, regarding which I shall have to make a special communication, and without counting the candidates for election, which you will be asked to admit by ballot this evening. I am happy to be able to point in our list of members to the historic names of Wheatstone, Cooke, and Morse, to the distinguished names of Thomson, Tyndall, and others scarcely less renowned for their important contributions to electrical science. Other well-known names will shortly appear in our next list of foreign and resident members. The support of the two great telegraph administrations of Great Britain and India is secure to us through the accession of the directors-general and the chief engineers connected with those systems. The military branch of telegraph engineering is very fully represented by the distinguished chemist and engineer officers charged with those departments. As regards professional telegraph engineers the list includes an array of names many of which will ever remain associated with important improvements and generally with early telegraphic enterprise by sea and by land. The list of associate members includes names of promise and administrative ability, but it is as yet far too short for the wellbeing and the useful action of the society. The aspirant telegraph engineer, the superintendent of a station, and others employed in the service, will find the Society of Telegraph Engineers, with its transactions, a useful source of technical information, and productive of excellent opportunities of meeting those who through personal acquaintance may forward their interests as well as extend their knowledge.

The council have refrained from conferring honorary memberships, because they feel that the young society has to establish its own worth before it can pretend to bestow such honorary distinc-
tions which at a later period it is to be hoped men of high position will have pleasure in accepting.

On the other hand it is most desirable to secure for the young society the support and cooperation of men occupying influential positions as directors and engineers of the great telegraphic systems of the world. The great network of international telegraphy extends already to every portion of the civilised and semi-civilised world; it traverses deserts and mountain chains, it passes over the deep plateau of the Atlantic and over the more dangerous bottom of tropical seas: what would be good practice in one country or under one order of climatic influences would be objectionable, insufficient, or wholly impracticable under another; but all these systems are intimately linked together, and the knowledge of the telegraph engineer must apply equally to all. In order, however, to combine the knowledge of these diverse circumstances, and of the diverse practice resulting therefrom, it is necessary for a Society of Telegraph Engineers to be a cosmopolitan institution, to be a focus into which the thoughts and observations of all countries flow, in order to be again radiated in every direction for the general advancement of this important branch of applied science.

In order to bring about such a result, the council have agreed to the creation of another class of members,—"the foreign members,"—who, while receiving the transactions of the society, and enjoying other privileges of membership, so far as distance will permit them to do so, will be called upon to pay only an annual subscription of 25 francs, or £1, instead of the £2 2s. payable by members residing in England. The council authorised me to invite the representatives of the telegraphic administrations of the world lately assembled in Congress at Rome to join our society under this special title, and I am happy to state that my appeal has been most cordially responded to by the directors-general and representatives of several of the most important telegraphic systems of the continent.

My application was conceived in the following terms:—

"Monsieur,—J'ai l'honneur de vous adresser par la présente les Statuts de la 'Society of Telegraph Engineers,' de laquelle pour l'année courante j'ai été élu le Président, et qui s'est constituée
dernièrement à Londres pour discuter et pour publier régulièrement les progrès théoriques et pratiques qui seront effectués de temps en temps dans le matériel télégraphique. Il est l'intention du Comité de cette Société de donner un caractère international à ses transactions, et de les publier avec tous les soins possibles. Elle cherche donc de s'associer aux Directeurs aussi bien qu'aux Ingénieurs des systèmes télégraphiques continentales, et je suis chargé de vous prier de vouloir bien vous associer à notre Société à titre de Membre étranger.

"Les Membres étrangers auront les mêmes droits que les Membres ordinaires de la Société ; ils recevront en outre toutes les Transactions, et dans le cas d'une participation suffisante il a été suggéré même de publier les transactions en plusieurs langues. Le Comité de Publication sera heureux de recevoir les communications que vous voudrez bien lui adresser pour être incorporées dans les Transactions. La souscription annuelle pour les Membres étrangers a été fixée à une livre sterling, au lieu de deux livres sterling et deux shillings, la souscription des Membres ordinaires.

"Les noms distingués qui se trouvent dans la liste de nos membres sera une garantie suffisante, j'espère, pour vous satisfaire du caractère sérieux de cette entreprise, dont le besoin s'est fait sentir vivement.

"En attendant votre considération favorable, j'ai l'honneur d'être, Monsieur, etc."

* * * * *

From His Excellency General von Lüders, Director-General of the Imperial Russian Telegraphs.

Rome, le 21 Décembre, 1871.

Monsieur,—En vous accusant reception des Statuts de la "Society of Telegraph Engineers," que vous avez eu l'obligance de me faire parvenir, je crois devoir vous exprimer ma vive reconnaissance pour l'invitation d'entrer à titre de Membre étranger dans la Société dont vous êtes le Président, et je m'empresse de vous annoncer que j'accepte avec plaisir votre proposition.

Parfaitement convaincu du caractère sérieux et éminemment utile de l'entreprise organisée sous votre direction, je tacherai autant qu'il me sera possible de communiquer à la Société les
renseignements qui pourront servir de matériel pour être incorporés dans les Transactions que vous avez l'intention de publier.

Je vous prie, Monsieur, d'agréer l'assurance de ma considération très distinguée.

Mr. William Siemens,
Président de la "Society of Telegraph Engineers."

From Sig. D'Amico, Director-General of Telegraphs in Italy.

Rome, le 25 Décembre, 1871.

Monsieur,—Je suis très flatté de l'honneur d'appartenir comme Membre étranger à la Société des Ingénieurs Télégraphiques, et je vous remercie de la communication que vous m'en avez faite par votre lettre de Rome récemment reçue.

J'ai pourtant disposé pour le paiement au Trésorier de la Société à Londres, du montant en fcs. 25 de ma première souscription annuelle.

Agréez, Monsieur, les expressions de ma parfaite estime.

Le Directeur Général,
D'Amico.

Monsieur Ch. William Siemens,
Président de la "Société des Ingénieurs Télégraphiques,"
Hotel Costanzi, Rome.

From Sig. Salvatori, Inspector-General of Telegraphs in Italy.

Rome, 28 Décembre, 1871.

Monsieur,—C'est avec plaisir que j'accepte l'invitation que vous m'avez fait l'honneur de m'adresser, par votre lettre du 15 du mois courant, de me joindre, à titre de Membre étranger, à la "Society of Telegraph Engineers," dont vous avez bien voulu me communiquer les Statuts. Je vous prie, par conséquent, de me faire connaître à qui je devrai adresser le montant de la souscription annuelle et l'époque du versement.

J'ai l'honneur d'être, Monsieur,
Votre très dévoué,
F. Salvatori.

Mr. W. Siemens, Hotel Costanzi, Rome.
From M. Ailhaud, the Representative of France.

ROME, 25 Décembre, 1871.

Monsieur,—Je vous remercie de la communication que vous avez bien voulu m'adresser. J'accepte avec reconnaissance la proposition que vous me faites, et j'ai l'honneur de vous prier de me compter au nombre des Membres étrangers de la "Society of Telegraph Engineers." Je tiens à la disposition de la Société la somme de 25f. pour ma souscription annuelle. Veuillez agréer, Monsieur, l'assurance de mes sentiments les plus distingués.

Ailhaud,
Inspecteur-Général des Lignes Télégraphiques, France.

From M. Vinchant, the Representative of Belgium.

ROME, HOTEL DE LA MINERVE, 17 Décembre, 1871.

Monsieur le Président,—En référence à la communication que vous avez bien voulu m'adresser au sujet de la "Society of Telegraph Engineers" j'ai l'honneur de vous informer que j'accepte avec empressement votre proposition de me joindre à cette Société, à titre de Membre étranger. Veuillez agréer, Monsieur le Président, l'assurance de mes sentiments les plus distingués.

J. Vinchant,
Inspecteur-Général au Département des Travaux Publics de la Belgique.

From the General Secretary of the International Bureau.

ROME, le 20 Décembre, 1871.

Monsieur le Président,—J'accepte avec empressement l'offre que vous avez bien voulu me faire d'être Membre étranger de la
Société des Ingénieurs électriens qui s'est constituée à Londres, et je vous serai reconnaissant de me faire connaître à qui je dois m'adresser pour faire parvenir le montant de ma contribution annuelle.

Veuillez agréer, Monsieur le Président, l'hommage de mes sentiments respectueux.

R. DE ST. MARTIAL.

ROMIE, 17 Décembre, 1871.

Monsieur le Président,—J'ai pris connaissance avec intérêt de votre communication au sujet de la “Society of Telegraph Engineers” qui a été constituée dernièrement à Londres, et j'accepte volontiers l'offre que vous avez bien voulu avoir l'obligeance de me faire, d'être admis dans la Société à titre de Membre étranger.

Veuillez agréer, Monsieur le Président, l'expression de mes sentiments distingués.

STARTING,
Chef de la Division des Télégraphes au Ministère des Finances des Pays Bas.

À Monsieur le Dr. C. William Siemens,
à Rome.

ROMIE, 11 Janvier, 1872.

Monsieur,—En réponse à votre bien obligeante lettre m'invitant à me faire inscrire à titre de Membre étranger dans la Société d'Ingénieurs Télégraphiques que vous si dignement dirigez, je m'empresse de vous faire connaître que j'accepte avec reconnaissance votre invitation, craignant seulement de n'être pas digne de l'honneur d'appartenir à une si illustre Corporation.

J'ai l'honneur d'être, Monsieur,
Votre très dévoué
Hippolyte Arango (Espagne).

Monsieur le Dr. C. William Siemens.

BERLIN, 20/2/72.

Folge leiste und bitte mich als auswärtiges Mitglied der Gesellschaft aufzunehmen.

Hochachtungsvoll und ergebenst,

DR. WERNER SIEMENS.

An den Präsidenten der Society of Telegraph Engineers.

HERRN DR. C. W. SIEMENS, London.

Other members of the conference have given their adhesion to our Society verbally. Professor Capanema, the Director-General of Brazilian Telegraphs, has also signified his intention to join as Foreign member. M. Lendi, the Director-General of the Swiss Telegraphs and chief of the Bureau International, and Professor Morse, our only but worthy representative of the United States of America, had already joined the Society, but will have to be transferred to the list of Foreign members, a privilege which may be claimed by all members (English or Foreign) residing permanently abroad.

Our list of Foreign members will, it is to be hoped, include before long the names of many of the Inspectors-General and engineers of the Telegraphic Government administrations of the Continent, several of the Directors-General having promised, if requested to do so, to exert their influence with the gentlemen of their staffs.

The idea of an International Society, or indeed of a practically useful Society of Telegraph Engineers, could not be realised without the publication of carefully edited transactions comprising not only the subject-matter of papers that may be brought before us from time to time, but of all matters of scientific or technical interest relative to Telegraphy that can be brought together.

Such transactions will be of great practical value to every Telegraph Engineer or Administrator, wherever he may be placed, being a reliable source of information for his guidance regarding authenticated progress in telegraphic science. Hereafter, they will form a valuable historic record. There is no lack of talent amongst our members for the accomplishment of so important an object, and it is to be hoped that the interest taken in the Society by its members will be sufficient for its accomplishment.

London is unquestionably the proper seat for such a Society,
because it is the principal centre of the telegraphic enterprise of
the world, and musters consequently the greatest number of
Telegraph Engineers. It is a remarkable fact that the manu-
ufacture of insulated wire, and of submarine cables, is almost
entirely confined to the banks of the Thames. London also is
very accessible, and is actually visited more than any other capital
by the engineers and the enterprising of all nations.

A serious difficulty in the way of giving to our proceedings an
international character, will arise, no doubt, through the diversity
of languages dividing different nations. Many foreign engineers
understand the English language, but others do not, and we could
hardly expect their accession to our number unless we offered them
our proceedings either in their own language, or at least in another
language besides English, which they may understand. It may
safely be assumed that every educated person throughout the
civilised world speaks either French, German, or English, and it
does not appear to me improbable that the time may come when
we shall publish our proceedings in those three languages. The
only condition necessary for such a course would be a sufficient
accession of foreign members to warrant the expense of translation
and printing.

The expense of publishing a complete record of Telegraphic
progress will certainly exceed the limits of our subscriptions, and
it is proposed to establish a publishing fund, by voluntary
donations and subscriptions, which it is hoped will be favourably
received. We shall in this respect only follow the example set us
by the Chemical Society, who have thus succeeded in producing
the most valuable record of chemical progress.

History teaches us how to read the events of the present day
and what we may reasonably look forward to even in the future; let
us therefore review shortly in our minds the remarkable history
of the Electric Telegraph, in order that we may be better prepared
to deal with questions of immediate interest.

A generation has hardly passed away since the remarkable dis-
coversies of Oersted, Ampère, Faraday, and Weber, which laid the
foundation of the electro-magnetic telegraph. The names of
Steinheil, Schilling, Ronalds, Wheatstone, Cooke, and Morse,
furnish us with striking illustrations of the readiness with which
the thinking men of different nations turn scientific discovery to
practical use. While these pioneers in the field of telegraphic progress were still contending against practical difficulties, other earnest labourers entered the same field, amongst whom Werner Siemens, Bain, and Breguet should not pass unmentioned here. But so rapid has been the progress of our branch of science, that, while I am obliged to speak of these men as belonging to our early history, they are still, almost without exception, living amongst us in full enjoyment of their faculties, and, I am happy to add, members of our new Society. They have the rare satisfaction to see their early day-dreams carried out upon so vast a scale that there is to-day hardly a country, however remote, that is not within a few minutes', or at all events a few hours' call from every central point of the civilised world, that diplomatic conferences have to be held to regulate international telegraphy, and that a proposal is seriously entertained by the leading powers of the earth to place telegraphic property upon the highest, I may almost say a sacred basis, by declaring it inviolable in case of war. The electric telegraph has indeed attained to the dignity of a commercial, a social, and an international institution of the highest importance; it is a civiliser of the first magnitude, and we may well be proud to meet here together in furtherance of such a cause.

You will pardon me if I abstain from making special reference to the numerous claims to recognition of the fellow-labourers of the present day whom I am now addressing; they are well known within our own circle and to the public at large, but neither my ability nor the time at my command would suffice for such a task. I will only endeavour, before concluding this Address, to summarize the subject-matters which, judging from my experience, should engage our principal attention.

Problems of pure electrical science meet the telegraph engineer at every turn, the methods of testing insulated wire, of determining the position of a fault in a submarine cable under various circumstances, or of combining instruments so as to produce recorded messages by the mere fluctuation of electrical tension in a long submarine conductor, are problems worthy of the most profound physicist and mathematician. On the other hand, there is hardly a problem in electrical science that is not of practical interest to the Telegraph Engineer; and, considering that electricity is not
represented at present by a separate learned society, ranking with the Chemical or Astronomical Societies, I am of opinion that we should not exclude from our subjects questions of purely electrical science. The phenomena of electrification and polarisation, of specific induction and conduction, the laws regulating the electrical wave, the influences of rise of temperature on conduction or the potential force residing in a coil of wire of a given form, when traversed by a current, involve questions belonging just as much to pure physical science as to the daily practice of the Telegraph Engineer, and would at any rate be inseparable from our proceedings. Next in order come questions of selection of materials for conduction or insulation, of apparatus for the best utilisation of feeble currents, of apparatus for producing, alternating, and directing electrical currents, which, although still intimately connected with physical science, call into play considerations of mechanical combinations. This brings us to questions of purely mechanical import, such as the mechanical construction of instruments for recording or printing messages, of protecting and supporting insulated conductors by sea or land, or of constructing machinery for the manufacture, the laying, and the repairing of submarine cables.

These questions again lead up to the more general ones of transport of materials through difficult and inhospitable countries, of navigation, of investigations into the depth and the nature of the bottom of seas, into the nature and effect of sea currents, and so forth, all of which belong, under certain aspects at least, to the province of the Telegraph Engineer.

I would go further, and include even statistical information respecting the nature and growth of telegraphic correspondence, without which it is impossible to adapt the construction of lines and of working instruments to the requirements of particular cases. The invention of a telegraphic instrument, for instance, is only of practical value if it is suited to the circumstances of the particular traffic for which it is intended, and to the electrical condition of the lines which it is proposed to work, and when the early pioneers of telegraphic progress elaborated ingenious instruments for sending and recording messages automatically or for printing them in Roman type, they invariably failed, because the then existing lines were insufficient in every way for such refinement, and the simple
needle instrument seemed to suffice for all practical purposes. It was only when the exigencies of the traffic demanded a change, that instruments of this nature proved to be valuable inventions.

In like manner the long underground lines that were established on the Continent at an early date had to give way to suspended line-wire, whereas the present practice and necessities undoubtedly tend toward a reversion to the former, as being less liable to interruption by accident or by atmospheric influences, and because an unlimited number of underground wires may be established between any two stations without encumbering the public thoroughfares. The best mode of insulating and protecting these underground wires with a view to reducing the inductive influence of the one upon the other, and of facilitating access to the one, for the purposes of repairs, without disturbing the others, are questions of practical interest for the present day.

The Electric Telegraph is applicable with the greatest positive advantage for the intercommunication between two points a great distance apart; through its agency New York and Calcutta are as near to us in point of time as are the suburbs of our metropolis from one another. It is probable indeed that in telegraphing from one suburb to another the message has to be oftener retransmitted than in going from the City of London to India or America, because a direct transmission from any one part of London to another would involve almost an infinite number of line-wires in all directions. For this reason there must be a limit to the applicability of the Electric Telegraph in populous districts, and it behoves us to examine whether another agent may not be preferable in dealing with a traffic of this description. The pneumatic tube seems to be well adapted to these circumstances, and having been first applied for short distances by Latimer Clark, and subsequently modified and extended by others, it will fall within the province of our Society to examine fully into this and kindred methods that may be devised for effecting rapid interchange of intelligence in towns.

The questions of field telegraphs and torpedo connections are other branches of inquiry to which we shall have to give our attention, and to these may be added the art of combining secret codes and semaphore signals.

These remarks may suffice to show how great is the field for our
activity, and how much remains to be accomplished notwithstanding the extraordinary progress of which we are apt to boast.

I am happy to state that papers on several of these subjects have already been promised by leading members of our body.

Before concluding I have to ask you in the name of your Council to give your post-factum approval to several of our acts which strictly speaking should have been submitted to you for approval beforehand. We have taken upon ourselves to elect, without ballot, several distinguished men who had not joined our Society on the outset; we have admitted Foreign members upon terms different from those originally laid down for general membership; and we have postponed this opening meeting from the month of November, which was the time originally fixed upon, till the end of February. We may plead in excuse that we have been guided in these matters solely by the desire to give stability to our enterprise, by collecting in the first place the elements necessary for its success.

I consider it a most fortunate circumstance for our Society that through the liberality of the Council of the Institution of Civil Engineers we are enabled to hold our first meetings in these commodious rooms, under the roof of the parent Institution of Engineers, and with their good wishes to cheer us on our way. May our success justify their liberality, and may we all have reason hereafter to feel that we have accomplished a useful task in contributing towards the formation of the Society of Telegraph Engineers.
ADDRESS

Of C. William Siemens, Esq., D.C.L., F.R.S.,
President of the Institution of Mechanical Engineers,
Delivered at Liverpool, on Tuesday, 30th July, 1872.

The President,* in opening the proceedings, said there were two important subjects that had occupied the consideration of the Council for some time past, to which he had now to draw the attention of the members.

The first was the question of holding one of the meetings of the Institution annually in London. The wish having been expressed by several of the members that a meeting should be held in London once a year, the Council had considered the question carefully, and had come to the conclusion that it was desirable for a trial of such a meeting to be held next year, and the time most suitable for the convenience and advantage of the members was considered to be in the spring. As, however, the present rules contained no provision for holding such a meeting, it would be necessary for them to be altered for the purpose; and notice would accordingly be given at the next meeting for enabling the requisite alteration to be made at the anniversary meeting in January, that being the only meeting at which an alteration of the rules could be effected.

The second question had regard to the house of the Institution. The present accommodation had now become very insufficient, and the ordinary meetings of the Institution had to be held in a room kindly lent for the purpose. It had long been felt a matter of considerable importance and desirability to have a suitable house for the Institution, as soon as the funds were sufficient to warrant such a step; and the financial position was now very flourishing, the funds of the Institution amounting already to about £8,000, while the annual income exceeded the present ex-

penditure by more than £700. The Council considered therefore that the time had arrived when, if approved by the members, steps might be taken for erecting a suitable building. Preliminary inquiries had been made respecting a site in the neighbourhood of the present house of the Institution, and one which appeared eligible having been offered, an approximate plan and estimate had been prepared by the officers for a building sufficient for the present requirements, the amount arrived at being about £12,000. This expenditure would exceed the actual balance in hand by about £4,000, but it was thought that to this limited extent the surplus income might be anticipated. It had been considered desirable to take this early opportunity of giving the members information regarding this important question; but formal notice was proposed to be given at the next meeting of its being brought forward for discussion at the anniversary meeting in January next.

The President further announced that a cordial invitation had been received from the Royal Cornwall Polytechnic Society to hold the annual meeting of the Institution next summer in Cornwall; and the Council of the Institution had accepted the invitation, considering it a very desirable one, as Cornwall was a district which had not been visited before, and presented so many objects of interest for the members of the Institution.

He stated also that a letter had been received from the Royal Commission of the International Exhibition to be held in Vienna next year, inviting the members of the Institution to aid in promoting a complete representation of British machinery on that occasion; and he had much pleasure in commending the subject to their attention, and hoped all the members who were able would assist in furthering this object.

The President continued as follows:—

In consequence of the very courteous invitation which our Institution received last year, we are now assembled in this great town of Liverpool, to discuss with our Lancashire brethren questions of considerable scientific and practical interest. Considering that only two years have elapsed since Liverpool opened its spacious halls to the British Association, the invitation given to our Institution to hold here our general meeting for the current year speaks well for the scientific interest astir in this community,
which is remarkable alike for its commercial and engineering interests.

It behoves me also to congratulate the Institution on the very able and appropriate papers which have been prepared for this occasion, and to call attention to the importance attaching to them, in order that we may be prepared for their discussion. Foremost on the list we find a paper "On the progress effected in Economy of Fuel in Steam Navigation" by a member of our body well known to us for his power of grasping a subject with a view to bringing out in relief its salient points. This forms an important branch of the general subject of saving fuel, which in the presence of ever-increasing demand and of failing supply is rapidly rising into a question of the utmost national importance. The annual coal production in Great Britain amounts at present to 120 millions of tons, which, if taken at 10s. per ton of coal delivered, represents a money value of £60,000,000. It would not be difficult to prove that in almost all the uses of fuel, whether for the production of force, for the smelting and re-heating of iron, steel, copper, and other metals, or for domestic purposes, fully one-half of the enormous consumption might be saved by the general adoption of improved appliances, which are within the range of our actual knowledge, without entering the domain of purely theoretical speculation; the latter, indeed, would lead to the expectation of accomplishing our ends with only one-eighth or one-tenth part of the actual expenditure, as may readily be seen from the following figures. One pound of ordinary coal develops in its combustion 12,000 (Fahr.) units of heat, which in their turn represent $12,000 \times 772 = 9,264,000$ ft. lbs. or units of force, and these represent a consumption of barely $\frac{1}{4}$ lb. of coal per indicated horse-power per hour; whereas few engines produced an indicated horse-power with less than ten times that expenditure, or say $2\frac{1}{2}$ lbs. of coal. Again, the heat required to raise a ton of iron to the welding point of say $2,800^\circ$ Fahr. requires $2240 \times 2800 \times 0.13$ (specific heat) = 815,360 units of heat, which are producible by $\frac{815,360}{12,000} = 68$ lbs. of coal; whereas the ordinary heating furnace consumes more than ten times that amount.

Taking account, however, of a saving of only 50 per cent. in the actual average expenditure, we arrive at an annual money saving...
of £30,000,000 per annum, a sum equal to nearly one-half the national income. Nor does this enormous amount of waste indicate all the advantages that might be realised by strict attention to appliances for saving fuel, which are, generally speaking, also appliances for improving the quality of the work produced; in a national point of view it is of great importance that our coal deposits should be made to last as long as possible; and regarding public health and comfort, the smoke nuisance is the bane of our towns and the chief source of our discomfort in travelling by steamboat or railway, yet smoke emission is only another name for waste of fuel, smoke being nothing more or less than unconsumed coal. I am ready to admit, however, that the introduction of all coal-saving appliances involves a considerable expenditure, an expenditure which has to be conducted carefully, under the guidance of the mechanical engineer, but which, if properly directed, yields immediate and very ample returns.

In reverting to the important branch of the general subject which will be prominently brought before us, we shall find that our best marine engines consume to-day rather less than one-half the amount of fuel which was thought practically indispensable nine years ago, when our former meeting was held in Liverpool, showing that one section of our fraternity have at any rate not been idle in the interim. If nine years hence my successor in this chair be able to announce a similar step in advance, which may be looked for, I rather think, in the mode of producing the steam than in extending its expansive action to a still greater degree, we shall have the satisfaction of knowing that our further discussions of the subject have not resulted in "lost energy."

Another kindred paper on our list deals with the economic getting of coal and recommends the substitution of a well-considered mechanical process instead of human labour with the pick, which latter constitutes in my opinion a reproach to our age of professed humanity and mechanical resource, forming as it does part of a system of coal-getting that is susceptible of great improvements which will tend to cheapen production and to ensure increased safety and comfort to the men.

Another paper deals with interesting applications of hydraulic force to the working of shop tools, being a branch of the same important question of the substitution of machine for hand labour,
which commands our special interest at the present time when the available labour of the country does not nearly suffice for its requirements.

In addition to these we shall have a paper on Buchholz's system of decorticating grain, which is interesting as involving a new process of separating the flour from the grain; of this process we shall have an opportunity of judging by seeing it in actual operation. On a late occasion a plan was brought before us for breaking up the grain by dashing it against the rapidly revolving beaters of Carr's disintegrator; whereas according to Buchholz's plan it is ripped open, and the flour scraped off the bran by a succession of pairs of fluted steel cylinders driven at differential speeds. Without wishing to express an opinion in favour of the one method or the other, it appears to me likely that the rational principles of action involved in each must ultimately triumph, and that the millstone—a contrivance represented on Egyptian monuments and mentioned in the earliest historical records, which has continued to prepare for us our staff of life up to the present day—may be arrested in its meritorious course in obedience to the just but harsh decrees of the most uncompromising of beings, the mechanical engineer of the present day.

It is not my intention to take up the time of the meeting by a lengthy address; enough has been said to illustrate the importance and variety of the subjects brought before us for our information and discussion.

REMARDS ON PROFESSOR W. J. M. RANKINE.

The President* (Mr. C. W. Siemens) said, amongst the names of members deceased which had been announced in the Report of the Council just read, occurs one of such importance that I cannot proceed to the further business of this meeting without giving expression to my own appreciation, and I am sure yours also, of the high merit attaching to that name, and of the loss we have sustained; I allude to Professor Rankine.

Although a man of science of the highest order, Rankine was professedly and essentially a mechanical engineer. His deep researches into the constitution of matter in the three aggregate conditions of solids, fluids, and gases, are of a strictly mechanical nature, involving as they do the mechanical laws according to which the particles are moved by heat, which is the greatest potential force in nature, essential alike to the constitution and to the outward motion of matter. The very numerous published investigations by Professor Rankine prove, more than words can convey, the breadth, energy, and profundity of his mind; his manuals on engineering science will ever be regarded as standard works, teeming with sound information for the student who is not deterred by the rather formidable array of mathematical expressions with which they are somewhat overcharged. As a consulting engineer, Rankine’s advice was sought on many important questions where exact appreciation of mechanical principles was involved. He leaves no great actual works executed by himself, because his mind was less remarkable for inventive faculty or practical resource than for power of working out the true balance between cause and effect when presented to him in the form of a problem. All who knew Professor Rankine intimately will bear testimony to his moral rectitude, his genial nature, his kind-heartedness, and the filial affection with which he clung to his aged parents, whom he survived only a few years. His profound knowledge of the mechanical nature of things did not prevent him from appreciating also the poetry of nature; he was a thorough musician, and could compose a humorous song, including the words, and sing it himself in a genial and unaffected manner. Whoever heard him sing his “three-foot rule” or his railway song will not easily forget the pleasing effect produced. Having been on terms of intimacy with the deceased, I may be excused for speaking of his personal as well as his scientific merits, the combination of both being necessary in order to produce the truly great man that he undoubtedly was. His death is keenly felt by his friends, by the University in which he, the worthy successor of Professor Lewis Gordon, had filled the chair of civil engineering for seventeen years, and by the world of science at large. We, the members of the Institution of Mechanical Engineers, deplore the loss in him of one of our most enlightened and important members.
ON FUEL.

A Lecture delivered to the Operative Classes at Bradford on behalf of the British Association, 20th September, 1873.

BY C. WILLIAM SIEMENS, D.C.L., F.R.S., C.E.

In accepting the invitation of the Council of the British Association to deliver an address to the operative classes of this great industrial district, I felt that I was undertaking no easy task. Having to speak on behalf of the Association, and in the presence of many of its most distinguished members, I am bound to treat my subject scientifically, but I have to bear in mind at the same time that I am addressing myself to men unquestionably of good intelligence, but without that scientific training which has almost created a language of its own.

It is no consolation for me to think, that those who have taken a similar task upon themselves in former years, have admirably succeeded in divesting highly scientific subjects of the formalism in which they are habitually clothed. The very names of these men—Tyndall, Huxley, Miller, Lubbock, and Spottiswoode—are such as to preclude in me all idea of rivalry, but I hope to profit by their example, and to remember that truth must always be simple, and that it is only where knowledge is imperfect that scientific formulae must take the place of plain statements.

The subject matter of my discourse is "Fuel;" a matter with which every one of us has become familiarised from his infancy, but which nevertheless is but little understood even by those who are most largely interested in its applications; it involves considerations of the highest a priori interest, both from a scientific and a practical point of view.

I purpose to arrange my subject under five principal heads:—

1. What is fuel?
2. Whence is fuel derived?
3. How should fuel be used?
4. The coal question of the day.
5. Wherein consists the fuel of the sun?
What is Fuel?

Some of you may have already said within yourselves that it is but wasted time to enlarge upon such a theme, since all know that fuel is coal drawn from the earth, from deposits, with which this country especially has been bountifully supplied; why disturb our plain understanding by scientific definitions which will neither reduce the cost of coal, nor make it last longer on our domestic hearth?

Yet I must claim your patience for a little, lest, if we do not first agree upon the essential nature of fuel, we may afterwards be at variance in discussing its origin and its uses, the latter at any rate being of practical interest, and a subject worthy of your most attentive consideration.

Fuel, then, in the ordinary acceptation of the term is carbonaceous matter, which may be in the solid, the liquid, or in the gaseous condition, and which, in combining with oxygen, gives rise to the phenomenon of heat. Commonly speaking, this development of heat is accompanied by flame, because the substance produced in combustion is gaseous. In burning coal, for instance, on a fire-grate, the oxygen of the atmosphere enters into combination with the solid carbon of the coal and produces carbonic acid, a gas which enters the atmosphere, of which it forms a necessary constituent, since without it, the growth of trees and other plants would be impossible. But combustion is not necessarily accompanied by flame, or even by a display of intense heat. The metal magnesium burns with a great display of light and heat, but without flame, because the product of combustion is not a gas but a solid, viz. oxide of magnesium. Again, metallic iron, if in a finely divided state, ignites when exposed to the atmosphere, giving rise to the phenomena of heat and light without flame, because the result of combustion is iron oxide or rust; but the same iron, if presented to the atmosphere—more especially to a damp atmosphere—in a solid condition, does not ignite, but is nevertheless gradually converted into metallic oxide or rust as before.

Here, then, we have combination without the phenomena either of flame or light; but by careful experiment we should find that
heat is nevertheless produced, and that the amount of heat so produced precisely equals that obtained more rapidly in exposing pulverulent iron to the action of oxygen. Only, in the latter case the heat is developed by slow degrees, and is dispersed as soon as produced, whereas in the former the rate of production exceeds the rate of dispersion, and heat, therefore, accumulates to the extent of raising the mass to redness. It is evident from these experiments that we have to widen our conception, and call fuel "any substance which is capable of entering into combination with another substance, and in so doing gives rise to the phenomenon of heat."

In thus defining fuel, it might appear at first sight that we should find upon our earth a great variety, and an inexhaustible supply of substances that might be ranged under this head; but a closer investigation will soon reveal the fact, that its supply is, comparatively speaking, extremely limited.

** Constituents of the Earth.**—In looking at the solid crust of the earth, we find it to be composed for the most part of siliceous, calcareous, and magnesious rock; the former, silica, consisting of the metal silicon combined with oxygen, is not fuel, but rather a burnt substance which has part ed with its heat of combustion ages ago; the second, limestone, being carbonate of lime, or thecombination of two substances, viz., calcic oxide and carbonic acid, both of which are essentially products of combustion, the one of the metal calcium, and the other of carbon; and the third, magnesia, a combination of oxygen with the metal magnesium (which I have just burnt before you,) and which, further combined with lime, constitutes dolomite rock, of which the Alps are mainly composed. All the commoner metals, such as iron, zinc, tin, aluminium, sodium, &c., we find in nature in an oxidized or burnt condition; and the only metallic substances that have resisted the intense oxidizing action that must have prevailed at one period of the earth's creation are the so-called precious metals, gold, platinum, iridium, and to some extent also silver and copper. Excepting these, coal alone presents itself as carbon and hydrogen in an unoxidized condition. But what about the oceans of water, which have occasionally been cited as representing a vast store of heat-producing power ready for our use when coal shall be exhausted? Not many months ago, indeed, on the occasion of a water gas
company being formed, statements to this effect could be seen in some of our leading papers. Nothing, however, could be more fallacious. When hydrogen burns, doubtless a great development of heat ensues, but water is already the result of this combustion (which took place upon our globe before the ocean was formed), and the separation of these two substances would take precisely the same amount of heat as was originally produced in their combustion. It will thus be seen that both the solid and fluid constituents of our earth, with the exception of coal, of naphtha (which is a mere modification of coal), and the precious metals, are products of combustion, and therefore the very reverse of fuel. Our earth may indeed be looked upon as "a ball of cinder, rolling unceasingly through space," but happily in company with another celestial body—the sun,—whose glorious beams are the physical cause of everything that moves and lives, or that has the power within itself of imparting life, or motion on our earth. This invigorating influence is made perceptible to our senses in the form of heat, but it is fair to ask, what is heat, that it should be capable of coming to us from the sun, and of being treasured up in our fuel deposits both below and on the surface of the earth?

Definition of Heat.—If this inquiry had been put to me thirty years ago, I should have been much perplexed. By reference to books on Physical Science, I should have learnt that heat was a subtle fluid, which somehow or other, had taken up its residence in the fuel, and which, upon the ignition of the latter, was sallying forth either to vanish or to abide elsewhere; but I should not have been able to associate the two ideas of combustion and development of heat by any intelligible principle in nature, or to suggest any process by which it could have been derived from the sun and petrified, or, as the empty phrase ran, rendered latent in the fuel.

It is by the labours of Mayer, Joule, and other modern physicists, that we are enabled to give to heat its true significance.

Heat, according to the "dynamical theory," is neither more nor less than motion amongst the particles of the substance heated, which motion, when once produced, may be changed in its direction and its nature, and thus be converted into mechanical effect, expressible in foot pounds, or horse power. By intensifying this motion among the particles, it is made evident to our
visual organ by the emanation of light, which again is neither more nor less than vibrating motion imparted by the ignited substance to the medium separating us from the same. According to this theory, which constitutes one of the most important advances in science of the present century, heat, light, electricity and chemical action are only different manifestations of "energy of matter," mutually convertible, but as indestructible as matter itself.

**Forms of Energy.**—Energy exists in two forms, "dynamic" or "kinetic energy," or force manifesting itself to our senses as weight in motion, as sensible heat or as an active electrical current; and "potential energy," or force in a dormant condition. In illustration of these two forms of energy, I will take the case of lifting a weight, say one pound one foot high. In lifting this weight kinetic, muscular energy has to be exercised in overcoming the force of gravitation of the earth. The pound weight when supported at the higher level to which it has been raised, represents "potential energy" to the amount of one unit or "foot pound." This potential energy may be utilised, in imparting motion to mechanism, during its descent, whereby a unit amount of "Work" is accomplished. A pound of carbon then, when raised through the space of one foot from the earth, represents, mechanically speaking, a unit quantity of energy, but the same pound of carbon when separated or, so to speak, lifted away from oxygen, to which it has a very powerful attraction, is capable of developing no less than 11,000,000 foot pounds or unit quantities of energy whenever the bar to their combination, namely, excessive depression of temperature, is removed; in other words, the mechanical energy set free in the combustion of one pound of pure carbon is the same as would be required to raise 11,000,000 * pounds weight one foot high, or as would sustain the work which we call a horse power during 5 hours 33 minutes. We thus arrive at once at the utmost limit of work which we can ever hope to accomplish by the combustion of one pound of carbonaceous matter, and we shall presently see

* In burning 1 lb. of carbon in the presence of free oxygen, carbonic acid is produced and 14,500 units of heat (a unit of heat is 1 lb. of water raised through 1° Fahr.) are liberated. Each unit of heat is convertible (as proved by the deductions of Mayer and the actual measurements of Joule) into 774 units of force or mechanical energy; hence 1 lb. of carbon represents really 14,500 × 774 = 11,223,000 units of potential energy.
how far we are still removed in our practice from this limit of perfection.

The following illustrations will show the convertibility of the different forms of energy. If I let the weight of a hammer descend in rapid succession upon a piece of iron it becomes hot, and on beating a nail thus vigorously and skilfully for a minute it will be red hot. In this case the mechanical force developed in the arm (by the expenditure of muscular fibre) is converted into heat. Again, in rapidly compressing the air in a fire syringe, ignition of a piece of tinder is obtained. Again, in passing an electrical current through the platinum wire it is directly converted into heat, which is manifested by ignition of the wire, whereas the thermopile gives an illustration of the conversion of heat into electricity; to which illustrations many others might be added. The heat of combustion being the result of the chemical combination of two substances, does it not follow that oxygen is a combustible as well as a carbonaceous substance which goes by the name of fuel? This is, unquestionably, the case, and if our atmosphere was composed of a carbonaceous gas we should have to conduct our oxygen through tubes and send it out through burners to supply us with light and heat, as will be seen by the experiment in which I burn a jet of atmospheric air in a transparent globe filled with common lighting gas; but we could not exist under such inverted conditions, and may safely strike out oxygen and analogous substances such as chlorine from the list of fuels.

We now approach the second part of our inquiry—

WHENCE IS FUEL DERIVED?

The rays of the sun represent energy in the form of heat and light, which is communicated to our earth through the transparent medium which must necessarily fill the space between us and our great luminary. If these rays fall upon the growing plant, their effect disappears from direct recognition by our senses, inasmuch as the leaf does not become heated as it would if it were made of iron or dead wood, but we find a chemical result accomplished, viz., carbonic acid gas, which has been absorbed by the leaf of the tree from the atmosphere, is there "dissociated," or separated
into its elements carbon and oxygen, the oxygen being returned to the atmosphere, and the carbon retained to form the solid substance of the tree.

Solar Energy in Fuel.—The sun thus imparts 11,000,000 units of energy to the tree for the formation of one pound of carbon in the shape of woody fibre, and these 11,000,000 units of energy will be simply resuscitated when the wood is burnt, or again combined with oxygen to form carboxic acid.

Fuel, then, is derived through solar energy acting on the surface of our earth.

But what about the stores of mineral fuel, of coal, which we find within its folds? How did they escape the general combustion which, as we have seen, has consumed all other elementary substances? The answer is a simple one. These deposits of mineral fuel are the results of primeval forests, formed in the manner of to-day through the agency of solar rays, and covered over with earthy matter in the many inundations and convulsions of the globe's surface, which must have followed the early solidification of its surface. Thus our deposits of coal may be looked upon as the accumulation of potential energy derived directly from the sun in former ages, or as George Stephenson, with a sagacity of mind in advance of the science of his day, answered, when asked what was the ultimate cause of motion of his locomotive engine, "that it went by the bottled-up rays of the sun."

It follows from these considerations that the amount of potential energy available for our use is confined to our deposits of coal, which, as appears from the exhaustive enquiries lately made by the Royal Coal Commission are still large indeed, but by no means inexhaustible, if we bear in mind that our requirements will be ever on the increase and that the getting of coal will become from year to year more difficult as we descend to greater depths. To these stores must be reckoned lignite and peat, which, although not coal, are nevertheless the result of solar energy, attributable to a period of the earth's creation subsequent to the formation of the coal beds, but anterior to our own days. These fuels may be made as efficient as coal if properly treated.

In discussing the necessity of using our stores of fuel more economically, I have been met by the observation that we need not be anxious about leaving fuel for our descendants—that the
human mind would surely invent some other source of power when coal should be exhausted, and that such a source would probably be discovered in electricity. I heard such a suggestion publicly made only a few weeks back at a meeting of the International Jury at Vienna, and could not refrain from calling attention to the fact that electricity is only another form of energy, that could no more be created by man than heat could, and involved the same recourse to our accumulated stores.

If our stores of coal were to ebb, we should have recourse, no doubt, to the force radiating from the sun from year to year, and from day to day; and it may be as well for us to consider what is the extent of that force, and what are our means of gathering and applying it.

_Growth of Plants._—We have, then, in the first place the accumulation of solar energy upon our earth's surface by the decomposition of carbonic acid in plants, a source which we know by experience suffices for the human requirements in thinly populated countries, where industry has taken only a slight development. Wherever population accumulates, however, the wood of the forest no longer suffices even for domestic requirements, and mineral fuel has to be transported from great distances.

_Water Power._—The sun's rays produce, however, other effects besides vegetation, and amongst these, that of evaporation is the most important as a source of available power. By the solar rays, an amount of heat is imparted to our earth that would evaporate yearly a layer of water fourteen feet deep. A considerable proportion of this heat is actually expended in evaporating sea water, producing steam or vapour, which falls back upon the entire surface of both land and sea in the form of rain. The portion which falls upon the elevated land flows back towards the sea in the form of rivers, and in its descent its weight may be utilised to give motion to machinery. Water power, therefore, is also the result of solar energy, and an elevated lake may indeed be looked upon as fuel, in the sense of its being a weight lifted above the sea level through its prior expansion into steam.

This source of power has also been largely resorted to, and might be utilised to a still greater extent in mountainous countries; but it naturally so happens that the great centres of industry are in the plains, where the means of transport are easy,
and the total amount of available water-power in such districts is extremely limited.

Wind Power.—Another result of solar energy are the winds, which have been utilised for the production of power. This source of power is, indeed, very great in the aggregate, but its application is attended with very great inconvenience. It is proverbial that there is nothing more uncertain than the wind, and when we were dependent upon windmills for the production of flour, it often happened that whole districts were without that necessary element to our daily existence. Ships also, relying upon the wind for their propulsion through the sea, are often becalmed for weeks, and so gradually give place to steam-power on account of its greater certainty.

Heat by Radiation.—It has been suggested of late years to utilise the heat of the sun by the accumulation of its rays into a focus by means of gigantic lenses, and to establish steam-boilers in such foci. This would be a most direct utilisation of solar energy, but it is a plan which would hardly recommend itself in this country, where the sun is but rarely seen, and which even in a country like Spain would hardly be productive of useful, practical results.

Tidal Power.—There is one more natural source of energy available for our uses, which is rather cosmical than solar—viz., the tidal wave. This might also be utilised to a very considerable extent in an island country, facing the Atlantic ocean, like this, but its utilisation on a large scale is connected with great practical difficulty and expenditure, on account of the enormous area of tidal basin that would have to be constructed.

In passing in review these various sources of energy which are still available to us, after we have run through our accumulated capital of potential energy in the shape of coal, it will have struck you that none of them would at all supply the place of our willing and ever-ready slave—the steam engine; nor would they be applicable to our purposes of locomotion, although means might possibly be invented of storing and carrying potential energy in other forms. But it is not force alone that we require, but heat for smelting our iron and other metals, and the accomplishment of other chemical processes. We also need a large supply for our domestic purposes. It is true that with an abundant supply of mechanical force we could manufacture heat, and thus actually
accomplish all our purposes of smelting, cooking, and heating, without the use of any combustible matter; but such conversion would be attended with so much difficulty and expenditure that one cannot conceive human prosperity under such laborious and artificial conditions.

We come now to the question—

**How should Fuel be used?**

I propose to illustrate this by three examples which are typical of the three great branches of consumption.

- **a. The production of steam power.**
- **b. The domestic hearth.**
- **c. The metallurgical furnace.**

*Steam Engine Consumption.*—I have represented on a diagram two steam cylinders of the same internal dimensions, the one being what is called a high pressure steam cylinder, provided with the ordinary slide valve for the admission of steam and its subsequent discharge into the atmosphere, and the other so arranged as to use the steam expansively (being provided with the Corliss variable expansion gear) and working in connection with a condenser. I have also shown two diagrams of the steam pressures at each part of the stroke, assuming in both cases the same initial steam pressure of 60 lbs. per square inch above the atmospheric pressure, and the same load upon the engine. They show that in the latter case the same amount of work is accomplished by filling the cylinder roughly speaking up to one-third part of the length as in the other by filling it entirely. Here we have then an easy and feasible plan of saving two-thirds of the fuel used in working an ordinary high-pressure engine, and yet probably the greater number of the engines now actually at work are of the wasteful type. Nor are the indications of theory in this case (or in any other when properly interpreted) disproved by practice; on the contrary, an ordinary non-expansive non-condensing engine requires commonly a consumption of from 10 to 12 lbs. per horse-power per hour, whereas a good expansive and condensing engine accomplishes the same amount of work with 2 lbs. of coal per hour, the reason for the still greater economy being, that the cylinder of the good engine is properly protected
by means of a steam jacket and lagging against loss by condensa-
tion within the working cylinder, and that more care is generally
bestowed upon the boiler and the parts of the engine, to ensure
their proper working condition.

A striking illustration of what can be accomplished in a short
space of time was brought to light by the Institute of Mechanical
Engineers, over which I have at present the honour to preside.
In holding their annual general meeting in Liverpool in 1863,
they instituted a careful inquiry into the consumption of coal by
the best engines in the Atlantic Steam Service, and the result
showed that it fell in no case below 4 3/4 lbs. per indicated horse-
power per hour. Last year they again assembled with the same
object in view in Liverpool, and Mr. Bramwell produced a table
showing that the average consumption by 17 good examples of
compound expansive engines did not exceed 2 1/4 lbs. per indicated
horse-power per hour. Mr. E. A. Cowper has proved a consump-
tion as low as 1 3/4 lbs. per indicated horse-power per hour in a
compound marine engine, constructed by him with an intermediate
superheating vessel. Nor are we likely to stop long at this point
of comparative perfection, for in the early portion of my address I
have endeavoured to prove that theoretical perfection would only
be attained if an indicated horse-power were produced with 1 1/5 lb.
of pure carbon, or say 1 1/4 lb. of ordinary steam coal per hour.

Here then we have two distinct margins to work upon, the one
up to the limit of say 2 lbs. of coal per horse-power per hour,
which has been practically reached in some and may be reached in
most cases, and the other up to the theoretical limit of 1 1/4 lb. per
horse-power per hour which can never be absolutely reached, but
which inventive power may and will enable us to approach!

Domestic Consumption.—The wastefulness of the domestic
hearth and kitchen fire is self-evident. Here only the heat
radiated from the fire itself is utilised, and the combustion is
generally extremely imperfect, because the iron back and excessive
supply of cold air, check combustion before it is half completed.
We know that we can heat a room much more economically by
means of a German stove, but to this it may be very properly
objected that it is cheerless, because we do not see the fire or feel
its drying effect upon our damp clothing; moreover, it does not
provide in a sufficient degree for ventilation, and makes the room

feel stuffy. These are, in my opinion, very weighty objections, and economy would not be worth having if it could only be obtained at the expense of health and comfort. But there is at least one grate that combines an increased amount of comfort with reasonable economy, and which, although accessible to all, is yet very little used. I refer to Captain Galton's "Ventilating Fireplace," of which you observe a diagram upon the wall. This fireplace does not differ in external appearance from an ordinary grate, except that it has a higher brick back, which is perforated at about midheight to admit warmed air into the fire so as to burn a large proportion of the smoke which is usually sent up the chimney unburnt, for no better purpose than to poison the atmosphere which we have to breathe.

The chief novelty and merit of Captain Galton's fireplace consists, however, in providing a chamber at the back of the grate, into which air passes directly from without, becomes moderately heated (to 84° Fahr.), and, rising in a separate flue, is injected into the room under the ceiling with a force due to the heated ascending flue. A plenum of pressure is thus established within the room whereby indraughts through doors and windows are avoided, and the air is continually renewed by passing away through the fireplace chimney as usual. Thus the cheerfulness of an open fire, the comfort of a room filled with fresh but moderately warmed air, and great economy of fuel, are happily combined with unquestionable efficiency and simplicity; and yet this grate is little used, although it has been fully described in papers communicated by Captain Galton, and in an elaborate report made by General Morin, le Directeur du Conservatoire des Arts et Métiers of Paris, which has also appeared in the English language.

The slowness with which this unquestionable improvement finds practical application is due, in my opinion, to two circumstances,—the one is, that Captain Galton did not patent his improvement, which makes it nobody's business to force it into use, and the other may be found in the circumstance that houses are, to a great extent, built only to be sold and not to be lived in. A builder thinks it a good speculation to construct a score of houses after a cheap design, in order to sell them, if possible, before completion, and the purchaser immediately puts up the standard bill of "Desirable Residences to Let." You naturally would think that
in taking such a house you had only to furnish it to your own mind, and be in the enjoyment of all reasonable creature comfort from the moment you enter the same. This fond hope is destined, however, to cruel disappointment; the first evening you turn on the gas, you find that although the pipes are there, the gas prefers to pass out by the joints into the room instead of by the burners; the water in like manner takes its road through the ceiling, bringing down with it a patch of plaster on to your carpet. But worst of all, the products of combustion from the firegrates (made probably to dimensions irrespective of the size of the room), stoutly refuse to avail themselves of the chimney flues, preferring to disperse themselves in volumes of smoke into the room. Plumbers and chimney doctors are now put into requisition, pulling up floors, dirtying carpets, and putting up gaunt-looking chimney-pots; the grates themselves have to be altered again and again, until by slow degrees the house becomes habitable in a degree, although you now only become fully aware of the innumerable drawbacks of the arrangements adopted. Nevertheless, the house has been an excellent one "to sell," and the builder adopts the same pattern for another block or two in an increasing neighbourhood. Why should this builder adopt Captain Galton's fireplace? It will not cost him much, it is true, and it will save the tenant a great deal in his annual coal bill, not to speak of the comfort it would give him and his family; but nobody demands it of him, it would give him some trouble to arrange his details and subcontracts, which are all settled beforehand, and so he goes on building and selling houses in the usual routine way. Nor will this state of things be altered until the dwellers in houses will take the matter in hand, and absolutely refuse to put up with builders' ways, or, what is still better, get builders who will put up houses in their way. This is done to some extent by building societies, but there is as yet too much of the old leaven left in the trade, and the question itself is too little understood.

Consumption in Smelting Operations.—We now come to the third branch of consumption, the smelting or metallurgical furnace, which consumes about 40,000,000 of the 120 million tons of the coal produced. Here also is great room for improvement, the actual quantity of fuel consumed in heating a ton of iron up to the welding point, or in melting a ton of steel is more...
in excess of the theoretical quantity required for these purposes than is the case with regard to the production of steam power and to domestic consumption. Taking the specific heat of iron at \(114\) and the welding heat at \(2,900^\circ\) Fahrenheit it would require \(114 \times 2900 = 331\) heat units to heat 1 lb. of iron. A pound of pure carbon develops 14,500 heat units, a pound of common coal say 12,000, and therefore one ton of coal should bring 36 tons of iron up to the welding point. In an ordinary re-heating furnace a ton of coal heats only \(1\frac{2}{3}\) ton of iron, and therefore produces only \(\frac{3}{7}\) part of the maximum theoretical effect. In melting one ton of steel in pots \(2\frac{2}{3}\) tons of coke are consumed, and taking the melting point of steel at \(3600^\circ\) Fahrenheit the specific heat at \(119\) it takes \(119 \times 3600 = 428\) heat units to melt a pound of steel, and taking the heat producing power of common coke also at 12,000 units, one ton of coke ought to be able to melt 28 tons of steel. The Sheffield pot steel melting furnace therefore only utilises \(\frac{1}{10}\) th part of the theoretical heat developed in the combustion. Here therefore is a very wide margin for improvement, to which I have specially devoted my attention for many years, and not without the attainment of useful results. Since the year 1846, or very shortly after the first announcement of the dynamical theory, I have devoted my attention to a realisation of some of the economic results which that theory rendered feasible, fixing upon the regenerator as the appliance which, without being capable of reproducing heat when once really consumed, is extremely useful for temporarily storing such heat as cannot be immediately utilised, in order to impart it to the fluid or other substance which is employed in continuation of the operation of heating, or of generating force.

Without troubling you with an account of the gradual progress of these improvements, in which my brother Frederick has taken an important part, I will describe to you shortly the furnace which I now employ for melting steel. It consists of a bed made of very refractory material, such as pure silica sand and silica or Dinas brick under which four regenerators (or chambers filled with checkerwork of brick) are arranged in such a manner, that a current of combustible gas passes upward through one of these regenerators, while a current of air passes upwards through the adjoining regenerator, in order to meet in combustion at the entrance
into the furnace chamber. The products of combustion, instead of passing directly to the chimney as in an ordinary furnace, are directed downwards through the two other regenerators on their way towards the chimney, where they part with their heat to the checkerwork in such manner that the highest degree of heat is imparted to the upper layers, and that the gaseous products reach the chimney comparatively cool (about 300° Fahr.). After going on in this way for half-an-hour, the currents are reversed by means of suitable reversing valves, and the cold air and combustible gas now enter the furnace chamber, after having taken up heat from the regenerators in the reverse order in which it was deposited, reaching the furnace therefore nearly at the temperature at which the gases of combustion left the same. A great accumulation of temperature within the regenerators is the result, one pair being heated while the other pair is being cooled; it is easy to conceive that, in this way, heat may be produced within the furnace chamber up to an apparently unlimited degree, and with a minimum amount of chimney draught.

 Practically the limit is reached at the point where the materials composing the furnace chamber begin to melt; whilst a theoretical limit also exists in the fact that combustion ceases at a point which has been laid down by St. Claire Deville at 4500° Fahr., and which has been called by him the point of "dissociation." At this point hydrogen might be mixed with oxygen and yet the two would not combine, showing that combustion really only takes place between the limits of temperature of about 600° and 4500° Fahr.

 To return to the regenerative gas-furnace. It is evident that there must be economy where, within ordinary limits, any degree of heat can be obtained, while the products of combustion pass into the chimney only 300° hot. Practically a ton of steel is melted in this furnace with 12 cwt. of small coal consumed in the gas-producer, which latter may be placed at any reasonable distance from the furnace, and consists of a brick chamber containing several tons of fuel in a state of slow disintegration. In large works, a considerable number of these gas-producers are connected by tubes or flues with a number of furnaces. Collateral advantages in this system of heating are, that no smoke is produced, and that the works are not encumbered with solid fuel and ashes.

*Gas Producers at Bottom of Coal-pit.*—It is a favourite project
of mine, which I have not had an opportunity yet of carrying practically into effect, to place these gas producers at the bottom of coal-pits. A gas shaft would have to be provided to conduct the gas to the surface, the lifting of coal would be saved, and the gas in its ascent would accumulate such an amount of forward pressure that it might be conducted for a distance of several miles to the works or places of consumption. This plan, so far from being dangerous, would insure a very perfect ventilation of the mine, and would enable us to utilise those waste deposits of small coal (amounting on the average to 20 per cent.) which are now left unutilised within the pit.

Heating Gas Supply.—Another plan of the future which has occupied my attention is the supply of towns with heating gas for domestic and manufacturing purposes. In the year 1863 a company was formed, with the concurrence of the Corporation of Birmingham, to provide such a supply in that town at the rate of 6d. per 1000 cubic feet; but the bill necessary for that purpose was thrown out in Committee of the House of Lords because their Lordships thought that if this was as good a plan as it was represented to be, the existing gas companies would be sure to carry it into effect. I need hardly say that the existing companies have not carried it into effect, having been constituted for another object, and that the realisation of the plan itself has been indefinitely postponed. It has, however, lately been taken up and partly carried into effect at Berlin.

Coal Question.

Having now passed in review the principal applications of fuel, with a view chiefly to draw the distinction between our actual consumption and the consumption that would result if our most improved practice were made general; and having, moreover, endeavoured to prove to you what are the ultimate limits of consumption which are absolutely fixed by theory, but which we shall never be able to realise completely, I will now apply my reasoning to the coal question of the day.

In looking into the “Report of the Select Committee appointed to Inquire into the Causes of the present Dearness of Coal,” we find that in 1872 no less than 123,000,000 tons of coal were got
up from the mines of England and Wales, notwithstanding famine prices and the colliers’ strikes. In 1862 the total getting of coal amounted to only 83,500,000, showing a yearly average increase of production of 4,000,000 tons. If this progressive increase continues, our production will have reached, thirty years hence, the startling figure of 250,000,000 tons per annum; which would probably result in an increase of price very much in excess of the limits yet reached. In estimating last year’s increase of price, which has every appearance of being permanent, at 8s. per ton all round, and after deducting the 13,000,000 tons which were exported abroad, we find that the British consumer had to pay £44,000,000 more than the market value of former years for his supply of coal,—a sufficient sum, one would think, to make him look earnestly into the question of “waste of fuel,” which, as I have been endeavouring to show, is very great indeed. The Select Committee just quoted sums up its report by the following expression:—“The general conclusion to be drawn from the whole evidence is, that though the production of coal increased in 1872 in a smaller ratio than it had increased in the years immediately preceding, yet if an adequate supply of labour can be obtained, the increase of production will shortly keep pace with that of the last few years.”

This is surely a very insufficient conclusion to be arrived at by a Select Parliamentary Committee after a long and expensive inquiry, and the worst of it is, that it stands in direct contradiction with the corrected table given in the same report, which shows that the progressive increase of production has been fully maintained during the last two years, having amounted to 5,826,000 for 1871, and 5,717,000 for 1872; whereas the average increase during the last ten years has only been 4,000,000 tons! It is to be hoped that Parliament will not rest satisfied with such a negative result, but will insist upon knowing whether a proper balance between the demand and supply of coal cannot be re-established, also what can be done to prevent the wholesale conversion of fuel into useless or positively hurtful products.

In taking the 105,000,000 tons of coal consumed in this country last year for our basis, I estimate that, if we could make up our minds to consume our coal in a careful and judicious manner, according to our present lights, we should be able to
reduce that consumption by 50,000,000 tons. The realisation of such an economy would certainly involve a very considerable expenditure of capital and must be a work of time; but what I contend is, that our progress in effecting economy ought to be accelerated, in order to establish a balance between the present production and the ever increasing demand for the effects of heat.

In looking through the statistical returns of the progressive increase of population, of steam power employed, and of production of iron and steel, &c., I find that our necessities increase at a rate of not less than 8 per cent. per annum, whereas our coal consumption increases only at the rate of 4 per cent., showing that the balance of 4 per cent. is met by what may be called our "intellectual progress." Now, considering the enormous margin for improvement before us, I contend that we should not be satisfied with this rate of intellectual progress involving, as it does, an annual deficit of 4,000,000 tons to be met by increased coal production, but that we should bring our intellectual progress up to the rate of our industrial progress, by which means we should make the coal production nearly a constant quantity for several generations to come. By that time our successors may be expected to have effected another great step in advance towards the theoretical limit of effect, which, as we have seen, lies so far above any actual result we have as yet attained, that an annual consumption of 10,000,000 tons would give more than the equivalent of the heat energy which we actually require.

Solar Heat.

I have endeavoured to show, in the early part of this lecture, that all available energy upon the earth, excepting the tidal wave, is derived from the sun, and that the amount of heat radiated year by year upon our earth, could be measured by the evaporation of a layer of water 14 feet deep, spread over the entire surface, which again would be represented by the combustion of a layer of coal 8 inches in thickness, covering our entire globe. It must, however, be taken into account that three-fourths of this heat is intercepted by our atmosphere, and
only one-fourth reaches the earth itself. The amount of heat radiated away from the sun would be represented by the annual combustion of a thickness of coal 17 miles thick, covering its entire surface, and it has been a source of wonderment with natural philosophers how so prodigious an amount of heat could be given off year after year without any appreciable diminution of the sun's heat having become observable.

Recent researches with the spectroscope, chiefly by Mr. Norman Lockyer, have thrown much light upon this question. It is now clearly made out that the sun consists near the surface, if not throughout its mass, of gaseous elementary bodies, and in a great measure of hydrogen gas, which cannot combine with the oxygen present, owing to an excessive elevation of temperature (due to the original great compression), which has been estimated at from 20,000° to 22,000° Fahr. This chemically inert and comparatively dark mass of the sun is surrounded by the photosphere, where its gaseous constituents rush into combustion, owing to reduction of temperature in consequence of their expansion and of radiation of heat into space. This photosphere is surrounded in its turn by the chromosphere, consisting of the products of combustion, which, after being cooled down through loss of heat by radiation, sink back, owing to their acquired density, towards the centre of the sun where they become again intensely heated through compression and are "dissociated" or split up again into their elements at the expense of internal solar heat. Great convulsions are thus continually produced upon the solar surface, resulting frequently in explosive actions of extraordinary magnitude, when masses of living fire are projected a thousand miles or more upward, giving rise to the phenomena of sun spots and of the corona which is visible during the total eclipses of the sun. The sun may therefore be looked upon in the light of a gigantic gas-furnace, in which the same materials of combustion are used over and over again.

It would be impossible for me at this late hour to enter further upon speculations regarding the "regeneration of the sun's heat upon its surface," which is a question replete with scientific and also practical interest. We should always remember that nature is our safest teacher, and that in trying to comprehend the great works of our Creator we shall learn how to utilise to
the best advantage those stores of potential energy in the shape of fuel which have providentially been placed at our disposal.

AIR-ENGINES.

TO THE EDITOR OF "ENGINEERING."

Sir,—In your article of last week on "Air-Engines" you inadvertently do scanty justice to the Institution of Civil Engineers, in alluding to their state of ignorance regarding the theory of air-engines and the dynamical theory of heat prior to the year 1854, when the late Professor Rankine read his Paper on "Air-Engines" before the British Association. When in 1845 the merits of Dr. Stirling's economiser were discussed before the Institution, the dynamical theory of heat was not known, and in consideration of this circumstance it was only natural that no just appreciation could be formed of the scope and utility of that most interesting appliance, the economiser, the mere physical conception of which may be traced back almost to antiquity.

Dr. Stirling introduced his air-engine under the title of the Paradox Engine, because, with many others, he believed that it involved the realisation of perpetual motion, allowance being made for the incidental losses of heat.

When however in 1852, Captain Ericsson appeared upon the stage with his regenerative air-engine, and re-asserted the same fallacy under which Stirling had been labouring, the Council of the Institution determined to sift the question to the bottom, and knowing that I had paid much attention to kindred subjects requested me to prepare a critical paper on air-engines, which was read accordingly during the session 1852-53. At that time the believers in the dynamical theory of heat, might be counted on your fingers, and I could hardly have selected a more unpopular title for my paper than "On the Conversion of Heat into Mechanical Effect."* Being convinced, however, that the new

* Published in the Scientific Papers of Sir William Siemens, Vol. I., p. 29.
theory of heat was the true one, I adopted it boldly, and by its
means arrived at sound conclusions regarding the relative merits
of the various steam and air-engines of known construction, by
showing what proportion of the heat employed was actually
converted in each case into mechanical effect, and what other
proportion must necessarily go to waste, notwithstanding the
application of an economiser or regenerator, which as I expressed
it, "is undoubtedly a useful agent for recovering the free, or
otherwise unproductive heat of a caloric engine." On reference to
the paper in question, Vol. XII., Minutes Inst. C.E., you will
find graphic representations, showing the proportion of heat lost,
and that converted into useful effect, similar to those employed in
your article in reference to Stirling's engine, but more complete
in that they take into consideration the simultaneous action of
the two cranks, which you neglect, for the sake, I presume, of
simplicity of demonstration.

In a table I gave the relative merits of different kinds of
engines as follows:—

<table>
<thead>
<tr>
<th>Description of Engine</th>
<th>Theoretical Performance Foot-lbs.</th>
<th>Actual Performance Foot-lbs.</th>
<th>Actual Performance in lbs. of Coal per H. P. per Hour.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Boulton and Watt condensing engine, low pressure</td>
<td>51.8</td>
<td>29</td>
<td>8.00</td>
</tr>
<tr>
<td>The best Cornish engine</td>
<td>158.8</td>
<td>82</td>
<td>2.38</td>
</tr>
<tr>
<td>Combined steam and expansive ether engine</td>
<td>150.0</td>
<td>75</td>
<td>3.09</td>
</tr>
<tr>
<td>The expansive air-engine</td>
<td>91.0</td>
<td>35</td>
<td>6.63</td>
</tr>
<tr>
<td>Stirling's engine</td>
<td>130.0</td>
<td>65</td>
<td>3.57</td>
</tr>
<tr>
<td>Ericsson's engine</td>
<td>196.0</td>
<td>65</td>
<td>3.57</td>
</tr>
<tr>
<td>A perfect engine</td>
<td>770.0</td>
<td>385</td>
<td>0.60</td>
</tr>
</tbody>
</table>

And although Rankine, Clausius, and others have since then
handled the dynamical theory of heat in its application to thermo-
motors in a much more comprehensive and elegant manner, they
in no way disprove the conclusions at which I had arrived, and
which I fully maintain.

Two other papers were presented to the Institution at the same
time as my own (one of them by a member of the French Institute
through the Secretary), in which it was attempted to clear up the
apparent mystery of the air-engine by the prevailing material theory of heat; and it must be recorded, I think, as a fact highly creditable to the Council of the Institution of the day, that notwithstanding my seeming heresy, the Telford medal was awarded me for my paper, and was withheld from my competitors.

In my paper above referred to, I gave experimental information regarding the limits of efficiency of the economiser, respirator, recuperator, or regenerator (by whichever term it may be most acceptable), whilst I purposely abstained from mixing up with my subject a description of the regenerative steam engine and condenser, which had enabled me to collect that information, and which was certainly the first, and remains almost the only serious attempt to realise the dictates of the dynamical theory of heat. This engine was conceived in 1845, and at a time when the writings of Carnot and Mayer had only just prepared the way for Joule to determine experimentally the mechanical equivalent of heat, and was constructed in 1846–7 by Messrs. Benjamin Hick and Son of Bolton, at whose works it was in operation for some time; it was described, moreover, in a somewhat modified form in my patent of 1847, No. 12,006, and is, I think, in some respects worthy of notice in such a review as that with which you are now presenting your readers.

The leading ideas attempted to be realised in this engine are:—

1. That heat is force, and that the engine itself is only a contrivance for giving the force of heat another direction.

2. That the medium employed for effecting this change is, theoretically speaking, immaterial, and that steam is preferable to air because its coefficient of expansion is greater than that of air, and that it can be brought back to its lowest temperature or point of saturation by bringing it into contact with water of the same temperature. The portion of the apparatus where this was effected was called by me the regenerator, a term which has since been applied to the mere exchanger of heat, which I at that time called the respirator.

3. That the amount of the elastic fluid employed in effecting a stroke of the working piston or plunger must be reduced to a minimum, because loss of heat arises in bringing the elastic medium back to its original condition of compression after expansion at elevated temperature.
4. The heating surface provided for superheating the steam or air under compression, must be increased proportionately to the force to be obtained, and to the necessary loss by cushioning.

In the employment of these engines the practical difficulty consisted in properly and safely superheating the steam; but several, not exceeding 10-horse power, have been working economically and for some time, and my reason for not pursuing the subject further, has been the progress made since, in using steam expansively, with due care to prevent loss by condensation, by which means nearly the same economical results could be realised with less risk of stoppages for repairs.

Yours faithfully,

C. WILLIAM SIEMENS.

12, QUEEN ANNE'S GATE, S.W., 13th April, 1875.

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AT THE ANNUAL MEETING OF THE IRON AND STEEL INSTITUTE, held on May 5, 1875, IT WAS ANNOUNCED THAT THE COUNCIL HAD AWARDED THE BESSEMER MEDAL FOR 1875 TO DR. SIEMENS, F.R.S., &C., IN RECOGNITION OF THE VALUABLE SERVICES HE HAS RENDERED TO THE IRON AND STEEL TRADES BY HIS IMPORTANT INVENTIONS AND INVESTIGATIONS.

MR. BELL* (the President) proceeded to congratulate Dr. Siemens, Fellow of the Royal Society, upon the medal, which he was about to place in his hands, having been awarded to him. He (the President) was glad to hear, during the reading of the report, judging from the applause with which the announcement was received, that the manner in which that portion of the Council's duties had been discharged met, he might say, with unanimous acceptance. He had only to congratulate his friend Dr. Siemens, and to present to him the Bessemer medal for 1875. (Dr. Siemens here stepped upon the platform, and received the medal.)

* Excerpt Journal of the Iron and Steel Institute, 1875, pp. 11-12.
Dr. Siemens said he would express his most heartfelt thanks for the great honour which the Council had conferred upon him by awarding to him the Bessemer medal, and he had also to thank the members for the cordial manner in which they had received the announcement. It was naturally a gratifying thing to receive an acknowledgment for hard labour, but that reward came with the greater force when it came from men who were fellow-labourers with himself in the same field. Nothing could be more pleasing than to receive a token of their appreciation in the manner in which that medal had been conferred upon him. He was much gratified in receiving the medal from the hands of their President, who himself had, by his elaborate researches into important branches of metallurgy, given proof of deep knowledge on those subjects, which had already been acknowledged by that Institute, by the award of the first Bessemer medal, which was granted last year. The name “Bessemer Medal” had for him (Dr. Siemens) another and peculiar interest. No one in modern times had produced a greater revolution by invention in the iron and steel trades than Mr. Bessemer; and, in receiving a medal to which his name was attached, he (Dr. Siemens) was particularly glad to see the utter want of anything approaching to jealousy that might possibly exist, or be supposed to exist, in the minds of men who were all working towards the same end, viz., the improvement of the art upon which they were engaged. He thanked them all—the President, the Council, and the members of the Institute—most heartily for the great honour they had conferred upon him.

REMARKS ON SIR CHARLES WHEATSTONE.

Dr. C. W. Siemens* (Past President) said: Mr. President and Gentlemen,—I have a proposition to make which I am sure you will all second and approve, that is, to ask our President to allow the address which he has just given us to be printed—not only in our Proceedings, but separately, and circulated among the members. I have listened, and I have no doubt all present

have listened, with great interest and pleasure to his address regarding the work of our most highly respected and esteemed member, the late Sir Charles Wheatstone. He has done it, I consider, in a very masterly manner. I have read other notices regarding the work of Sir Charles Wheatstone, amongst others the address of M. Tresca before the French Academy, and I have taken part in a memorial addressed by the Royal Institution in his honour, but I have not hitherto found his works recorded in such a temperate, just, and complete manner as has been done this evening by Mr. Clark. We should honour the dead, but we should also be just with regard to them, and, whilst we avoid fulsome praise, we should take care to give them fairly and fully that amount of credit which is due to them. In the case of Sir Charles Wheatstone that amount of credit is very large indeed. Sir Charles Wheatstone laboured during a period of between thirty and forty years incessantly in the field of science, and his fertile mind has produced results such as few have been allowed to attain; therefore, he can well afford to have his work justly dealt with, and they need not be increased or diminished by one iota. There are one or two points mentioned by the President which I think could hardly be claimed for Sir Charles Wheatstone. I would mention the one regarding the effect of electricity in capillary tubes. Sir Charles Wheatstone followed up the experiments on that subject with his usual energy, but I believe the idea was first suggested at Frankfort by Professor Lippmann. I think our President will be too glad to correct any excess of credit; it would not be a credit to Wheatstone, but rather detract from his real merits, if anything that was not fairly due to him was attributed to him. I think, however, on the whole, we have heard an address regarding the work of Sir Charles Wheatstone which deserves to live amongst us as a lasting record of the work of one of the greatest men this century can boast of. I beg to propose that our President be requested to allow his address to be printed and circulated amongst the members.
THE ADDRESSES, LECTURES, ETC., OF

PRICE'S RETORT FURNACE.

To the Editor of "Engineering."

Sir,—In a paper read by Mr. Bell before the Iron and Steel Institute describing Price's patent retort furnace, and which you publish in your issue of the 8th inst., allusion is made to the Siemens furnace, and I shall be obliged by your allowing me to say a few words in reply. It is stated "The preliminary conversion, however, of the coal into a gas is attended with a certain amount of loss, inasmuch as the whole of the fixed carbon is burnt to the condition of carbonic oxide, which means a sacrifice of about 30 per cent. of its heating power." This would be perfectly true if solid carbon were employed without decomposition of water, but as common coal is the fuel burnt, the actual results are different. In the gas producer three operations are performed: in the lower portion the fuel is burnt, and this may be called the zone of combustion; higher up the carbonic acid takes up a further equivalent of carbon, becoming carbonic oxide, this may be called the zone of carbonisation; whilst at the uppermost layer of the producer hydrocarbons are produced in what may be called the zone of distillation. The temperature of the first zone would be about 2400° C., and that of the second about 960° C., provided no water was admitted with the air for combustion. The mixture of carbonic oxide and nitrogen resulting from this reaction, and at the temperature of 960° C., has still all the work to do which is accomplished in a gas retort, namely, to deprive the coal of its hydrocarbons and vaporous constituents, amounting to from 30 to 35 per cent. of the weight of fuel supplied; the work done in this third or uppermost zone of the gas producer may be valued at 300 heat units per pound of fuel charged,* which would deprive the gases of 270° C. of temperature, reducing that temperature to 690°. In practice I find that the temperature of the gas-producer chamber does not exceed 400° C., the difference being due to farther useful work performed by the heat resulting from the first operation, namely, in the decomposition of water introduced below

* In practice it takes 4·5 cwts. to distil the gases from a ton of coal.
the grate in a pool, into which the hot clinkers falling generate steam, which must be delivered in the proportion of at least 0.007 lb. per pound of fuel, or 6 lbs. per ton. It is therefore evident that the loss of heat caused in converting the fuel to the gaseous condition amounts only to 12% per cent. of the total quantity in the fuel, and this even is turned to useful account by causing an onward pressure towards the furnace, in the passage of the gas through the cooling syphon, thus avoiding the necessity of an artificial blowing apparatus and a closed grate, which would be sources of considerable inconvenience in practice.

Against this small theoretical loss must be set the advantages of perfect combustion in the furnace, into which gas and air are admitted through valves in proper proportions, and the further main advantage resulting from the application of the regenerators, which I need not here particularise.

The unfavourable estimate which Mr. Bell has formed of the working condition of the gas producer has betrayed him into under-estimating the practical saving realised by the adoption of the regenerative gas-furnace. The amount of this saving depends in a great measure upon the temperature at which the work in the furnace is being accomplished, the economy increasing with the degree of that temperature. Thus in melting mild steel in crucibles, an operation requiring intense heat, about 3 tons of Durham coke are required in the old process per ton of steel melted, which work is accomplished in the regenerative gas furnace with a consumption not exceeding 25 cwt. of ordinary coal. In carrying out such operations as the melting of glass and the reheating and puddling of iron great saving has also been effected, but one of the largest applications of the system has been made to the reheating of Bessemer steel, requiring, as is well known, less intense heat than is required for the heating of glass and iron, and with reference to this application I cannot do better than quote Mr. J. J. Smith's paper, read before the Iron and Steel Institute on the 22nd September, 1869, in which he says, "The results at the Barrow Works, taken over a period of two years, show 44 per cent. (saving), but the comparison is taken with furnaces built expressly to consume the hardest and best coal which could be procured, and notwithstanding the known loss previously mentioned in forcing the producers; but as the quality of the coal
used was inferior, and very much less in price, the actual money saving has been more than one-half."

It would be as well to look these facts fairly in the face before proceeding too far in the prosecution of new projects, involving, perhaps, unnecessary expenditure of time and money.

Yours faithfully,
C. W. Siemens.

12, Queen Anne's Gate, S.W., October 20, 1875.

ADDRESS

Of Dr. C. W. Siemens, F.R.S.*

* Excerpt "Nature," May 18, 1876.
referred to? Yet were mechanical science at these Conferences to be limited to the objects exhibited in the South Gallery (and separated unfortunately from apparatus representing physical science by lengthy corridors filled with objects of natural history), we should hardly find material worthy to occupy the time set apart for us. But, thanks to the progress of opinion in recent days, the barrier between pure and applied science may be considered as having no longer any existence in fact. We see around us practitioners, to whom seats of honour in the great academies and associations for the advancement of pure science are not withheld, and men who, having commenced with the cultivation of pure science, think it no longer a degradation to follow up its application to useful ends.

The geographical separation between applied science and physical science just referred to, must therefore be regarded only as accidental, and the subjects to be discussed in our section comprise a large proportion of the objects to be found within the rooms assigned more particularly to physics and chemistry. Thus all measuring instruments, geometric and kinematic apparatus, have been specially included within our range, and other objects, such as telegraphic instruments, belong naturally to our domain.

With these accessions, mechanical science represents a vast field for discussion at these conferences, a field so vast indeed that it would have been impossible to discuss separately the merits of even the more remarkable of the exhibits belonging to it. It was necessary to combine exhibits of similar nature into subdivisions, and the committee have asked gentlemen eminently acquainted with these branches to address you upon them in a comprehensive manner.

Thus they have secured the co-operation of Mr. Barnaby, the Director of Construction of the Navy, to address you on the subject of naval architecture, and of Mr. Froude to enlarge upon the subject of fluid resistance, upon which he has such an undoubted right to speak authoritatively. Mr. Thomas Stevenson, the Engineer of the Northern Lighthouses, will describe the modern arrangements of Dioptric lights, which mark a great progress in the art of lighting up our coasts. Mr. Bramwell has undertaken the important task of addressing you on the subject of prime movers, and Prof. Kennedy upon the kinematic apparatus.
forwarded by Prof. Reuleaux, of Berlin. M. Tresca will bring before us his interesting subject, the flow of solids. Mr. William Hackney will address you upon the application of heat to furnaces, for which he is well qualified both by his theoretical and practical knowledge. Mr. R. S. Culley, Chief Engineer of the Postal Telegraphs, will refer you to a most complete and interesting historical collection of instruments, revealing the rapid and surprising growth of the electric telegraph.

Measurement.—Regarding the question of measurement, this constitutes perhaps the largest and most varied subject in connection with the present Loan Exhibition. In mechanical science, accurate measurement is of such obvious importance, that no argument is needed to recommend the subject to your careful consideration. But it is not perhaps so generally admitted, that accurate measurement occupies a very important position with regard to science itself, and that many of the most brilliant discoveries may be traced back to the mechanical art of measuring. In support of this view I may here quote some pregnant remarks made by Sir William Thomson in his inaugural address delivered in 1871 to the members of the British Association, in which he says—"Accurate and minute measurement seems to the non-scientific imagination, a less lofty and dignified work than looking for something new. But nearly all the grandest discoveries of science have been but the rewards of accurate measurement and patient long-continued labour in the minute sifting of numerical results. The popular idea of Newton's grand discovery is that the theory of gravitation flashed upon his mind, and so the discovery was made. It was by a long train of mathematical calculation, founded on results accumulated through prodigious toil of practical astronomers, that Newton first demonstrated the forces urging the planets towards the sun, determined the magnitude of those forces, and discovered that a force following the same law of variation with distance urges the moon towards the earth. Then first, we may suppose, came to him the idea of the universality of gravitation; but when he attempted to compare the magnitude of the force of the moon with the magnitude of the force of gravitation of a heavy body of equal mass at the earth's surface, he did not find the agreement which the law he was discovering required. Not for years after would he publish his discovery as made. It is
recounted that, being present at a meeting of the Royal Society, he heard a paper read, describing geodesic measurement by Picard, which led to a serious correction of the previously accepted estimate of the earth’s radius. This was what Newton required; he went home with the result, and commenced his calculations, but felt so much agitated, that he handed over the arithmetical work to a friend; then (and not when, sitting in a garden he saw an apple fall) did he ascertain that gravitation keeps the moon in her orbit.

“Faraday’s discovery of specific inductive capacity, which inaugurated the new philosophy, tending to discard action at a distance, was the result of minute and accurate measurement of electric forces.

“Joule’s discovery of thermo-dynamic law, through the regions of electro-chemistry, electro-magnetism, and elasticity of gases was based on a delicacy of thermometry which seemed impossible to some of the most distinguished chemists of the day.

“Andrews’s discovery of the continuity between the gaseous and liquid states was worked out by many years of laborious and minute measurement of phenomena scarcely sensible to the naked eye.”

Here, then, we have a very full recognition of the importance of accurate measurement, by one who has a perfect right to speak authoritatively on such a subject. It may indeed be maintained that no accurate knowledge of any thing or any law in nature is possible, unless we possess a faculty of referring our results to some unit of measure, and that it might truly be said—to know is to measure.

To resort to a homely illustration of this proposition, let us suppose a traveller in the unknown wilds of the interior of Africa, observing before him a number of elevations of the ground, not differing materially from one another in apparent magnitude. Without measuring apparatus the traveller could form no conclusion regarding the geographical importance of those visible objects, which might be mere hillocks at a moderate distance, or the domes of an elevated mountain range. In stepping his base line, however, and mounting his distance-measurer, he soon ascertains his distances, and observations with the sextant and compass give the angles of elevation and position of the objects. He now knows that a mighty mountain chain stands before him, which
must determine the direction of the watercourses and important climatic results. In short, through measurement he has achieved perhaps an important addition to our geographical knowledge. As regards modern astronomy, this may almost be defined as the art of measuring very distant objects, and this art has progressed proportionately with the perfection attained in the telescopes and recording instruments employed in its pursuit.

By the ancients the art of measuring length and volume was tolerably well understood, hence their relatively extraordinary advance in architecture and the plastic arts. We hear also of powerful mechanical contrivances which Archimedes employed for lifting and hurling heavy masses; and the books of Euclid constitute a lasting proof of their power of grappling with the laws regulating the proportion of plane and linear measurement. But with all the mental and mechanical power displayed in those works, it would seem strange that no attempt should have been made on the part of the ancients to utilise those subtle forces in nature, heat and electricity, by which modern civilisation has been distinguished, were it not for their want of the means of measuring these forces.

Hero of Alexandria tells us that the power of steam was known to the Egyptians, and was employed by their priesthood to work such pretended miracles as that of the spontaneous opening of the doors of the temple, whenever the burnt offering was accepted by the gods, or as we moderns would put it, whenever the heat generated by combustion was sufficient to produce steam in the hollow body of the altar, and thus force water into buckets whose increasing weight, in descending, caused the gates in question to open.

Unfortunately for them, the Accademia de Cimento of Florence had not yet presented the world with the thermometer, nor had Toricelli shown how to measure elastic pressures, or there would at any rate have been a probability of those clear-headed ancients applying the power of steam for preparing and transporting the materials, which they used in the erection of their stupendous monuments, and for raising and directing the water used in their elaborate works of irrigation.

The art of measuring may be divided into the following principal groups.
First. That of linear measurement, the measurement of area within a plane, and of plane angles; comprising Geometry, Trigonometry, Surveying, and the construction of linear measures, distance meters, sextants and planimeters, of which a great variety will be found within this building.

The subject of linear measurement will, I am happy to state, be brought before you by one whose name will ever be remembered as the introducer into applied mechanics of the absolute plane, and of accurate measure, I mean Sir Joseph Whitworth. It is to be regretted, I consider, that Sir Joseph Whitworth adopted as the unit of measure, the decimalized inch, instead of employing the centimetre, and I hope that he will see reason to adapt his admirable system of gauges, also to metrical measure, which, notwithstanding any objections that could be raised against it on theoretical grounds—that, namely, of not representing accurately the ten millionth part of the distance from one of the earth's poles to its equator—is, nevertheless, the only measure that has been thoroughly decimalized, and which establishes a simple relationship between measures of length, of area, and of capacity. It possesses, moreover, the great practical advantage of having been adopted by nearly all the civilised nations of Europe, and by scientific workers throughout the world. Sir Joseph Whitworth's gauges, based upon the decimalized inch, are calculated to maintain their position for many years, owing to the intrinsic mechanical perfection which they represent, but the boon conferred by their author would be still greater than it is if, by adopting the metre, he would remove the last and only serious impediment in the way of the unification of linear measurement throughout the world. A discussion will probably arise regarding the relative merits of measurement à bout, of which Sir Joseph Whitworth is the representative, and of measurement à trait, which is the older method, but is still maintained by the Standard Commissioners, both in this country and in France.

The second group includes the measure of volume or the cubical contents of solids, liquids, and gases, comprising stereometric methods of measurement, the standard measures for liquids, and the apparatus for measuring liquid and gaseous bodies flowing through pipes, such as gas meters, water meters, spirit meters, of which, likewise a great variety of ancient and modern date will
meet your eye, and upon which Mr. Merrifield will address you.

Another method of measuring matter is by its attraction towards the earth, or, thirdly, the measurement of weight, represented by a great variety of balances of ancient and modern construction. These may be divided into beam weighing machines, which appear to be at the same time the most ancient and the most accurate, into spring balances, and torsion balances. The accuracy obtained in weighing is truly surprising, when we see that a mass of one ten-millionth part of a gramme suffices to turn the scale of a well-constructed chemical balance. Perfect weighing, however, could only be accomplished in a vacuum, and, in accurate weighing, allowance has to be made for the weight of the air displaced by the object under consideration. The general result is that the mass of light substances is really greater than their nominal weight implies, and this difference between true and nominal weight must vary sensibly with varying atmospheric density.

Among measures of weight, may be noted a balance, which weighs to the five-millionth part of the body weighed, sent by Beckers Sons of Rotterdam; another from Brussels weighing to within a fourteen-millionth part of the weight, in weighing small quantities; a balance formerly used by Dr. Priestley; and Professor Hennessy's standards derived from the earth's polar axis, as common to all terrestrial meridians.

Weighing in a denser medium than atmospheric air, namely, in water, leads us fourthly to the measurement of specific gravity which was originated by Archimedes when he determined the composition of King Hiero's crown by weighing it in water and in air.

Next comes fifthly, the Measurement of Time, which although of ancient conception has been reduced to mathematical precision only in modern times. This has taken place through the discovery by Galileo, of the pendulum, and its application by Huygens to time-pieces in the 17th century. The most interesting exhibits in this branch of measurement are, from an historical point of view, the Italian, German, and English clocks of the 17th century, the Timekeeper which was twice carried out by Captain Cook, first in 1776, and which, after passing through a number of hands, was brought back to this country in 1843, and an ancient striking
clock, supposed to have been made in 1348; it has the verge escapement which is said to have been in use before the pendulum. The methods employed in modern clocks and watches for compensating for variation of the thermometer and barometer, are illustrated by numerous exhibits, notably the Astronomical Clock, with Sir George Airy's compensation, which will form the subject of a special demonstration by Messrs. Dent and Co.

The measurement of small increments of time has been rendered possible only in our own days by the introduction of the conical pendulum, and other apparatus of uniform rotation, which alone conveys to our minds the true conception of the continuity of time. Among the exhibits belonging to this class, must be mentioned Sir Charles Wheatstone's rotating mirror, moved by a constant falling weight, by which he made his early determination of the velocity of electricity through metallic conductors; the rotative cylindrical mirror, marked by successive electrical discharges, which was employed by Dr. Werner Siemens in 1846, to measure the velocity of projectiles, and has been lately applied by him for the measurement of the velocity of the electric current itself, and the Chronometric Governor, introduced by him in conjunction with myself, for regulating chronographs, as also the velocity of steam engines under their varying loads; Foucault's Governor, and a considerable variety involving similar principles of action.

Another entity which presents itself for measurement is, sixthly, that of Velocity, or distance traversed in a unit of time, which may either be uniform or one influenced by a continuance of the cause of motion, resulting in acceleration, subject to laws and measurements applicable both in relation to celestial and terrestrial bodies. I may here mention the instruments latterly devised for measuring the acceleration of a cannon ball before and after leaving the mouth of the gun, of which an early example has been placed within these galleries. Other measurers of velocity are to be found here, ships' logs, current meters, and anemometers.

In combining the ideas of weight or pressure with space, we arrive at, seventhly, the conception of work, the unit of which is the foot-pound, or kilogrammetre, and which, when combined with time, leads us to the further conception of the performance of duty, the horse-power as defined by Watt. The machines for the
measurement of work, here exhibited, are not numerous, but are interesting. Among these may be mentioned Professor Colladon's Dynamometrical Apparatus constructed in 1844; Richard's Patent Steam Engine Indicator, an improvement on Watt's, and Mr. G. A. Hirn's Flexion and Torsion Pandynamometers.

Eighth. The Measurement of Electrical Units—of electrical capacity, of potential, and resistance, forms a subject of vast research, and of practical importance, such as few men are capable of doing justice to. It may be questioned, indeed, whether Electrical Measurement belongs to the province of mechanical science, involving, as it does, problems in physical science of the highest order; but it may be contended on the other hand that at least one branch of Applied Science, that of Telegraphy, could not be carried on without its aid. I am happy to say that this branch of the general subject will be brought before you by my esteemed friend Sir William Thomson, than whom there is no one more eminently qualified to deal with it. I may, therefore, pass on to the next great branch of our general subject, the ninth, Thermal Measurement.—The principal instrument here employed is the thermometer, based in its construction, either upon the difference of expansion between two solids, or on the expansion of fluids such as mercury or alcohol—(the common thermometer) or upon gaseous expansion (the air thermometer); or again, it may be based upon certain changes of electrical resistance, which solids and liquids experience when subjected to various intensities of heat. With reference to these, the air thermometer represents most completely the molecular action of matter which is the equivalent of the expansibility. I shall not speak of the different scales that have been adopted by Réaumur, Celsius and Fahrenheit, which are based upon no natural laws or zero points in nature, and which are therefore equally objectionable upon theoretical grounds. Would it not be possible to substitute for these a natural thermometric scale? One commencing from the absolute zero, of the possible existence of which we have many irrefutable proofs, although we may never be able to reach it by actual experiment. A scale commencing in numeration from this hypothetical point would possess the advantage of being in unison throughout with the physical effects due to the nominal degree, and would aid us in appreciating correctly the relative dynamical
value of any two degrees of heat which could be named. Such a
scale would also fall in with the readings of an Electrical Resist-
ance thermometer or pyrometer, of which a specimen has been
added to this collection by myself.

When temperature or intensity of heat is coupled with mass we
obtain the conception of quantity of heat, and if this again is
referred to a standard material, usually water, the unit weight of
each being taken, we obtain what is known as specific heat. The
standard to which measurements of quantity of heat are usually
referred is the heat required to raise a pound of water one degree
Fahrenheit, or the cubic centimetre of water one degree Centi-
grade.

The most interesting exhibits in this branch of measurement,
are, from an historical point of view, the original spirit thermo-
meter of the Florentine Accademia del Cimento, and the photo-
graphs of old thermometers ; the original Lavoisier Calorimeter
for measuring the heat disengaged in combustion, Wedgwood’s
and Daniell’s Pyrometers.

As illustrating modern improvement may be instanced a long
brass-cased thermometer showing the variation in the readings,
when the bulb and when the whole thermometer is immersed ; a
thermometer with flat bulb to improve sensitiveness ; a thermo-
electric alarum, for giving notice when a given temperature is
reached ; an instrument for measuring the temperature of fusion
by means of electric contact invented by Prof. Himly ; Dr.
Andrews’ apparatus for measuring the quantity of heat disengaged
in combustion; Dr. Guthrie’s diacalorimeter for measuring the
conductivity of liquids for heat, and a thermometric tube by Prof.
Wartmann for determining the calorific capacities of different
liquids by the process of cooling.

Finally, Joule has taught us how to measure the unit of heat
dynamically, and the interesting apparatus employed by him from
time to time in the various stages of the determination of this
most important constant in applied mechanics, are to be found,
rightly placed, not among thermometers, and other instruments
placed in the physical sections, but among the instruments re-
quired in the determination of three great natural standards—of
length, time, and mass, and their combinations.

Another branch of the general subject is the Measurement of
Light, which may be divided into two principal sections, that including the measurement of the wave-length of lights of different colours, and the angle of polarization, which belongs purely and entirely to physical science; and the measurement of the intensity of light by photometry, which, while involving also physical problems of the highest order, has an important bearing also upon applied science. The principal methods that have been hitherto employed in photometry are by the comparison of shadows, that of Rumford and Bouguer; by employing a screen of paper with a grease-spot, the lights to be compared being so adjusted that the spot does not differ in appearance from the rest of the paper, Bunsen's method; Elster's, by determining in combustion the amount of carbon contained in a given volume of a gas; and the one lately introduced by Prof. Adams and Dr. Werner Siemens, by measuring the variation in the electrical resistance of selenium, under varying intensities of light.

Before concluding, I wish to call your attention to two measuring instruments which do not fall within the range of any of the divisions before indicated. The first is an apparatus designed chiefly by my brother, Dr. Werner Siemens, by which a stream composed of alcohol and water, mixed in any proportion, is measured in such a manner that one train of counter wheels records the volume of the mixed liquid; whilst a second counter gives a true record of the amount of absolute alcohol contained in it. The principle upon which this measuring apparatus acts may be shortly described thus:—The volume of liquid is passed through a revolving drum, divided into three compartments by radial divisions, and not dissimilar in appearance to an ordinary wet gas-meter; the revolutions of this drum produce the record of the total volume of passing liquid. The liquid, on its way to the measuring drum, passes through a receiver containing a float of thin metal filled with proof spirit, which float is partially supported by means of a carefully adjusted spring, and its position determines that of a lever, the angular position of which causes the alcohol counter to rotate more or less for every revolution of the measuring drum. Thus, if water only passes through the apparatus the lever in question stands at its lowest position, when the rotative motion of the drum will not be communicated to the alcohol counter, but in proportion as the lever ascends a greater
proportion of the motion of the drum will be communicated to the alcohol counter, and this motion is rendered strictly proportionate to the alcohol contained in the liquid, allowance being made in the instrument for the change of volume due to chemical affinity between the two liquids. Several thousand instruments of this description are employed by the Russian Government in controlling the production of spirits in that empire, whereby a large staff of officials is saved, and a perfectly just and technically unobjectionable method is established for levying the excise dues.

Another instrument, not belonging to any of the classes enumerated, is one for measuring the depth of the sea without a sounding line, which has recently been designed by me, and described in a paper communicated to the Royal Society. Advantage is taken in the construction of this instrument, of certain variations in the total attraction of the earth, which must be attributable to a depth of water intervening between the instrument and the solid constituents of the earth. It can be proved mathematically that the total gravitation of the earth diminishes proportionately with the depth of water, and that if an instrument could be devised to indicate such minute changes in the total attraction upon a scale, the equal divisions on that scale would represent equal units of depth.

Gravitation is represented in this instrument by a column of mercury resting upon a corrugated diaphragm of thin steel plate, which in its turn is supported by the elastic force of carefully tempered springs representing a force independent of gravitation. Any change in the force of gravitation must affect the position of this diaphragm and the upper level of the mercury, which causes an air-bubble to travel in a convolute horizontal tube of glass placed upon a graduated scale, the divisions of which are made to signify fathoms of depth. Special arrangements were necessary in order to make this instrument parathermal, or independent of change of temperature, as also independent of atmospheric density, which need not be here described. Suffice it to say that the instrument, which has been placed on board the S.S. "Faraday" during several of her trips across the Atlantic, has given evidence of a remarkable accordance in its indications with measurements taken by means of Sir William Thomson's excellent pianoforte wire-sounding machine; and we confidently expect that it will prove
a useful instrument for warning mariners of the approach of danger, and for determining their position on seas, the soundings of which are known.

Another variety of this instrument is the horizontal attraction meter, by which it will be possible to obtain continuous records of the diurnal changes in the attraction of the sun and moon as influencing the tides. This instrument belongs, however, rather to the domain of physics than to that of mechanical science.

These general remarks upon the subject of measurement may suffice to call your attention to its importance, several branches of which, those of Linear, Cubical, and Electrical Measurement, will now be dealt with.

The discussions which will follow these addresses will be carried on under circumstances such as have never before co-operated, namely, the presence of leading men of science of all civilised nations, who will take part in them, and the easy reference which can be had to the most comprehensive collection of models of scientific apparatus—both modern and ancient—which has ever been brought together.

ADDRESS

Of C. William Siemens,* D.C.L., F.R.S.,

The President of the Iron and Steel Institute, delivered on the 20th March, 1877.

The Iron and Steel Institute was called into existence in 1869 by a few of those leading members, who, assisted throughout by our energetic General Secretary, are still giving it their zealous and disinterested support. At their head stood his Grace the Duke of Devonshire, who, as its first President, pointed out to the young Society the useful results that would be realized through a

* Excerpt Journal of the Iron and Steel Institute, 1877, pp. 6-34.
judicious combination of natural science with practical experience, and by attention to the progress in metallurgical processes effected in other countries. He thus implanted upon this Institute a vitality which has resulted in a rapid increase of its members, and a career of usefulness such as scarcely any other society for the promotion of applied science can boast of.

With regard to the progress of the Institute, in the numerical strength of its membership, the number has risen from 292 in 1869, to 960 in 1876, and the proposals of candidates coming in show that the interest in the Society has not abated. This numerical progress, however, cannot be expected to continue, because the Institute has now arrived at a point where it counts among its members those gentlemen who can best aid us in the objects we have in view, and it can thus afford to restrict the privilege of membership to candidates, who by their previous training, and actual position, have qualified themselves to join profitably in our discussions.

During last year, as the report shows, meetings were held in London and Leeds, at which numerous papers were brought before you regarding subjects of considerable interest, and which gave rise to important discussions.

But besides the reading and discussion of papers, there has been much other useful work done by the Institute; I refer to the special committees that have on various occasions been appointed by the Council for the purpose of investigating questions of importance relative to the production of iron and steel, and the interest evinced in those special enquiries proves how much more may yet be accomplished by more systematic organisation for the attainment of similar objects.

Another branch of useful action of this Institute has been to place before the members, through its Journal, the latest results obtained in other countries, which work was ably performed by our late Foreign Secretary, Mr. David Forbes, F.R.S. The death of this distinguished gentleman must be a matter of deep regret to every member of the Institute.

Out of our still young society has grown another—the British Iron Trade Association—which, under the able presidency of Mr. Geo. T. Clark, already gives promise of useful results in supplying us with reliable statistics regarding the extent and progress of the
iron trade of this and other countries, and in calling the attention of our legislators to questions of tariffs, and to other measures, likely to affect the interests of the British iron trade.

Educational.—Intimately connected with the interests of this Institution, and with the prosperity of the iron trade, is the subject of technical education. It is not many years since practical knowledge was regarded as the one thing requisite in an iron smelter, whilst theoretical knowledge of the chemical and mechanical principles involved in the operations was viewed with considerable suspicion. The aversion to scientific reasoning upon metallurgical processes extended even to the authors who professed to enlighten us upon these subjects; and we find, in technological works of the early part of the present century, little more than eye-witness accounts of the processes pursued by the operating smelter, and no attempt to reconcile those operations with scientific facts. A great step in advance was made in this country by Dr. Percy, when, in 1864, he published his remarkable "Metallurgy of Iron and Steel." Here we find the gradual processes of iron smelting passed in review, and supported by chemical analyses of the fuel, ores, and fluxing materials employed, and of the metal, slags, and cinder produced in the operation. On the continent of Europe, the researches of Ebelmann, and the technological writings of Karsten, Tunner, Gruner, Karl, Akermann, Wedding, and others, have also contributed largely towards a more rational conception of the processes employed in iron smelting.

It must be conceded to the nations of the Continent of Europe that they were the first to recognize the necessity of technical education, and it has been chiefly in consequence of their increasing competition with the producers of this country, that the attention of the latter had been forcibly drawn to this subject. The only special educational establishment for the metallurgist of Great Britain is the School of Mines. This institution has unquestionably already produced most excellent results in furnishing us with young metallurgists, qualified to make good careers for themselves, and to advance the practical processes of iron making; but it is equally evident that that institution is still susceptible of great improvement, by adding to the branches of knowledge now taught at Jermyn Street, and I cannot help thinking that a step in the wrong direction has recently been made in separating
geographically and administratively the instruction in pure chemistry from that in applied chemistry, geology, and mineralogy. If properly supported, the School of Mines might become one of the best and largest institutions of its kind, but it would be an error to suppose that, however successful it might be, it could be made to suffice for the requirements of the whole country. Other similar institutions will have to be opened in provincial centres, and we have an excellent example set us by the town of Manchester, which, in creating its Owen’s College, has laid the foundation for a technical university, capable of imparting useful knowledge to the technologist of the future.

Technical education is here spoken of in contradistinction to the purely classic and scientific education of the Universities, but it must not be supposed that I would advocate any attempt at comprising in its curriculum a practical working of the processes which the student would have to direct in after-life. This has been attempted at many of the polytechnic schools of the Continent with results decidedly unfavourable to the useful career of the student; the practice taught in such establishments is devoid of the commercial element, and must of necessity be objectionable as tending to engender conceit in the mind of the student, which will stand in the way of the unbiased application of his mind to real work. Let technical schools confine themselves to teaching those natural sciences which bear upon practice, but let practice itself be taught in the workshop and in the metallurgical establishment.

Labour.—Equal in importance to an enlightened direction of metallurgical works, is the obtaining of labour upon reasonable terms. The wages paid in this country are, as a rule, higher than those prevailing on the Continent of Europe, and I do not belong to those who would wish to see them materially reduced. The late Mr. Brassey found as the result of his experience that the cost of labour, that is the co-efficient resulting from the division of the work done per day, by the day’s wage, was a constant quantity for all countries. This rule would lead to the conclusion that the more costly but effective labour, as measured by a day’s wage, must be the cheaper in the end, because it produces a greater result with a given amount of plant. I have no reason to doubt the general truth of this proposition, provided only that it is not
disturbed by misconceptions, regarding the supposed antagonism between labour, and the capital and skill directing it, which misconceptions have exercised a baneful influence upon the industries of this and other countries in recent times. Both employer and employed have reason to reflect seriously upon the experience gained during the late period of high prices. Whilst employers added largely to their producing plant, and acquired additional colliery and mining property in order to increase their output, and so took advantage, unwisely I think, of the temporary inflation, it can hardly be considered a matter for surprise, that the working classes caught up the feverish excitement, and endeavoured to obtain their share of the golden fruits that were supposed to accrue to their employers. Scarcity of labour was naturally suggestive of combination, and high rates of wages supplied the means of imposing onerous conditions upon the employer, whereby the development of economical processes was effectually retarded.

The commercial crisis which ensued has rendered the depression more general and more sweeping than could have been reasonably expected, and now that we find ourselves at what we hope may be regarded as the extreme ebb of the ever-fluctuating tide of prosperity, it behoves us to consider carefully how a recurrence of the same causes of mischief may in the future be rendered less dangerous in their results.

One of the most effectual methods of attaining this important result would consist in establishing the relations between employers and employed upon the basis of mutual interest. I hold that capital has its duties to perform as well as its rights to maintain, and that whilst the minimum of wages is that which enables the workman to live with reasonable comfort, both parties would be materially benefited by so arranging wages as to make them payable in great measure upon results, both as regards quality and quantity of work produced, whilst, by the establishment of mechanics' institutes, reading rooms, and mutual benefit associations, in connection with individual works, the feeling of community of interest would be further strengthened, and a recurrence of antagonistic action, so destructive to commercial results, might be avoided.

FUEL.—Next in importance to cheap, or rather to efficacious
labour in the production of iron and steel, comes cheap fuel,—a subject to which, as you are aware, I have devoted considerable attention, and I would therefore treat it, with your permission, rather more fully than other subjects of perhaps equal importance. Fuel, in the widest acceptation of the word, may be said to comprise all potential force which we may call into requisition for effecting our purposes of heating and working the materials with which we have to deal, although in a more restricted sense it comprises only those carbonaceous matters which, in their combustion, yield the heat necessary for working our furnaces, and for raising steam in our boilers. It may safely be asserted that the great supply of energy available for our purposes has been, or is being, derived from that great orb which vivifies all nature—the sun. In the case of coal, it has been shown that its existence is attributable to the rays of the sun, which in former ages broke up or dissociated carbonic acid and water in the leaves of plants, and rendered the carbon and hydrogen, thus separated from the oxygen, available for re-combustion. The same action still continues in the formation of wood, peat, and indeed all vegetable matter.

The solar ray produces, however, other forms of energy through the evaporation of sea water, and the resulting rainfall upon elevated lands, and through currents set up in the atmosphere and in the sea, which give rise to available sources of power of vast aggregate amount, and which may also be regarded in the light of fuel in the wider sense.

The form of fuel, however, which possesses the greatest interest for us, the iron-smelters of the 19th century, is without doubt the accumulation of the solar energy of former ages, which is embodied in the form of coal, and it behoves us to inquire what are the stores of this most convenient form of fuel.

Recent enquiry into the distribution of coal in this and other countries has proved that the stores of these invaluable deposits are greater than had at one time been supposed.

I have compiled a table of the coal areas and production of the globe, the figures in which are collected from various sources. It is far from being complete, but will serve us for purposes of comparison.
THE COAL AREAS AND ANNUAL COAL PRODUCTION OF THE GLOBE.

<table>
<thead>
<tr>
<th>Area in Square Miles</th>
<th>Production in 1874. Tons.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Britain</td>
<td>11,900</td>
</tr>
<tr>
<td>Germany</td>
<td>1,800</td>
</tr>
<tr>
<td>United States</td>
<td>192,000</td>
</tr>
<tr>
<td>France</td>
<td>1,800</td>
</tr>
<tr>
<td>Belgium</td>
<td>900</td>
</tr>
<tr>
<td>Austria</td>
<td>1,800</td>
</tr>
<tr>
<td>Russia</td>
<td>11,000</td>
</tr>
<tr>
<td>Nova Scotia, and adjoining Provinces</td>
<td>18,000</td>
</tr>
<tr>
<td>Spain</td>
<td>3,000</td>
</tr>
<tr>
<td>Other Countries</td>
<td>28,000</td>
</tr>
<tr>
<td></td>
<td><strong>270,200</strong></td>
</tr>
</tbody>
</table>

This table shows roughly that the total area of the discovered coalfields of the world amount to 270,000 square miles.

It also appears that the total coal deposits of Great Britain compare favourably with those of other European countries; but that both in the United States and in British North America, there exist deposits of extraordinary magnitude, which seem to promise a great future for the New World.

According to the report of the Coal Commissioners, published in 1871, there were then 90,207 million tons of coal available in Great Britain, at depths not greater than 4,000 feet, and in seams not less than 1 foot thick, besides a quantity of concealed coal estimated at 56,273 millions of tons, making a total of 146,480 millions. Since that period, there have been raised 600 millions of tons up to the close of 1875, leaving 145,880 millions of tons, which, at the present rate of consumption of nearly 182 millions of tons annually, would last 1,100 years. Statistics show that during the last 20 years there has been a mean annual increase in the output of about 3½ millions of tons, and a calculation made at this rate would give 250 years as the life of our coalfields.

In comparing, however, the above rate of increase with that of population and manufactures, it will be found that the additional coal consumption has not nearly kept pace with the increased demand for the effects of heat, the difference being ascribable to
the introduction of economical processes in the application of fuel. In the case of the production of power, the economy effected in our best engines within the last 20 years exceeds 50 per cent., and an equally important saving has probably been realised in the production of iron and steel within the same period, as may be gathered from the fact that a ton of steel rails can now be produced from the ore with an expenditure not exceeding 55 cwt. of raw coal, whereas a ton of iron rails, 20 years ago, involved an expenditure exceeding 100 cwt. According to Dr. Percy, one large works consumed, in 1859, from 5 to 6 tons of coal per ton of rails. Statistics are unfortunately wanting to guide us respecting these important questions.

Considering the large margin for further improvement in almost every application of fuel, which can be shown upon theoretical grounds to exist, it seems not unreasonable to conclude that the ratio of increase of population and of output of manufactured goods will be nearly balanced, for many years to come, by the further introduction of economical processes, and that our annual production of coal will remain substantially the same within that period, which under those circumstances will probably be a period of comparatively cheap coal.

The above-mentioned speculation leads to the further conclusion that our coal supply at a workable depth will last for a period far exceeding the shorter estimated period of 250 years, especially if we take into account the probability of fresh discoveries, of which we have had recent instances, particularly in North Staffordshire, where a large area of coal and blackband ironstone is being opened up, under the auspices of his Grace the Duke of Sutherland, by our member, Mr. Homer.

Wherever coalfields are found in Great Britain, they exist, generally speaking, under favourable circumstances. The deposits are for the most part met with at reasonable depths, the quality of the coal is unsurpassed by that of other countries, and although the coal and ironstone do not occur together in all the iron-producing districts, the distance from the coal to the iron is small, compared with that met with in other countries, and the insular position of Great Britain renders water carriage, both for internal communication and for the purpose of export, more readily available than elsewhere. These advantages ought to decide the
present contest for supplying the markets of the world with iron and steel, at the lowest rates, in favour of this country.

Coal assumes, in many instances, the form of anthracite, and although the South Wales district contains large deposits of this mineral fuel, comparatively little use has been hitherto made of it for smelting purposes. When raw anthracite is used in the blast furnaces mixed with coke, it has been found that the amount so used should be limited to from 10 to 15 per cent., or the furnace is apt to become choked by an accumulation of decrepitated anthracite. At Creusot, in France, this difficulty was overcome many years ago, by crushing the anthracite coal, mixing it intimately with crushed binding coal, and coking a mixture of about equal proportions in Appold's vertical coke ovens. The result is a somewhat unsightly, but exceedingly hard and efficacious coke. A similar method has been followed for some time in South Wales, where coke is now produced, containing as much as 60 per cent. of anthracite, bound together by 35 per cent. of binding coal, and a further admixture of 5 per cent. of pitch or bitumen, the whole of the materials being broken up and intimately mixed in a Carr's disintegrator prior to being coked in the usual manner. Coke of this description possesses great power of endurance in the furnace, and is worthy the attention of iron-smelters.

In the United States of America anthracite plays a most important part, being in fact the only mineral fuel in the Northern States east of the Alleghany mountains. Its universal application for blast furnaces, for heating purposes, and for domestic use, imparts to the eastern cities of the United States a peculiar air of brightness, owing to the entire absence of smoke, which must impress every visitor most agreeably, and the difference of effect produced by the general use of this fuel, as contrasted with that of bituminous coal, is most strikingly exemplified in a short day's journey from Philadelphia, the capital of the anthracite region, to Pittsburg, the centre of application of bituminous coal.

In visiting lately the deposits of anthracite coal of the Schuylkill district, I was much struck with their vastness, and with the manner and appliances adopted for working them. The American anthracite is less decrepitating than ours, but its successful application to its various purposes is the result chiefly of the judicious
manner in which it is prepared for the market. The raw anthracite as it comes from the mine is raised to the top of a wooden structure some 60 to 70 feet high, in descending through which it is subjected to a series of operations of crushing, dressing, sieving, and separating of slaty admixtures, and is then delivered through separate channels into railway wagons, as large-coal, egg-coal, walnut-coal, and pea-coal, each kind being nicely rounded and uniform in size. The dust coal, which amounts to nearly one-half of the total quantity raised, is at present allowed to accumulate near the mine, but experiments are now being carried out to utilise this also for steam-boiler purposes.

Next in importance to mineral fuel, properly speaking, come lignite and peat, of which vast deposits are met with in most countries. These may be looked upon as coal still in course of formation, and the chief drawback to their use, as compared with that of real coal, consists in the large percentage of water which they contain rendering them inapplicable, in their crude condition, to the attainment of high degrees of heat. These difficulties may be overcome by subjecting the wet material to processes of compression, desiccation, and coking, whereby excellent fuel and products of distillation are obtained; but the cost of their production has hitherto exceeded their market value. Crude air-dried peat has, however, been rendered applicable for obtaining high degrees of heat such as are required for metallurgical operations, by means of the regenerative gas furnace; and it is important to observe that the calorific value of a ton of air-dried peat or lignite, if used in this manner, is equal to that of a ton of good coal, if in both cases deduction is made of the percentage of moisture and earthy matter. The carbonaceous constituents of peat yield indeed a very rich gas suitable for melting steel or for re-heating iron, the only precaution necessary being to pass the gas from the producer over a sufficient amount of cooling surface to condense the aqueous vapour it contains, before its arrival at the furnace. This precaution is not necessary, however, in dealing with some of the older lignites, such as occur abundantly in Austria and Hungary, which may be ranked as almost equal in value with real coal, except for blast-furnace purposes.

Fuel also occurs naturally in the gaseous condition, a fact but too well known to every practical coal miner. Occasionally, how-
ever, it is found separated from the coal with which it may have been primarily associated, and in those cases it has been made practically available as fuel. At Bakoo, on the Caspian Sea, natural gas has issued spontaneously from the ground for centuries past, and the column of perpetual fire thus produced, has served the purpose of giving the Parsees a holy shrine at which to worship their deity. In the district of Pennsylvania, a more substantial application has been made of the gas issuing from many of the borings, which serves as fuel for working pumping machinery and as illuminating gas for the district. The quantity of gas issuing from some of these wells may be judged from the fact, that one of them, after discharging for three years as much gas as could escape into the atmosphere under a pressure estimated at not less than 200 lbs. on the square inch, has lately been connected by means of a 5-inch pipe with Pittsburg (a distance of 18 miles), where 70 puddling and re-heating furnaces are worked entirely by the fuel so supplied. But even this result furnishes only an imperfect idea of the calorific power represented by this single issue of natural gas, inasmuch as the combustion is carried on in these furnaces on the most wasteful plan, the gas being mixed imperfectly with cold air, and converted to a large extent into dense masses of smoke. An analysis of this gas gives—Hydrogen, 18·50 ; Marsh Gas, 80·11 ; Ethylene, 5·72 ; Carbonic acid, 0·66.

The use of natural gas is not likely to assume very large proportions owing to its rare occurrence, but its application at Pittsburg has forcibly reminded me of a project I had occasion to put forward a good many years ago, namely, to erect gas-producers at the bottom of coal mines, and by the conversion of solid into gaseous fuel, to save entirely the labour of raising and carrying the latter to its destination. The gaseous fuel, in ascending from the bottom of the mine to the bank, would (owing to its temperature and low specific gravity), acquire in its ascent an onward pressure sufficient to propel it through pipes or culverts to a considerable distance, and in this way it would be possible to supply townships with heating gas, not only for use in factories, but, to a great extent, for domestic purposes also. In 1869, a company, in which I took a leading interest, was formed at Birmingham, under the sanction of the Town Council, to supply the town of Birmingham with heating gas at the rate of 6d. per 1,000 cubic feet, but
the object was defeated by the existing Gas Companies, who opposed their bill in Parliament, upon the ground that it would interfere with vested interests. I am still satisfied, however, that such a plan could be carried out with great advantage to the public; and although I am no longer specifically interested in the matter, I would gladly lend my aid to those who might be willing to realise the same.

Fuel also occurs naturally in the liquid state, and if mineral oils could be obtained in quantities at all comparable to those of solid fuel, liquid fuel would possess the advantages of great purity and high calorific value; but, considering its rare occurrence, and comparatively high price, even in the oil districts of Pennsylvania and Canada, its use, for smelting purposes, need not be here considered.

According to the general definition of fuel given above, we have to include the evaporative effect of the sun's rays, by which sea-water is raised to elevated mountain levels, whence it descends towards the sea, and in so doing is capable of imparting motion to machinery.

This form of fuel, which takes the place of the coal otherwise expended in raising steam, has been resorted to in all countries since the dawn of civilization, and it is owing to this circumstance that the industries of the world were formerly very much scattered over the valleys and gorges of mountainous districts, where the mountain stream gave motion to the saw-mill or flour-mill, to the trompe of the iron-smelter, and to the helve of the iron and steel manufacturer.

The introduction of the steam engine, towards the end of last century, changed the industrial aspect of the world in causing manufactories to be massed together in great centres, and this tendency has been still further augmented in consequence of the construction of canals and railways, which enable us to bring together the raw material, and to disperse the manufactured product at a comparatively low cost. It is not unreasonable, however, to expect that a certain reaction in this process of centralization will gradually take place, because, in consequence of ever-increasing competition, the advantage of utilising natural forces, which we could afford to neglect during a period of general prosperity, becomes again an essential element in determining the
very lowest price at which our produce may be sent into the market.

The advantage of utilising water-power applies, however, chiefly to Continental countries, with large elevated plateaus, such as Sweden and the United States of America, and it is interesting to contemplate the magnitude of power which is now for the most part lost, but which may be, sooner or later, called into requisition.

Take the Falls of Niagara as a familiar example. The amount of water passing over this fall has been estimated at 100 millions of tons per hour, and its perpendicular descent may be taken at 150 feet, without counting the rapids, which represent a further fall of 150 feet, making a total of 300 feet between lake and lake. But the force represented by the principal fall alone amounts to 16,800,000 horse-power, an amount which, if it had to be produced by steam, would necessitate an expenditure of not less than 266,000,000 tons of coal per annum, taking the consumption of coal at 4lbs. per horse-power per hour. In other words, all the coal raised throughout the world would barely suffice to produce the amount of power that continually runs to waste at this one great fall. It would not be difficult, indeed, to realize a large proportion of the power so wasted, by means of turbines and water-wheels erected on the shores of the deep river below the falls, supplying them from races cut along the edges. But it would be impossible to utilize the power on the spot, the district being devoid of mineral wealth, or other natural inducements for the establishment of factories. In order to render available the force of falling water at this, and hundreds of other places similarly situated, we must devise a practicable means of transporting the power. Sir William Armstrong has taught us how to carry and utilize water-power at a distance, if conveyed through high-pressure mains, and at Schaffhausen, in Switzerland, as well as at some other places on the Continent, power is conveyed by means of quick-working steel ropes passing over large pulleys; by these means, it may be carried to a distance of one or two miles without difficulty. Time will probably reveal to us effectual means of carrying power to great distances, but I cannot refrain from alluding to one which is, in my opinion, worthy of consideration, namely, the electrical conductor. Suppose water-
power to be employed to give motion to a dynamo-electrical machine, a very powerful electrical current will be the result, which may be carried to a great distance, through a large metallic conductor, and then be made to impart motion to electromagnetic engines, to ignite the carbon points of electric lamps, or to effect the separation of metals from their combinations. A copper rod 3 in. in diameter would be capable of transmitting 1,000 horse-power at a distance of say 30 miles, an amount sufficient to supply one quarter of a million candle-power, which would suffice to illuminate a moderately sized town.

The use of electrical power has sometimes been suggested as a substitute for steam power, but it should be borne in mind that so long as the electric power depends upon a galvanic battery, it must be much more costly than steam power, inasmuch as the combustible consumed in the battery is zinc, a substance necessarily much more expensive than coal; but this question assumes a totally different aspect if in the production of the electric current a natural force is used which could not otherwise be rendered available.

The force of the wind is another source of natural power representing fuel according to the general definition above given, which, though large in its aggregate amount, is seldom used, except in navigation, owing to its proverbial uncertainty. On this account we may dismiss it from serious consideration until our stores of mineral wealth are well-nigh exhausted, by which time our descendants may have discovered means of storing and utilising it in a manner entirely beyond our present conceptions.

Processes.—Having thus dwelt—too long, I fear, for your patience—upon the subject of fuel, I now approach the question as to the processes by which we can best accomplish our purpose of converting the crude iron ore into such materials as leave our smelting works and forges.

The subject of blast furnace economy has already been so fully discussed by you, during the term of office of your past President, Mr. I. Lowthian Bell, M.P., F.R.S., who has done so much himself to throw light upon the complicated chemical reactions which occur in the blast furnace, that I may be permitted, on the present occasion, to pass over this question, and to call your attention more particularly to those processes by which iron is made to
attain its highest qualities both as regards power of resistance and ductility.

Iron and Steel were known to the ancients, and are referred to in their writings, but we have no account of the processes employed in the manufacture of these metals until comparatively speaking recent times. Aristotle describes steel as purified iron, and says that it is obtained by remelting iron several times, and treating it with various fluxes; we are hence led to suppose that in Aristotle's time steel was made by careful selection, and treatment of steely iron, which latter was produced by something analogous to the Catalan process.

A method referred to by ancient authors, is to bury iron in damp ground for some time, and then to heat and hammer it. Another process first described in Biringuccio's "Pyrotechnology," one of the earliest works on Metallurgy, and later in Agricola's "De Re Metallica," both published in the 16th century, is to retain malleable iron for some hours in a bath of fused cast iron, when it becomes converted into steel. Réaumur, in 1722, produced steel by melting three parts of cast iron with one part of wrought iron (probably in a small crucible) in a common forge, but he failed to produce steel in this manner upon a working scale.

A similar method of producing steel to that proposed by Réaumur has been employed in India for ages, the celebrated Wootz steel being the result of partial or entire fusion of steely iron and carbonaceous matter, in small crucibles arranged in a primitive air furnace, followed by a lengthy exposure of the ingots to heated air in order to effect a partial decarburization.

In 1750, Hasenfratz refers, in his "Siderotechnic," to three processes for producing steel: melting broken fragments of steel with suitable fluxes, fusing malleable iron with carbonaceous matter and so treating cast iron (probably with oxides) as to obtain cast steel directly from it.

The credit of producing cast steel upon a working scale is due to Huntsman, who was the first to accomplish its entire fusion in crucibles, placed amongst the coke of an air furnace, which fluid metal he poured into metallic moulds. This process is still carried on largely at Sheffield for the production of special qualities of steel, such as tool steel, tyre steel, castings and forgings, and a ton
of cast steel in ingots is produced with the expenditure of from 2\frac{1}{2} to 3 tons of Durham coke, according to the degree of mildness of the metal desired.

At Pittsburg, where pot-melting is employed on a considerable scale, plumbago pots having nearly double the capacity of the Sheffield clay pots are invariably used; 18 or 24 of these pots, each containing about a hundredweight of metal, are placed in a gas furnace, and each pot lasts twenty-four hours, yielding five charges during that interval. The fuel consumed amounts to one ton of small slack per ton of steel melted, which is delivered to the works at the surprisingly low price of 30 cents per ton. With these important advantages in his favour, the American steel-melter should be able, one would think, to meet without protection his Sheffield competitor in the open market.

With regard to Bessemer steel, great advances have been made in recent times in cheapening its production. At Creusot and other Continental works, a system of direct working, or of transferring the pig metal in the molten condition from the blast furnace to the Bessemer converter, has been introduced, and the same method has been recently adopted at several of the leading English works. By this method of working, the fuel usually employed in re-melting the pig metal in the cupola (say 2\frac{1}{2} cwt. per ton) is clearly saved, and other advantages are realized; but, on the other hand, the Bessemer converter is made dependent upon the working of the blast furnace both as regards time and the quality of the resulting metal. At Barrow and other large works, where a number of blast furnaces supply several Bessemer converters, in addition to pig metal, for the open market, this mode of working appears to be practically free from the objection above stated; and a hot ladle, with its engine, may be kept steadily at work transferring the pig metal from one blast furnace or another to the converters. But it still remains to be seen whether any practical advantage can be realized by this method of working at smaller works, where a change in the working of the blast furnace from Bessemer to forge pigs would cause a serious interruption in the working of the Bessemer plant.

In America, the effort of the ironmaster has been directed—chiefly under the guidance of Mr. A. L. Holley—towards a saving of labour, by increasing to an almost incredible extent the number
of blows per diem from each converter. Thus I was informed that at the North Chicago Steel Works, as many as 73 blows had been obtained in one pit in 24 hours, although I have reason to doubt whether this rate of working could be maintained for any length of time. The Americans have not adopted, so far as I could ascertain, the direct process of working, but are content to remelt their pig metal in large cupolas in immediate proximity to the converters; the capacity of the converters has latterly been much increased, and the degree of heat engendered by a blast of increased power, has been augmented to such an extent that a considerable amount of scrap metal can be re-melted within the fluid bath before discharging the same into the ingot moulds.

Whilst the Bessemer process has been making rapid strides, another process has gradually grown up by its side, which I cannot pass over without remark. I allude to the open-hearth steel process, with which my name and the joint names of Siemens and Martin are associated. The conception of this process is really as old as that of cast steel itself. The ancient Indian steel, the Wootz, was the result of a fusion of a mixture of malleable iron and carbon. Réaumar, as already stated, proposed to melt wrought iron and pig metal together for the production of steel, as early as 1722; and J. M. Heath,—to whom we owe the important discovery that by the addition of manganese to cast steel its malleability is greatly increased,—endeavoured to realize the conception of producing steel in large masses upon the open hearth of the furnace in the year 1839, and he again has been followed in these endeavours by Gentle Brown, Richards, and others in the same direction.

When, in 1856, I first seriously gave my attention, in conjunction with my brother (Frederick Siemens) to the construction of a regenerative gas furnace, I perceived that this furnace would be admirably adapted to the production of steel upon the open hearth, and I remember proposing it for such a purpose to Mr. Abraham Darby, of Ebbw Vale, in 1861. Ever since that time I have been engaged in the realization of this idea, which has been retarded, however, by those untoward circumstances which ever intervene between a mere conception and its practical realization. Although two of my earlier licensees, Mr. Chas. Attwood, of Tow Law, and the Fourchambault Company, in France (with whom
was my esteemed friend, the late M. Lechatelier, the Inspecteur-Général des Mines), succeeded, in 1865 and 1866, in producing steel upon the open hearth, they did not persevere sufficiently to attain commercial results; and it was not until after I had established experimental steel works at Birmingham, that I was enabled to combat in detail the various difficulties which at one time looked well-nigh insuperable.

Whilst thus engaged, Messrs. Pierre and Emile Martin, of Sireuil, who had obtained licences for furnaces to melt steel both in pots and on the open hearth, succeeded, after a short period of experimenting, in introducing into the market open-hearth steel of excellent quality.

Messrs. Martin gave their attention to the production of steel by the dissolution of wrought iron and steel scrap in a bath of pig metal, whilst my own efforts were more especially directed to the production of steel by the use of pig metal and iron ores, either in the raw state, or in a more or less reduced condition, which latter process is the one mostly employed in this country.

One of the advantages that may be claimed for the open-hearth process consists in its not being dependent upon a limited time for its results. The heat of the furnace is such that the fluid bath of metal, after being reduced to the lowest point of carburization, may be maintained in that condition for any reasonable length of time, during which samples can be taken and tested, and additions either of pig metal, of wrought scrap, spongy metal, or ore, may be made to it so as to adjust the metal to the desired temper. The requisite proportion of spiegeleisen, or ferro-manganese, is then added in the solid condition, and the result is a bath of metal, the precise chemical condition of which is known, and which has the advantage, if properly managed, of being what is technically called "dead melted." This circumstance renders it applicable for certain purposes for which pot steel has hitherto been mostly employed.

The purpose to which the open-hearth process is more especially applicable is for the conversion of scrap steel, and iron of every description into steel or ingot metal, and it is now used, indeed, to a large extent for the conversion into steel of old iron rails. The wearing qualities of these converted rails have been under test since 1867, when the Great Western Railway Company had some
old Dowlais iron rails converted into steel at my Experimental Steel Works at Birmingham, which was rolled into rails by Sir John Brown & Co.; these have been down ever since that time at Paddington, subjected to great wear and tear.

The manufacture of steel, both by the Bessemer and the open-hearth processes, is much facilitated by the use of ferro-manganese. This material was introduced into the market in 1868, by Mr. Henderson, of Glasgow. It was produced successfully by charging carbonate or oxide of manganese, and manganiferous iron ore intimately mixed with carbonaceous matter upon the open hearth of a Siemens furnace with a carbonaceous lining; but the demand for this material was not sufficient to render the manufacture profitable at that time, and it was not until the year 1875 that it was re-introduced into the market by the Terrenoire Company.

Manganese, when added in a proportion of '5 per cent., or more, to steel or ingot metal, containing only from '15 to '20 per cent. of carbon, has the effect of removing red-shortness, and of making it extremely malleable both in the heated and cold conditions. In using spiegeleisen containing only from 10 to 15 per cent. of metallic manganese, it is impossible to supply the amount necessary to produce this malleability without adding, at the same time, such a percentage of carbon as would produce a hard metal. The use of ferro-manganese enables us to overcome this difficulty, and greatly facilitates the production of a metal so malleable and with so little carbon, as to remain practically unaffected in its temper when plunged red-hot into water.

Another result produced by the use of manganese without carbon, upon mild steel or ingot metal, is to neutralize the objectionable effect of phosphorus, so long as the latter does not exceed the limit of '25 per cent. This metal, in which phosphorus may be said to take the place of carbon, presents a large specular fracture, and is, contrary to what might have been expected, extremely ductile when cold.

Iron when in the fluid condition can be alloyed with other metals, and some of the compounds thus formed are known to possess very remarkable properties. Thus, iron combined with '3 per cent. of tungsten and '8 per cent. of carbon, yields a metal which can be worked like ordinary steel, but which, when hardened, retains magnetism to a very remarkable degree, a property which
was discovered by Dr. Werner Siemens in 1853. A further addition of tungsten produces an exceedingly hard metal (introduced into the market by Mr. Mushet in 1868) which cannot be forged, but which when cast into bars, and ground so as to form a sharp edge, produces cutting tools capable of great endurance.

An admixture of chromium has for many years past been known to produce steel of great hardness and strength, but it is only quite recently that it has been brought into practical use in America by Mr. Julius Baur, and has been taken up in this country by Sir John Brown & Co., of Sheffield, who claim for it very remarkable properties as regards strength, malleability, and freedom from corrosion.

The formation of compounds such as these is a matter of great interest in connection with the future development of the applications of steel, and is one of those subjects which I venture to suggest might be much advanced by an organized research, under the auspices of a Committee of the Iron and Steel Institute.

The value of the material known as mild steel or ingot metal, consists in its extreme ductility under all possible conditions. Its ultimate strength is much inferior to that of ordinary steel, and rarely exceeds 28 tons per square inch; its limit of elasticity is reached at 15 tons per square inch, whilst the limit of elasticity of a harder steel may reach from 25 to 30 tons per square inch, and that of hard-drawn steel wire from 45 to 50 tons. But in estimating the relative value of these different materials by the amount of work that has to be expended in causing rupture, it will be found that the mild steel has the advantage over its competitors. When subjected to blows or sudden strains, such as are produced by the explosion of gun-cotton or dynamite, extra mild steel differs in its behaviour from that of BB iron and ordinary steel, by yielding to an extraordinary extent without fracturing, and it is in consequence of this non-liability to rupture that it may be loaded to a point much nearer to its limit of elasticity than would be safe with any other material.

Attention has been recently directed in various quarters to remedy defects appertaining to steel, viz., piping and showing honey-combed appearance in the ingot. It is well known that if such steel is hammered and rolled, the open spaces contained in it are elongated, and seemingly closed up, but in reality continue to
form severances within the metallic mass, to the prejudice of the uniform strength of the finished forging.

In casting steel containing more than 0.5 per cent. of carbon, the defect of honey-combing can easily be avoided if care is taken to have the metal "dead melted" before pouring it into the mould; and that of piping by continuing the inflow of fluid metal for a sufficient length of time while it is setting. But in dealing with mild steel containing only say 0.2 per cent. of carbon, the difficulty of making a sound casting is greatly increased. Much may be done, however, by careful manipulation of the fluid metal, and by the judicious addition to it of manganese or other oxidizable metals, such as silicon or lead, by which occluded oxygen is removed.

Sir Joseph Whitworth, who, as you well know, has given much attention to this subject, has overcome the evil mechanically by subjecting the steel, while setting in the mould, to great hydraulic compression. He has thus succeeded in producing, in large masses, mild steel of extremely uniform strength, and the only doubt which could possibly be raised against the advisability of producing steel for ordinary applications by this method is founded on considerations of cost.

The subject of producing sound steel castings is one which we shall have an opportunity to discuss in reference to a paper which will be presented by M. Gautier.

Applications of Steel.—The employment of steel for general engineering purposes dates only from the year 1851, when Krupp, of Essen, astonished the world by his exhibits of a steel ingot weighing 2,500 lbs., and of his first steel gun, and introduced a comparatively mild description of pot steel for steel tyres, axles, and crank shafts. For the production of these he constructed his celebrated monster hammer, with a falling weight of 45 tons, which, at that time, far surpassed in magnitude and power our boldest conception, and is now only being exceeded by a still more powerful hammer in course of erection at the Essen Works. Krupp's steel was, however, not cheap steel, and it is to our past president, Mr. Henry Bessemer, and to the important addition made to his process by Mr. Mushet, that we are indebted for the production of steel at such a reduced cost as to make it available for railway bars and structural purposes in substitution for iron,
since which event the applications of this superior material show a most extraordinary rate of increase. Not only do we travel upon steel tyres, running over steel rails, but at least one of our leading railway companies, the London and North Western, has, under the able management of Mr. F. W. Webb, constructed as many as 748 locomotive engines, including boiler, frame, and working parts, entirely of that material, excepting only the fire-boxes, which are still made of copper. In France, also, much attention has been given to the introduction of steel for machinery purposes, and there, as well as in the United States, Germany, and Holland, that material is used largely in the construction of bridges and other engineering works.

In this country the application of steel for structural purposes has occupied the attention of some of our leading civil engineers for many years, and Sir John Hawkshaw, when called upon to construct a railway bridge at Charing Cross in 1859, proposed the use of steel in order to lighten the structure. He was prevented, however, from carrying his idea into effect by the rules of the Board of Trade, which provide that wrought material of any kind shall not be weighted either in compression or extension to more than 5 tons per square inch. Repeated efforts have been made since that time to induce the Board of Trade to adopt a new rule, in which the superior strength of steel should be recognized, and in order to facilitate their action a committee was formed, consisting of Mr. William Henry Barlow, Capt. Galton, and others, who carried out—with the pecuniary aid of leading steel manufacturers—a series of valuable experiments, showing the limit of elasticity and ultimate strength of various steels. The results obtained are published separately in "Experiments on the Mechanical and other Properties of Steel by a Committee of Civil Engineers."

At the instance of Mr. Barlow, the British Association appointed a further Committee to promote the object of obtaining for steel its proper recognition, and this has led finally to the appointment, under the sanction of the Board of Trade, of three gentlemen, viz., Sir John Hawkshaw, F.R.S., and Mr. William Henry Barlow, F.R.S. (who were nominated by the Council of the Institution of Civil Engineers), and of Colonel Yolland, F.R.S., of the Board of Trade, who have agreed upon a report recommending the use of
steel as a building material, subject to a limit of strength greatly in excess of the limit assigned to wrought iron. It is to be hoped that the Board of Trade, by adopting that report, will remove the serious drawback which has too long stood in the way of the application of steel for structural purposes, and which has rendered the construction of large works, such as the projected bridge over the Frith of Forth practically impossible.

As regards the construction of ships of extra mild steel, the English Admiralty, following the example set by France, has, under the advice of Mr. Barnaby, the Chief Constructor, taken the lead of the commercial navy of the country, and several corvettes have recently been constructed entirely of that material at the Government Yard at Pembroke, and upon the Clyde. The constructors of merchant shipping have hitherto been restricted by rules laid down by Lloyd's Registry, which make no distinction between common iron and steel in determining the classification of a vessel. It is to be hoped that the important engineering and shipbuilding interests of the country will soon be released from regulations which may have been well adapted to the use of an inferior material such as common iron, but fail entirely to meet the requirements of the present day.

In shipbuilding, the use of a material superior in toughness and in strength produces the double advantage of greater safety to life and property, and of an increase of carrying capacity to the full amount of weight saved in the construction of a ship. It should be borne in mind that this additional weight of merchandise is carried without increasing the working expenses of the ship and power required in its propulsion, and may just suffice to strike the balance between working a vessel designed for long voyages at a fair profit or at a loss. In constructing the masts and yards of vessels of the stronger material, the weight saved is a matter of still greater importance, and I am glad to say that this question now engages earnest attention.

In the United States, a committee, composed of both military and civil engineers, have been engaged for some time upon the subject of determining experimentally the structural value of iron and steel. This Committee have the advantage of substantial support from the United States Government, who, after a first grant of 75,000 dollars, have, I observe, voted a further sum of
40,000 dollars in aid of the experimental enquiries which have been instituted.

The Council of the Iron and Steel Institute are not unmindful of the importance of this subject, and have invited those gentlemen of this and other countries, who have given most attention to the production and application of steel, to aid us in our forthcoming discussion with the results of their experience.

In the course of this discussion, the distinctive limits between steel and iron will necessarily engage your attention. Considering the extraordinary change of physical condition which iron undergoes when alloyed with small percentages of carbon, manganese, phosphorus, tungsten, chromium, and other substances, and considering, further, that it is never quite free from some admixture, the question of nomenclature is one naturally surrounded with difficulty, but it is becoming one of considerable practical importance, when rules are to be laid down regulating the permissible strength of different grades of these materials.

Dr. Percy has, in his "Metallurgy of Iron and Steel," defined steel as iron containing a small percentage of carbon, the alloy having the property of taking a temper, and this definition is substantially equivalent to those found in the works of Karsten, Wedding, Grünér, and Tunner; on the other hand, Messrs. Jordan, Greiner, Gautier, Phillipart, Holley, and others, define as steel all alloys of iron which have been cast and are malleable, whilst Sir Joseph Whitworth considers that steel should be defined mechanically by a co-efficient representing the sum of its strength and ductility.

With the object of settling this question of nomenclature, an International Committee was appointed at Philadelphia, by the Institution of American Mining Engineers. The Committee consisted of the following gentlemen:—Mr. I. Lowthian Bell, M.P.; Dr. Hermann Wedding; Professor Tunner; Professor Åkermann; M. Grünér; Mr. A. L. Holley, and Mr. T. Egleston, and they resolved upon the following recommendation:—

"I. That all malleable compounds of iron, with its ordinary ingredients, which are aggregated from pasty masses, or from piles, or from any form of iron not in a fluid state, and which will not sensibly harden and temper, and which generally resemble..."
what is called wrought iron, shall be called Weld-iron (German Schweisseisen; French, Fer-soudé).

"II. That such compounds when they will from any cause harden and temper, and which resemble what is now called 'puddled steel,' shall be called Weld-steel (German, Schweiss-stahl; French, Acier-soudé.)

"III. That all compounds of iron, with its ordinary ingredients, which have been cast from a fluid state into malleable masses, and which will not sensibly harden by being quenched in water while at a red heat, shall be called Ingot-iron (German, Fluss-eisen; French, Fer-fondu).

"IV. That all such compounds, when they shall from any cause so harden, shall be called Ingot-steel (German, Fluss-stahl; French, Acier fondu)."

The nomenclature here proposed is entitled to careful consideration from the eminence for both theoretical and practical knowledge of the gentlemen composing the committee; but I apprehend that, for common use, the distinctions desired to be drawn are too manifold. Moreover, the lines of demarcation laid down run through materials very similar, if not identical, in their application, where a distinction in name would be extremely difficult to maintain, and awkward to draw. Take, for instance, railway bars from Ingot-metal, which are usually specified to bear a given dead load without deflecting beyond certain limits, and to resist a certain impact without rupture. The materials answering to these requirements contain from '2 to '6 per cent. of carbon, depending in a great measure upon the mode of production, and upon the amount of admixture of phosphorus, sulphur, silicon, and manganese. But inasmuch as the quality of tempering is chiefly due to carbon, part of the rails delivered under such specification might have to be classified as ingot-iron, and part as ingot-steel. The committee omits to define the degree of hardening which it considers necessary to bring a material within the denomination of ingot-steel; it is well known, however, that the temper depends upon the exact temperature to which the metal is heated before being plunged into the refrigerating medium, and also upon the temperature and conductivity of the latter, and that ingot metal with only '2 per cent. of carbon, when plunged hot into cold water, takes a certain amount of temper. The question
of the amount of import duties payable in foreign countries upon metal occupying a position near the proposed boundary line, would also lead to considerable inconvenience.

Difficulties such as these have hitherto prevented the adoption of any of the proposed nomenclatures, and have decided engineers and manufacturers in the meantime, to include, under the general denominations of cast steel, all compounds consisting chiefly of iron, which have been produced through fusion, and are malleable. Such a general definition does not exclude from the denomination of steel, materials that may not have been produced by fusion, and which may be capable of tempering such as shear steel, blister steel, and puddled steel, nor does it interfere with distinctions between cast steels produced by different methods, such as pot steel, Bessemer steel, or steel by fusion on the open hearth. The forthcoming discussion will, I hope, lead to some general agreement regarding this question of nomenclature.

WROUGHT IRON.—While steel is gradually supplanting wrought iron in many of its applications, efforts are being made to maintain for the latter material an independent position, for cheapness and facility of manipulation, by improving the puddling process.

Mechanical puddling, like many other important inventions, has taken a long time for its development, and has engaged the attention of many minds, but I will only here mention the names of Tooth, Yates, and Mr. Menclaus, our past President, who have pioneered the road; and of Danks, Spencer, Crampton, and others who have followed more recently in the same direction. It is chiefly owing, however, to the persevering endeavours of Mr. Heath, and of Messrs. Hopkins, Gilkes, & Co., that the mechanical puddling of pig metal has been accomplished with a considerable amount of success.

All these efforts have had reference to puddling in a chamber rotating upon a horizontal axis, but numerous attempts have also been made to accomplish mechanical puddling by the introduction into stationary chambers of rabbles moved by mechanical power, and by the use of chambers rotating upon an inclined axis, in connection with which latter, the names of Maudsley, Sir John Alleyne, and Pernot, should be mentioned. The principal difficulty connected with the rotary puddling furnace consists in providing a lining of sufficient power to resist the corrosive action produced
by siliceous slags, and it is important therefore, that the pig metal introduced into the rotative puddler should be as free from silica as possible. By charging fluid metal into the furnace, the silica adhering to the pigs in the form of sand is got rid of; but efforts have latterly been made, with satisfactory results, I believe, to subject the pig iron itself to a simple finery process on its way from the blast furnace to the rotative puddler, with a view of removing the silicon chemically combined with the pig. M. Hamoir, of Belgium, has been engaged upon this subject for some years, as you will have seen from the "Report on the Progress of the Iron and Steel Industries in Foreign Countries," in our Journal, while in this country, Mr. I. Lowthian Bell has called the Bessemer converter into requisition for effecting the desired object.

We are informed that not only does the lining of the furnace stand better in using this semi-refined metal, but that the yield per furnace per diem, as well as the quality of the metal obtained, are much improved.

It is intended to roll the metal thus produced into railway bars, without any intermediate process of re-heating, and to subject the rails to a process of case-hardening similar to what was practised some years ago by Mr. Dodds, in South Wales. The case-hardened iron rails are expected to rival steel rails in quality, but it remains to be seen whether their wearing properties will not be obtained at the cost of brittleness, and whether rails manufactured by this method will be able to compete in price with steel rails.

Three years ago, I had the honour of bringing before this Institute a plan of producing wrought iron directly from the ore, in a rotative furnace of special construction, and heated by gas. This process was at that time only carried on upon a small scale at my Sample Steel Works, in Birmingham. It has since been carried out upon a working scale, at Towcester, and in Canada, and although the results hitherto obtained cannot yet be considered entirely satisfactory from a commercial point of view, I see no reason to feel discouraged as regards the ultimate result of this method of treating iron ores. By it, iron of almost entire freedom from sulphur and phosphorus is obtained from ores containing a considerable percentage of these impurities. If steel is to be produced, the raw balls, as they leave the rotatory furnace, are
either immediately transferred to the bath of the open-hearth furnace, or are previously subjected to the processes of squeezing and hammering for the removal of scoria, which otherwise carries some of the impurities contained in the ore into the metallic bath, and prevents the attainment of steel of a high quality.

One of the drawbacks to the use of iron and steel for structural purposes is found in their liability to rust when exposed to air and moisture. The ordinary means of protection against rust consists in covering the exposed surfaces with paint, and if this is renewed from time to time, iron or steel may be indefinitely preserved from corrosive action. Another mode of protection consists in dipping articles of iron and steel while hot into a bath of oil, when some of the oil penetrates to a slight depth into the pores of the metal, while other portions become decomposed, and form a very tenacious resinous coating. For the protection of iron and steel, when in the form of thin sheets or wire, galvanizing, as is well known, is largely resorted to.

The protection in this case depends upon the fact that zinc, although more oxidisable than iron, forms, with oxygen, an oxide of a very permanent nature which continues to adhere closely to the metal, and thus prevents further access of oxygen to the same. This mode of protection presents the further advantage that so long as any metallic zinc remains in contact with the iron in presence of moisture, the latter metal forms with the zinc the negative element of an electrolytic couple, and is thus rendered incapable of combining with oxygen.

Galvanising is not applicable in those cases in which structures of iron and steel are put together by the aid of heat, or are brought into contact with sea water, which would soon dissolve the protecting zinc covering. But even in these cases the metal may be effectually protected against corrosion by attaching to it pieces of zinc, which latter are found to dissolve in lieu of the iron, and must, therefore, be renewed from time to time.

Captain Ainslie, of the Admiralty, has lately made a series of valuable experiments, showing the relative tendency towards corrosion of both iron and steel when in contact with sea water, and of the efficacy of pieces of zinc in preventing this corrosion. These experiments further show that mild steel is—contrary to the results obtained by M. Gautier—more liable to corrosion than
wrought iron in its unprotected condition, but that zinc acts most efficaciously in protecting it.

Quite recently, another mode of protecting iron and steel plates from corrosion has been suggested by Professor Barff. This consists in exposing the metallic surfaces, while heated to redness, to the action of superheated steam, thus producing upon their surface the magnetic oxide of iron, which, unlike common rust, possesses the characteristic of permanency, and adheres closely to the metallic surface below. In this respect it is analogous to zinc oxide adhering to and protecting metallic zinc, with this further advantage in its favour, that the magnetic oxide is practically insoluble in sea water and other weak saline solutions. Time will show to what extent this ingenious method of protecting iron and steel can be made practically available.

Before concluding this address, I wish to call your attention to a matter which will require your early consideration. The Iron and Steel Institute has now attained an influential position, and is likely to increase from year to year in its beneficial action, upon the further development of a trade which may justly be claimed to be the most important in this country. In order to give additional weight to its action, it seems necessary that its position should be recognized in official quarters, and that it should be possessed of a habitation in a central locality, which should comprise office accommodation, a library, a model room, a lecture room, and laboratory. Such a building, if specially erected for the Iron and Steel Institute, would exceed the means at their disposal for such a purpose, but the moment has arrived when other institutions devoted to the cultivation of different branches of applied science feel the necessity for similar accommodation. Would it not be possible for our Institute to join efforts with those kindred institutions, for the erection of a joint building, representing applied science as completely as Burlington House represents pure science. Such a project could not be realised without the concurrence of the parent institution of applied science, "The Institution of Civil Engineers," whose building, though large, is by no means sufficient for its actual requirements. The new building might, therefore, accommodate the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Naval Architects, the Society of Telegraph
Engineers, the Iron and Steel Institute, and possibly other societies which hold their ordinary meetings on different days of the week, and some of them at considerable intervals of time; it would not, therefore, be necessary to provide more than one, or perhaps two, general meeting rooms, and one library, but each society would require separate office accommodation and council chambers, the whole being so arranged as to be able to be thrown open for the holding of conversazioni.

The common interests of the societies might be placed under the supervision of a joint House and Library Committee, presided over by the President of the Institution of Civil Engineers, and comprising amongst its members one or two members of councils and the secretaries of the different societies.

The Government would probably not be unwilling to further the realisation of an object of such great usefulness by granting a site in a central portion of the metropolis. Each society might be called upon to furnish a portion of the capital required, either out of its accumulated funds, or by voluntary contributions of its members, and the remainder could probably be raised upon debentures, and thus become chargeable upon the ordinary subscriptions of future years.

The details of such a scheme would, of course, require most careful consideration; but I believe that the present moment would be favourable for its realisation if you, as well as the other scientific bodies concerned, consider the matter worthy your attention.

The great variety and importance of subjects of interest to our Institution are my apology for having detained you longer than I intended to do in reading this address.
REMARKS ON

THE HOUSE OF APPLIED SCIENCE,

BY C. WILLIAM SIEMENS, D.C.L., F.R.S.

President of the Iron and Steel Institute.

The President *(Dr. Siemens)* said their discussion of the papers had been rather interrupted, as it had been thought important by some of the members of the Institute that the suggestion, which he threw out in his address, with regard to obtaining a building for themselves and for other societies devoted to applied science, should be advanced a step by asking the members of the Iron and Steel Institute to endorse it with their approval; and as the time drew near when they would have to adjourn, Mr. Samuelson had kindly taken the matter in hand, and proposed the resolution that was now before them. Mr. Brogden had alluded to an attempt which had been made some years ago to attain a similar object, suggesting that its having failed then would perhaps be against the probability of better success now; but if Mr. Brogden would permit him, he (the President), would point out one essential difference between the two schemes. It was then intended to invite a few other societies—without regard to the objects they had in view—to join the Institute in the erection of a building, and the most important society—the Institution of Civil Engineers—was, he believed, left entirely out of consideration; therefore, he (the President), did not wonder that that attempt failed. If they were going to have a building in which several societies should join, it was necessary that that building should represent something, and that something he would propose should be "Applied Science." He would object absolutely to the admission of societies into that circle that might be excellent in themselves, but which were devoted to objects foreign to applied science. They must have applied science represented, and represented by all the institutions that cultivated its main branches. At the head of their number stood the Institution of

* Excerpt Journal of the Iron and Steel Institute, 1877, pp. 102-103.
Civil Engineers, and he should hardly hope to succeed in erecting such a building as he, and many of them would like to see, without the active co-operation of that Institution. They would all gladly play second rôle to the parent institution of engineering, which had been long established under a charter, and represented the science of engineering of the country. The President having put the resolution, said he was glad to say it was carried unanimously, and he hoped that would be the first step towards the realization of a very important object. They would have to adjourn the discussion until the following day.

PUDDLING IRON IN GAS FURNACES.

TO THE EDITOR OF "THE ENGINEER."

SIR,—The merits of the regenerative gas furnace are now so generally admitted, that it took me somewhat by surprise to see in your journal of the 12th inst. a letter signed "Arthur Coyte," in which it is asserted that the application of these furnaces at the works of Messrs. Nettlefold and Chamberlain—meaning, no doubt, Messrs. Nettlefolds' Castle Iron Works—near Wellington, had been attended with disastrous loss.

Messrs. Nettlefolds erected their first gas furnace forge, consisting of ten puddling and two heating furnaces, in 1870, in accordance with my designs, and as they have not only expressed themselves highly satisfied with the performance of these furnaces, but have given proof of their confidence in them by erecting a second forge of the same capacity in 1873, and a third forge in 1876, I immediately wrote to those gentlemen, asking them to account, if possible, for the extraordinary statement volunteered by your correspondent. I enclose the reply I received to my inquiry, from which it is evident that Mr. Arthur Coyte has drawn for his statements upon his own imagination, being influenced perhaps by a desire to supersede existing regenerative gas furnaces by some inspiration of his own.
Mr. Coyte, in that case, may be looked upon as another of those pseudo-improvers of the regenerative gas furnace whose names have been brought a good deal under public notice latterly, and who, without exception, obtained their information from my office, either as draughtsmen formerly employed there, or as licensees. Some of them have used a modification of the arrangements described in my patents of 1857 and 1861, whilst it is curious to observe that the construction adopted by the others is identical with an early variety of the regenerative furnace, in which the heat was transferred from the outgoing to the incoming currents through the refractory walls of passages. This plan was tried by me in 1847, and again in connection with my brother, in 1856, but was abandoned in favour of the present more efficacious method, in which the same regenerator surfaces serve the double purpose of alternately absorbing and giving up heat.

I have no desire to interfere with the independent action of others, so long as they confine themselves to setting forth the merits of their particular arrangements without thinking it incumbent upon them to disparage what is more generally accepted as the Siemens furnace, and upon which I am quite content to stake my reputation.

I shall be obliged if you will give a place to this letter, and the inclosure from Messrs. Nettlefolds in your next publication.

C. William Siemens.

12, Queen Anne's Gate, S.W., May 23rd, 1877.

[Copy].

Birmingham, May 17th, 1877.

Dr. C. Wm. Siemens, F.R.S., London.

Dear Sir,—Your letter and telegram addressed to the works have been forwarded to us. In reply we beg to say that Mr. Arthur Coyte evidently knows nothing about our works. He begins by calling them Nettlefold and Chamberlain, whereas no Chamberlain has been connected with the works for nearly three years.
His statement about "losses to their owners and poor performances" exist only in his own mind; sufficient for us to say that we are now, and have always been, perfectly satisfied with your gas system. If it were not so, we should not have gone on increasing the plant. We have never applied against the income tax in respect of these works. It is a pity people do not make themselves better acquainted with their subject before they rush into print.

Yours truly,

(Signed) Nettlefolds.

THE REGENERATIVE GAS FURNACE.

To the Editor of "The Engineer."

Sir,—In your last impression I noticed a letter signed "H. L.," containing a few questions regarding the regenerative gas furnace, to which I have no objection to reply. Your correspondent wishes to know "what are the defects to prevent its universal application? what is the reason it was abandoned at the Elswick factories? and why it was put up at Woolwich, tried, discarded and taken down?" In answer to the first question, it may be said that the substitution of the regenerative gas furnace for the ordinary furnace in existing works is attended with considerable expense, and the working of the furnace requires an intelligent supervision which is not always bestowed upon it. The merits of the furnace are perhaps not sufficiently advertised; whereas persons interested to disparage it are less reticent. It is a significant fact, however—which any one interested can easily ascertain for himself—that in all the great works of this and other countries in which the regenerative gas furnace has once been established, it has rapidly and entirely superseded the ordinary furnace.

The slowness with which any important change is carried into practical effect is, perhaps, best illustrated in reference to the application of my furnace to the melting of steel in crucibles. The few works in this country which have taken advantage of the
improvement, have done so to the exclusion of the old pot holes; one ton of slack is thereby rendered amply sufficient to melt a ton of mild steel, or, in other words, to do the work of three tons of coke, for the production of which five tons of coal are required. Here we have a clear saving of 80 per cent. in the weight of the fuel employed, coupled with other advantages, such as increased durability, and a larger output, amounting probably in money value to not less than £2 per ton of steel produced; and yet the greater number of the Sheffield melting furnaces are still working on the old plan, whereas abroad, and especially in America, the improved furnace for this purpose is all but universally adopted. As regards your correspondent’s second question, I consider that it is not a fair one to ask, inasmuch as it implies a state of things the very opposite of what really exists. The Elswick Ordnance Company were among the first to adopt the regenerative gas furnace for heavy forgings, and having always been and still continuing satisfied with the advantages of the system, have gradually increased its application.

With reference to the third question, your correspondent was rightly informed that a gas furnace—supposed to be a regenerative gas furnace—was erected at the Woolwich Arsenal in 1867, tried, found wanting, and stopped; but it is apparently not so well known that I had nothing to do with the construction of that furnace. The Woolwich authorities of that day, acting upon the representations of a person previously in my employ, to the effect that he could design and erect for them a regenerative gas furnace of an improved construction, and that they, as a Government Department, were not bound to apply for a license under a patent, authorised the construction of a most expensive furnace. In this, among other “improvements,” the ventilation of the cinder bottom was virtually suppressed, and finding that this furnace would not work, although reheating furnaces for similar purposes were at that time successfully at work at the Elswick Gun Factory, the War Office requested me to inspect and report upon it. As I could, however, only advise them to pull down the furnace, and build de novo with the old material, no further steps were taken in the matter.

I cannot admit that the result of the application of the regenerative gas furnace has been on the whole unsatisfactory, inasmuch
as there are few important works where intense heat is employed (including glass works) in this and other countries in which that furnace is not largely, or even exclusively, used; and this result justifies me in the belief that smaller works will (notwithstanding interested disparagements) follow sooner or later in the same direction.

As regards a second letter signed "Arthur Coyte," in which a fresh batch of vague misrepresentations is put forward, I must decline to give any reply, the more so as his assertion with regard to yields is dealt with in your notice of the "Proceedings of the Institution of Mechanical Engineers," at page 379 of the same number in which his letter appears.

C. WILLIAM SIEMENS.

12, Queen Anne's Gate, London, June 6th, 1877.

REMARKS

Of Dr. C. W. Siemens, D.C.L., F.R.S.,

At the Newcastle Meeting of the Iron and Steel Institute.

The President (Dr. C. W. Siemens),* in responding to the Mayor, said he had great pleasure, on behalf of the Institute, in accepting the invitation given them to visit that great centre of industry. Their Institution, as Mr. Cowen had so eloquently remarked, cultivated one branch of science—that of the smelting of iron and steel. Formerly, the Royal Society of London was almost the only scientific body to cultivate and to advance science, but as the country progressed in its applications of science to marine architecture, to telegraphy, to mechanics, and to the smelting of metals, it became necessary that separate institutions should be called into existence to take up those branches, and to cultivate the same for the material advancement of the industries of the country. Now, there was no industry more important than

* Excerpt Journal of the Iron and Steel Institute, 1877, pp. 313-316.
that of iron and steel. At the present time it was said that the iron and steel trade was in a very low and depressed condition. This meant that with our present modes of production we could not command a sufficient market. Other nations had learned to smelt iron ores, and to compete with us in the open market. The products of the iron smelter, although ever increasing in demand, had to be cheapened continually in order to meet increasing requirements. While a few years ago we used steel only for the purpose of making cutlery, pins and needles, and magnets, now we used steel, or something of the character of steel, not only for constructing locomotive engines, but for the rails upon which the locomotive ran; therefore, they had to meet conditions utterly distinct from those that prevailed not many years ago, and, as a natural consequence, they had to improve and modify their processes in order to meet those conditions. He believed their institution had contributed very powerfully towards the accomplishment of those ends; and in meeting that day in that great and ancient centre of industry, they would be lifted up by the thought that the locomotive engine was born there, and that it was the town where Nicholas Wood and the Stephensons commenced their arduous labours. It was a town where the chemical manufacture was carried on with great advantage, and where new improvements (such as that introduced by Mr. Pattinson) were brought to light. It was the town of such living men as Armstrong and Bell, and others who were happily amongst them—men who would ever lead them on to new exertions. After the most eloquent address they had heard from Mr. Cowen, it would be quite unnecessary for him to say more, except to thank the town of Newcastle, as represented by its Mayor and Sheriff and Parliamentary members, as well as the members of the local committee, very heartily for the kind invitation which they had extended to the Institute. He could assure them that his fellow-members not only highly appreciated that invitation, but they would endeavour by the earnestness of their labours to do justice to their expectations.

The members then adjourned to the Lecture Hall of the Literary and Philosophical Society, the chair being taken by

The President, who said on the last occasion when he
addressed them in London he congratulated their Society upon possessing a Secretary who had worked for and with the Institute since its beginning. He little thought at that time that on this occasion he would have to express regret at his loss—a loss which was in many respects irreparable. An address would be presented, and certain suggestions would be made to show their sympathy and their appreciation of his past services. Meantime, as the world could not stand still, they had to turn their attention to the filling up of his place. That was no easy task. A committee of the Council was formed to make suggestions, and that committee, after very mature consideration, and after weighing carefully the merits of several of the candidates who had applied for the post—candidates who were very meritorious as regards their scientific and literary knowledge—arrived at the unanimous conclusion to suggest to the Council the nomination and the appointment of Mr. Jeans, as the successor of Mr. Jones. Other candidates had, perhaps, greater claims than Mr. Jeans as scientific men, and as men who had produced work of scientific importance; but the committee and the Council thought that in a Secretary a combination of qualities was required not often found in one person; and without going into the particulars of a case of such delicacy, he could only communicate the broad fact that they decided to recommend the appointment of Mr. Jeans, as a gentleman who was not a stranger to that Institution, who knew a great deal of its past working, and who, by his experience and knowledge seemed well fitted to—and no doubt would—fulfil the duties of the office with great satisfaction to the members. Before he called upon them to commence the discussion of the papers, he had been requested to correct an impression produced by the address he delivered last spring with regard to Lloyds' Registry for Shipping. He said in that address—and with justice, he thought—that Lloyds' Registry had refused to give to steel a position as a shipbuilding material superior to that of iron. They had since, however, sanctioned the construction of ships to be made of steel, and boilers for those ships, with an allowance of 25 per cent. in the scantling, and it was a firm in that town (Newcastle) that had first undertaken to construct shipping under those amended rules; and thus one of the difficulties which stood in the way of the application of that new material had been removed.
There was another question of a somewhat delicate nature upon which he had to touch. In the course of the discussions at their last meeting, Mr. Bessemer made a remark regarding a well-known engineering firm in France which (whatever the extent to which those remarks might or might not be called for) were not applicable to the objects of their Institution. That Institution had nothing whatever to do with legal matters, and he regretted that those remarks had found their way into the Transactions. He had hoped after the letter had been received from Messrs. Schneider and Co. that there would have been time to erase those remarks; but the volume was already progressing in type, and all they could do was to publish Mr. Schneider's letter in the same volume; but he wished there to give testimony to the liberal and honourable manner in which that firm had dealt with him, and in which they were known to deal generally in the transaction of their business. He thought it was due to them that he should make that statement in order to let the matter appear simply as an incidental thing, which they all rather regretted, without wishing to throw the slightest imputation upon the position of an honourable firm.

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THE ELECTRIC LIGHT.

TO THE EDITOR OF "ENGINEERING."

SIR,—In your very able article of this week upon "The Electric Light" there is only one matter, personal to myself, calling for an observation on my part. You say, "The most important discovery connected with this subject was made by Dr. C. W. Siemens and the late Sir Charles Wheatstone simultaneously, but independently of each other, and the discovery was brought before the Royal Society on the same evening."

It is true that upon that occasion I presented to the Royal Society a paper describing the action of a machine which I had constructed in this country, but the merit of the discovery of the principle upon which it acted is really due to my brother, Dr. Werner Siemens, who presented a memorial to the Berlin
Academy of Sciences on the same subject fully a month previous to the two communications referred to in your article.

This communication was not published at the time the Royal Society papers were presented, but suffices to give Dr. Werner Siemens a prior claim.

Yours faithfully,

C. WILLIAM SIEMENS.

12, QUEEN ANNE'S GATE, WESTMINSTER, Oct. 20, 1877.

TO THE EDITOR OF "ENGINEERING."

Sir,—Among the letters written to you in consequence of your article on "The Electric Light," contained in your issue of the 19th inst., is one by Mr. C. Varley, claiming to be the original discoverer of the dynamo-electric or reaction principle involved in the machines now employed for producing intense light. Mr. Varley refers your readers to a provisional specification which he filed on the 24th of December, 1866, and which will have been published in due course by the Patent Office in July, 1867.

It appears strange that when the first publication of the principle in question took place through the reading of my paper sent into the Royal Society on the 14th of February, 1867, and Professor Wheatstone's sent in on the 24th, Mr. Varley did not come forward to join in the discussion, which created considerable interest among scientific men at the time, nor did Mr. Varley ever file a complete specification of his patent. As a matter of fact, therefore, the first publication of the principle took place in the Proceedings of the Royal Society in February, 1867.

But as regards the dates of invention, I may add that my brother Werner tried his first experimental machine in December, 1866. I was present at Berlin during these early trials, which were in fact undertaken in consequence of a discussion between my brother and myself regarding the question whether the dynamical principle of the convertibility of natural forces was applicable generally.

It occurred to my brother that if this were the case an electric current must result in driving an electro-magnetic machine in the
contrary direction to the motion that would be imparted to it by the current, and in trying the experiment we were startled by the fact that a considerable current was the immediate result of imparting such motion.

Immediately after obtaining this result my brother invited Professors Dove, Magnus, Du Bois Reymond, and several other of the leading physicists of Berlin, to witness in our presence these striking results. This inspection took place before Christmas, 1866, and therefore previous to the date of Mr. Varley's provisional specification, and a little time naturally elapsed before my brother and myself prepared our respective papers for the Berlin Academy of Sciences and the Royal Society.

I have the highest regard for Mr. Varley's ingenuity, but think that in the present instance he has really been anticipated in the discovery of the principle which seems destined to be productive of important practical results.

I am, Sir, yours faithfully,

C. William Siemens.

12, Queen Anne's Gate, October 30, 1877.

To the Editor of "Engineering."

Sir,—The two letters appearing in your issues of the 2nd and 9th inst., both signed S. Alfred Varley, call for a few remarks on my part in reply.

It is of course impossible for me to say when the idea of the magneto-electro reaction principle may have occurred to Mr. S. Alfred Varley, and possibly to others before him, but I do not see in his observations any good reason to alter the view to which I have given expression in my letter to you of the 20th ult., in assigning the merit of having first publicly enunciated the principle in question to my brother, Dr. Werner Siemens.

I am sorry to have given offence to Mr. S. Alfred Varley in referring to his letter of the 22nd ult. as that of Mr. C. Varley, a mistake which arose from the circumstance that in the provisional specification referred to in that letter the name of Mr. C. Varley stands first. It seems somewhat surprising under these circum-
stances that Mr. S. Alfred Varley should be impatient to be considered the whole and sole originator of the principle in question.

But there is a circumstance connected with the provisional specification itself which would lead one to suppose that at the time of its being deposited in the Patent Office the Messrs. Varley could not have submitted it to actual trial. They say, "Before using the apparatus we generally send an electric current through the electro-magnets; the object of this is to secure a small amount of permanent magnetism in the direction we wish in the soft iron cores of the electro-magnets." A single trial of the apparatus would have convinced those gentlemen that no such excitement of the magnet is at all necessary for starting the apparatus in action, terrestrial magnetism or a magnetic tension in the iron set up in its manufacture being sufficient to engender the requisite action. I am, however, not disposed to contest Mr. S. Alfred Varley's assertion that the idea of the reaction principle occurred to him in the autumn of 1866, and can only express my surprise that he should have remained mute upon the subject until the 14th of December, 1867, when his final specification was filed, which patent I need hardly say was invalidated through the several prior publications which had at that time taken place.

Yours faithfully,

C. WILLIAM SIEMENS.

12, QUEEN ANNE'S GATE, WESTMINSTER, NOV. 14, 1877.

TO THE EDITOR OF "ENGINEERING."

SIR,—Mr. Robert Sabine, in writing to you on the 28th November, put the question of priority in conceiving the dynamo-electrical reaction principle very tersely, and having conceded the priority of publication to my brother, I should not have thought it necessary to trouble you with any further remarks upon this subject, if Mr. S. Alfred Varley had not lost sight of his avowed intention of allowing the question to drop, by sending the letter published in your last issue.

Mr. S. Alfred Varley again brings forward as a proof of his priority the bare fact of his having filed a provisional specification
(which I need hardly say is a strictly private document) on the 24th December, 1866, that is to say, some time after the principle in question had been communicated at Berlin to a number of scientific men. In order to improve his position, Mr. S. Alfred Varley, in his previous letter of the 5th November, 1877, shows that his machine had been constructed in September, 1866, or three months previous to his application for provisional protection; Mr. Sabine in his letter brings forward proof that a machine was constructed for the late Sir Charles Wheatstone somewhat previous to Mr. S. Alfred Varley's date; and I am in a position to state that the machine upon which the first experiments were tried at Berlin (a Wippe or automatic current reverser) had actually been constructed several years previous to 1867. The explanation of this fact is simple, and is contained in my letter to you of the 30th October last, viz., that the dynamo current is produced by simply turning an electro-magnetic engine what may be termed "the wrong way." The mere circumstance, therefore, that the apparatus used in these experiments had been constructed previous to 1867, proves simply nothing, except perhaps the futility of tracing the origin of a discovery from any other date than that of its first publication.

Mr. S. Alfred Varley endeavours to throw a doubt upon my brother's first publication of the accumulative principle by the fact that we applied for certain letters patent involving that principle sixteen days later, and concludes "that business men are not in the habit of invalidating their patent rights by publishing their invention before provisional protection has been obtained or at least applied for." Mr. S. Alfred Varley seems to have lost sight of the fact, that the enunciation of natural principles belongs to pure science, and does not form a legitimate subject for a patent, whereas applications of those principles to useful purposes, and combinations of parts to give effect to such useful applications, are what does form a proper subject for a patent. In searching further Mr. S. Alfred Varley will find not one but several such patents taken out by my firm since 1866, leading up step by step to the light-producing machine now adopted by the Elder Brethren of the Trinity House.

Yours faithfully,

C. WILLIAM SIEMENS.

12, Queen Anne's Gate, December 10, 1877.
ADDRESS

Of Dr. C. WILLIAM SIEMENS, F.R.S.,
President of the Society of Telegraph Engineers,
Delivered on the 23rd January, 1878.*

GENTLEMEN,—Six years have now elapsed since I had the honour of addressing you as first President of the Society of Telegraph Engineers. The hopes which I then expressed as to the probable development of the Society have been fully realised under the able guidance of my successors in office, combined with the active and ever-increasing support of our honorary secretary Colonel Bolton.

At the time I addressed you first the Society was composed of only 110 Members of every description. This number increased during my term of office to 353, whilst it has now reached up to nearly 1000 Members, a number quite sufficient I should say to insure a continuance of its prosperous career.

The six volumes of Transactions issued by the Society since its origin are proof of its activity as a scientific institution, whilst its status has been much advanced through the establishment of a scientific library, bequeathed to us in trust by the late Sir Francis Ronalds, containing a most valuable record of all publications having reference to the advancement of Telegraphy. In order to make this collection of permanent value it will be necessary to complete the record always up to date, a duty which I trust will be faithfully and well discharged by the officers of the Society.

In reviewing the progress made in Telegraph Engineering during the last few years, I propose to notice in the first instance the subject of Duplex and Quadruplex Telegraphy, which has recently much occupied the attention of the Telegraph Engineer. Duplex Telegraphy has been known and practised to a very limited extent since 1854 when it was first announced by C. A. Nyström of Örebro, Sweden, and by Dr. Gintl, of Vienna, and carried out practically by Frischen and Dr. Werner Siemens. Although

quite successful in some of the applications made at that time in
Germany, in Holland (between Amsterdam and Rotterdam), and
in this country under my own superintendence between Manchester
and Bowden, telegraphy itself had not advanced sufficiently to call
for an application of this invention upon a more extended scale,
and it has only met with favour on the part of telegraph adminis-
trations since its re-introduction to public notice by Mr. Stearn, of
Boston, in 1872, who improved however upon the original arrange-
ment by balancing the discharge from the line by the discharge
from an arrangement of condensers. Another important advance
in duplex telegraphy has been made by Mr. Louis Schwendler,
who by the application of an improved Wheatstone Bridge
arrangement has produced the means of readily adjusting the effect
of the neutralizing current during the working of the instrument,
and has carried duplex telegraphy into effect with great
advantage upon the long lines of India, with which he is
connected.

The quadruplex telegraph, which may be considered to have been
theoretically introduced by Dr. Stark, of Vienna, in 1855, and
contemporaneously by Dr. Boscha of Leyden, has been developed
by Mr. Edison of New Jersey, U.S., and has been for some time
established upon the line between New York and Boston, under the
superintendence of Mr. Prescott, the engineer of the Western
Union Line. In this system the principle of duplex telegraphy is
combined with the equally well-known system of producing different
effects by currents differing in strength, and it is, indeed, not diffi-
cult to conceive that by further combinations of the same nature
six or eight pairs of instruments may be worked simultaneously
and independently through one and the same conductor. The
success of these improved methods of transmission depends almost
entirely upon the perfect insulation and undisturbed condition of
the line-wire, a subject which has yet to receive much attention on
the part of the Telegraph Engineer.

Our attention is next arrested by the great novelty of the day, the
Telephone.

This remarkable instrument owes its origin to the labours of
several inventors.

In the year 1859 the late Sir Charles Wheatstone devised an
arrangement by which the sounds of a reed or tuning-fork, or
a combination of them, could be conveyed to a distance by means of an electric circuit, including at both stations a powerful electro-magnet. In striking any one of the tuning-forks differential currents were set up which caused the vibration of the corresponding tuning-fork at the distant station, and thus communicated the original sound. In 1862 Reiss enlarged upon this ingenious suggestion in attempting to convey the varying vibrations of a diaphragm agitated by atmospheric sound-waves. His apparatus consisted of a parchment diaphragm with a thin platinum wire attachment set into vibration by sound, which caused a series of contacts to be made, and the galvanic currents thus sent through an electric circuit produced sounds by the making and unmaking of an electro-magnet at the distant station.

This instrument transmitted currents only of equal intensity, and produced therefore sounds of equal calibre, distinguishable only by their periods. It was thus capable of transmitting simple tunes, but was quite incapable of transmitting the human voice with its innumerable modulations of sounds, varying both in period and intensity.

These defects in the instrument of Reiss have been remedied by Mr. Edison, who, by establishing contacts through the medium of powdered plumbago, has succeeded in transmitting galvanic currents varying in intensity with the amount of vibration of the diaphragm.

As another step towards the accomplishment of the perfect transmission of sound, I should mention also the logograph, or recorder of the human voice, which Mr. William Henry Barlow, F.R.S., a member of our Society, communicated in a paper to the Royal Society, on the 23rd February, 1874.

In adding a contact arrangement to the recording pencil of Mr. Barlow's instrument, the message could obviously be transmitted to a distance to be recorded there either by graphical or audible signals.

The beautifully simple instrument of Professor Graham Bell, of Cambridge, U.S., must be regarded as a vast step in advance of all previous attempts in the same direction. In making the diaphragm of iron, and having recourse to Faraday's great discovery of magneto-induction, Mr. Bell has been able to dispense with the complication of electrical contacts and batteries, and to cause the
vibrations of the diaphragm imparted by the voice to be accurately represented in strength and duration by electrical currents, thus producing the marvellous results of setting up analogous vibrations in the diaphragm of the receiving instrument, which, though weaker than the vibrations imparted to the transmitting diaphragm, so closely resemble them as to repeat the quality of voice which causes the original vibrations.

The currents transmitted are so minute as to escape observation by the most delicate galvanometer, as the magnetic needle, however light, must be too sluggish to be moved visibly by such quick impulses, and it requires an electro-dynamometer of exceeding sensitiveness to bring them into evidence. The rapidity with which these reversing currents follow each other can be accurately determined in transmitting the sound of a high-pitched tuning-fork, and Mr. Köntgen concludes from experiments he has made in this direction that not less than 24,000 currents can be transmitted in one second. We here detect a rapidity of electrical transmission far exceeding our most sanguine expectations in endeavouring to increase the rate of transmission of telegraph instruments by mechanical means, thus opening out a new field for the inventive faculties of the Telegraph Engineer.

The telephone is no doubt capable of great improvement, which should chiefly be directed towards increasing the relative amount of vibration of the receiving diaphragm.

Improvements will doubtless be directed also towards the accomplishment of simple methods of recording the audible messages received, which has already been attempted by Mr. Edison, and of carrying out such accessory objects as the ringing of call-bells and the transmission of the sound-waves through additional circuits.

Considering the minuteness of the electrical impulses and their high electro-motive force, it seems probable that they will be capable of being transmitted to very great distances through conductors of comparatively small dimensions, provided only that those conductors are not subjected to the disturbing influence by induction of currents flowing through adjoining wires. It is well known that owing to these disturbing currents the telephone cannot be worked through a wire suspended with other wires upon posts in the ordinary way, and it will be necessary to devise other means of carrying the telephone conductor.
The system of suspended line-wire now generally in use is open to many grave objections. Atmospheric electricity frequently causes such disturbances as to interrupt the working of long lines for hours at a time, and the most perfect lightning dischargers do not always prevent damage to the working instruments, when atmospheric discharges of electricity into the line-wire take place. Again, the mutual induction between parallel line-wires and the leakage from one wire to another through the supporting poles are a permanent source of trouble in working telegraph instruments, and this difficulty increases as we advance from the simple needle or recording instrument to the more refined duplex or quadruplex system, to the mechanical transmitter or the telephone.

Again, it happens that not unfrequently suspended line-wires are thrown down, causing the almost entire cessation of telegraphic communication for days in the event of a great gale or snowstorm, interruptions which are quite incompatible with the idea that the electric telegraph has become a great public institution.

The remedy for these interruptions is undoubtedly the underground line-wire system. This was first tried in Germany upon an extended scale in 1848—49, but was given up in favour of the suspended line in consequence of the want of experience in manufacture and imperfect protection afforded to the gutta-percha covered copper wire. Since then it has been largely used in this country for underground communication in cities, also for aërial lines, by suspending a bunch of the insulated conductors by steel wires in the air, as we see them supported on the house-tops of this metropolis. The German Telegraph Administration, under the able direction of Dr. Stephan, has within the last year or two again resorted to the application of the underground conductor for long lines. A representative cable of what it was intended to lay was put down in 1876 between Berlin and Halle, a distance of 120 English statute miles. The success of this line induced his Government to lay down last year multiple cables between Berlin and Cologne, and Berlin, Hamburg, and Kiel, an aggregate distance of 600 miles, and further extensions are in course of execution. These cables consist of seven separate conductors, each insulated with gutta-percha, surrounded with a complete iron sheathing and a double outer covering consisting of hemp steeped
in asphalt, producing altogether a flexible cable of 1½ inch outer diameter, which is laid along railways or roads at a depth of about 3 feet below the ground.

Great precautions have been adopted to prevent failure of these newly established lines, whilst the ease with which these comparatively long circuits can be worked by means of every description of instrument, including the telephone, and their perfect immunity from atmospheric disturbances, will lead, I venture to predict, to the gradual substitution of underground wires for suspended lines for all the main arteries of the telegraphic system.

In submarine telegraphy no startling feat of novelty can be reported, although steady progress has recently been made in improving the manufacture of the insulated conductor, in the attainment of an increased rate of transmission through long distances, in the outer protection given to the insulated conductor, and in the vessels and other appliances employed for submerging and repairing deep-sea cables.

The conductor almost universally adopted in the construction of submarine cables has been a strand of seven copper wires, covered with three thicknesses of gutta-percha, with intervening layers of a fusible resinous compound. In the case of the Direct United States Telegraph Company’s cable, the conductor consists of one large central wire of 0·090 in. diameter, surrounded by eleven small copper wires of 0·035 in. diameter. By this construction an increase of about 10 per cent. of conductivity is obtained for a given outer diameter, which increase has been found to exercise an important effect upon the rate of transmission through the cable.

The careful selection of the insulating material employed has also an important influence upon the rate of transmission through long cables, as it is found that different kinds of gutta-percha behave very differently in this respect. India-rubber has, it is well known, considerably less inductive capacity than gutta-percha, and appears on this account the preferable material, but its application to the conductor, without the risk of faults and of gradual changes in the condition of the material, is beset with considerable practical difficulty which has as yet limited its application. Compounds of india-rubber and gutta-percha, with other materials such as shellac, paraffin, and bitumen, have been proposed from time to time with promising results, but it has been impossible
hitherto to give to such compounds all the properties necessary in the dielectric substance covering the conductor, viz., a low inductive capacity and high insulation, coupled with considerable toughness and permanency at all ordinary temperatures and the requisite plasticity at higher temperatures.

The supply of gutta-percha has hitherto been sufficient for the demand, but a large extension in the use of insulated conductors both by sea and land will, it may be apprehended, outrun the supply, and it is well on this account that we should steadily fix our attention upon such compounds as are likely to furnish a suitable substitute. Regarding a continued supply of gutta-percha and india-rubber, it is satisfactory to observe that the Indian Government have turned their attention seriously to the question of making plantations of trees bearing these gums, chiefly in the Malay Peninsula, under the able direction of Sir Joseph Hooker, and of Dr. Brandes, the Director of the Forest Department in India. It is to be hoped that by these wise measures a continued supply of these invaluable materials will be secured, while their quality for insulating purposes will probably be improved by means of cultivation.

The outer covering now generally applied to shallow sea cables consists of a sheathing of iron wire covered with a double layer of hemp steeped in asphalte, and applied to the cable in a heated condition, and this, if properly carried out, affords very efficient protection for the iron sheathing against corrosion.

In the construction of deep-sea cables, steel wires are generally used, each wire being covered in the first instance with jute with a view to reduce the weight of the cable. This construction affords the advantage of lightness combined with strength, and thus facilitates the operation of submerging the cable, but is objectionable, inasmuch as it affords no complete metallic sheath against the inroads of the teredo and xylophaga to the core, and, in the case of a cable having to be raised from considerable depths, it is apt to untwist, and run itself into kinks at the bottom.

The use of a light cable for deep seas has been ably advocated by some electricians, and its adoption has the one great argument in its favour, that its first cost is much below that of a strong cable; on the other hand the risk incurred in successfully submerging such a cable is much greater, and in the case of a fault
appearing in deep water it will be hopeless to bring the light cable to the surface for the purpose of repair. It is possible that the manufacture of cables will be made a matter of such absolute certainty that the case of faults making their appearance in submerged cables may be left entirely out of consideration, but in the meantime telegraph companies have given the preference, and wisely so, I think, to a cable which, though more costly than its light competitor, affords a greater security to their property in case of an accident or a fault.

Whilst the art of submerging deep-sea cables, involving, as it does, problems of very considerable scientific and practical interest, has latterly received the attention of this Society, but little discussion has as yet taken place of the best means for effecting the repair of cables after submersion.

The important primary condition towards effecting the repair of a submerged cable is that its general insulation should be perfect, without which it would be impossible to determine the position of a break or fault with any degree of accuracy. Another important condition is the possession of a cable-ship furnished with special facilities for manoeuvring. The old practice of using ordinary steamships of the mercantile marine appears very primitive and objectionable, as such vessels are ill-adapted for going astern, are not steady when laden with cable and armed with heavy deck machinery, and are incapable of turning or maintaining their position against a side-wind unless going nearly full speed, whereas the cable ship should be capable of effecting these operations independently of any onward motion. The paying-out and hauling-in machinery, the tackle for fixing and lighting buoys, the arrangements for sounding, and the construction of grapnels capable of finding, cutting, and holding the end of deep-sea cables, are also matters influencing greatly these delicate operations, upon which the permanent success of submarine telegraphy must mainly depend.

The transmission of telegraphic messages through long submarine cables is a subject which was at one time involved in great practical difficulty owing to the retardation by lateral induction experienced by the electrical current in its transit. It is to our past President, Sir William Thomson, that we are indebted for a solution of this difficulty, through the application of his celebrated mirror instru-
ment, which is capable of revealing to the eye extremely slight remnants of electric waves, readily transferred by means of a human relay to ordinary recording instruments, and for the further introduction of his syphon recording instrument by which those slight currents are rendered in a written code. This latter instrument, however, is of a somewhat delicate and complicated nature, and it would be desirable if its place could be taken by a relay of extreme sensitiveness, coupled with ordinary recording instruments worked by local circuits, the accomplishment of which result we may anticipate before long, considering the great improvements that have been effected in the construction of polarized relays.

Although this country has from the first taken a prominent part in the invention and development of the electric telegraph, and is still the seat of oceanic telegraphic enterprise, almost to the exclusion of other countries, it has lately been asserted that other countries, and especially the United States, are now taking the lead in telegraphic improvement, and it behoves us to inquire whether such an allegation is founded on fact, and if so whether it is attributable to indolence on our part or to circumstances beyond our control. Steady progress has, as I have shown, been made by us up to the present day in the instruments and other appliances used in telegraphy, but it cannot be denied that the more startling innovations of recent days have chiefly emanated from the United States, the only civilized country in which, as it happens, internal telegraph communication is still in the hands of private companies. Is it, it may be asked, this open competition which has stimulated the American inventor to bring forth duplex and quadruplex telegraphy, the telephone, and other innovations? I incline to the belief that the open competition for public favour does act as a powerful stimulant to invention in the United States, a stimulant which was equally active in this country in producing a variety of novel instruments, at the time prior to the purchase of the telegraphs by the Government.

In frankly giving expression to this opinion, I do not mean to call in question the wisdom of the policy which dictated the purchase on public grounds of the telegraphs by Government. Through it we have obtained a uniform and moderate tariff, an extension of the telegraph system to minor stations (although the number of stations opened in this country does not yet exceed that
provided in the United States, being in the one case a station for every 5,607, and in the other for every 5,494 inhabitants*), and a better guarantee for the secrecy of messages. The growing connection between the telegraph systems of this and other countries would have compelled by degrees the active intervention of the Government, which alone could arrange effectively with the telegraph administrations of other countries general questions of tariff and modes of working. The triennial meeting of the Telegraph Conference will, as you are aware, take place this year in London, and will enable us to judge more fully of the beneficial results of co-operation between the telegraphic systems of the world.

The conference does not interfere, however, with matters of technical import, such as the construction of lines and improvement of instruments for working the same, in which we are chiefly interested, and it is a question worthy of consideration whether the Acts of Parliament of 1868—69, by which the Government Department of Telegraphs was created in this country, do not go beyond the limits necessary to insure a well-regulated public service in taking the construction as well as the working of the lines out of the hands of public enterprise. They give for instance to the Department the faculty of purchasing letters patent, whereby an interest is created in favour of particular instruments, to the prejudice of others of perhaps equal merit, and such a course is by no means calculated to stimulate invention.

The erection of lines for local and private purposes is an important branch of telegraphy which I submit should have remained entirely outside the scope of a public department, in order that competition might have a free opportunity of developing such applications, as is the case in the United States, where private and circular telegraphy is undoubtedly in advance of other countries.

In venturing upon these observations, I wish it to be clearly understood that I do not mean to insinuate that the engineers and other officers of the telegraph administration have not been most anxious to secure the greatest amount of public benefit, or that they have been remiss in their endeavours to improve the condition

* See Statistical Tables in the "Iron Age," for 14 June, 1877.
of the line-wire and working instruments upon which the public service depends.

Great improvements have indeed been recently made by the Postal Telegraph Department in the rate of working of Wheatstone's automatic circuits, and in the employment of fast-speed translators or repeaters, as is proved by the following data, for which I am indebted to our Vice-President, Mr. W. H. Preece. For instance, it has been found that the insertion of one of the new fast-speed translators in Dublin has more than doubled the rate of working between London and Cork, and the insertion of one of these relays in Anglesea has improved the rate of working between London and Dublin about 50 per cent.

As an indication of the rate at which messages can be transmitted, it appears that the Queen's Speech, containing 801 words, was sent to Leicester in 4m. 28secs., being at the rate of 179 words per minute. The quickest rate at which it was sent by key was between London and Reading, where it occupied seventeen minutes, or at the very high speed of 47.1 words per minute.

It is perhaps interesting to remark that on the first night of the Session over 420,000 words were actually transmitted from the central station, and over 1,000,000 words were delivered in different parts of the country.

The quadruplex system of telegraphy continues to be worked with very satisfactory results between London and Liverpool, and it has quite quadrupled the power of the one wire to carry messages. The highest number of messages transmitted in one hour has been 232; about 200 per hour have frequently been sent.

The system of duplexing Wheatstone automatic circuits is gradually extending, and on the Leicester wire which carried the Queen's Speech at the rate named messages were being transmitted in the opposite direction by the duplex arrangement at the same time.

In submarine telegraphy ample scope still exists, as I have endeavoured to show, for the ingenuity and enterprise of the telegraph engineer; but here again the free exercise of these faculties is threatened, not by legislative action, but by a powerful financial combination. It is intended by this combination to merge the interests of all oceanic and international lines and the construction of new lines into one interest; but it seems hardly
probable that such a monopoly will be able to maintain itself in the long run against that irrepressible spirit of British enterprise, which, though languishing at the present time of unparallelled depression, is likely to reassert itself before long.

Electricity has hitherto rendered service as the swift agency by which our thoughts are flashed to great distances, but it is gradually asserting its right also as a means of accomplishing results where the exertion of quantitative effects are required. Much has been said about the application of electricity for producing light, and the French Company Alliance, as well as the Gramme Company, have it is known for some years been establishing magneto-electric apparatus to illuminate the lighthouses upon the French coast, and for galvano-plastic purposes.

By an ingenious combination of two magneto-electric machines, with Siemens armatures, Mr. Wilde, of Manchester, succeeded in greatly augmenting the effects produced by purely mechanical means, but the greatest impulse in this direction was given in 1866-67 by the introduction of the dynamo-electrical principle, which enables us to accumulate the current active in the electric circuit to the utmost extent permissible by the conductive capacity of the wire employed. Dr. Tyndall and Mr. Douglass, chief engineer to the Trinity Board, in reporting lately to the Elder Brethren upon the power of these machines and their applicability to lighthouses, give a table showing that a machine weighing not more than 3 cwt. is capable of producing a light equal to 1,250-candle power per horse-power expenditure of mechanical energy. Assuming that each horse-power is maintained with an expenditure of 3 lbs. of coal per hour (which is an excessive estimate) it would appear that one pound of coal suffices to maintain a light equal to 417 normal candles for one hour. The same amount of light would be produced by 139 cubic feet of gas of 18-candle power, for the production of which 30 pounds of coals are consumed. Assuming that of this quantity, after heating the retorts, &c., 50 per cent. is returned in the form of gas-coke, there remains a net expenditure of 15 pounds of coal in the case of gas-lighting to produce the effect of one pound of fuel expended in electric lighting, or a ratio of 15 to 1 in favour of the latter. Add to the advantages of cheapness in maintenance, and of a reduced capital expenditure in favour of the electric light, those of its great superiority in quality
and its freedom from the deleterious effects of gas in heating and polluting the atmosphere in which it burns, and it seems not improbable that it will supersede before long its competitor in many of its applications. For lighthouses, for military purposes, and for the illumination of large works and public buildings the electric light has already made steady progress, while for domestic applications the electric candle proposed by Jabloschkoff, or modifications of the same, are likely to solve the difficulty of moderating and distributing the intense light produced by the ordinary electric lamp. The complete realization of all the advantages of the electric light remains, however, a problem to be solved, and it would be extravagant to expect from applications on a small scale such as have hitherto been made anything like the amount of relative advantage indicated by theory.

The dynamo-electric machine has also been applied with considerable success to metallurgical processes, such as the precipitation of copper in what is termed the wet process of smelting. The effect of one horse-power expended in driving a dynamo-electric machine of suitable construction is to precipitate 1120 pounds of copper per 24 hours, equivalent to an expenditure of 72 pounds of coal, taking a consumption of 3 lbs. of coal per horse-power per hour.

Electrolytic action for the separation of metals need not be confined however to aqueous solutions, but will take perhaps an equally important development for the separation while in a state of fusion of the lighter metals, such as aluminium, calcium, and of some of the rarer metals, such as potassium, sodium, &c., from their compounds. Enough has been shown by Professor Himly, of Kiel, and others, to prove what can be done in this direction, although there remain practical difficulties (chiefly the rapid destruction of the vessels containing the fused masses), the removal of which will require patient perseverance, but is not likely to prove of an insuperable character.

In an inaugural address which I had occasion to deliver to the Iron and Steel Institute a twelvemonth ago I called attention to another application of the dynamo-electric current, that of conveying mechanical power, especially the power of such natural sources as waterfalls, to distant places, where such power may find useful application.
Experiments have since been made with a view to ascertain the percentage of power that may thus be utilized at a distance, and the results of these experiments are decidedly favourable for such an application of the electrical conductor. A small machine, weighing 3 cwt. and entirely self-contained, was found to exert 2.3 horse-power as measured by a Prony's brake, with an expenditure of five horse-power at the other end of the electric conductor, thus proving that above 40 per cent. of the power expended at the distant place may be recovered; the 60 per cent. lost in transmission includes the friction of both the dynamo-electric and electro-motive engines, the resistance of the conductor, and the loss of power sustained in effecting the double conversion. This amount of loss seems considerable, and would be still greater if the conductor through which the power were transmitted were of great length and relatively greater resistance; but on the other hand it must be remembered that the power of a natural motor is obtained without expenditure of coal, and that a small caloric motor which the electric motor is intended to supplant is inconvenient and very extravagant in fuel. The electric motor presents moreover this great advantage, that it requires hardly any installation, and would be available at any time by merely closing the electric circuit without incurring the risk and inconvenience inseparable from steam and gas engines.

Without considering at present the utilization of natural forces, let us take the case of simply distributing the power of a steam-engine of say 100 horse-power to twenty stations, within a circle of a mile diameter, for the production of both light and power. The power of 100 horses can be produced with an expenditure of 250 pounds of coal per hour, if the engine is constructed upon economical principles, or of \( \frac{250}{20} = 12.5 \) lbs. per station. In the case of the current being utilized for the production of light 2.3 \( \times 1200 = 2760 \), or say 2,000 candle-power, are producible at the station, whereas if power is desired 2.3 horse-power may be obtained, in both cases with the expenditure of 12.5 pounds of coal, representing a penny an hour for cost of fuel, taken at fifteen shillings a ton. The size of the conductor necessary to convey the effect produced at each station need not exceed half an inch in external diameter, and its cost of establishment and main-
tenance would be small as compared with that of gas or water pipes for the conveyance of the same amount of power.

Electricity, which in the days of Franklin, Galvani, Volta, and Le Sage, was regarded as an ingenious plaything for speculative minds, and did not advance materially from that position in the time of Oersted and Ampère, of Gauss and Weber, and not indeed until the noon-day of our immortal Faraday, has, in our own times, grown to be the swift messenger by which our thoughts can be flashed either overland or through the depths of the sea to distances, circumscribed only by terrestrial limits. It is known to be capable of transmitting, not only language expressed in conventional cypher, but facsimile copies of our drawings and handwriting, and at the present day even the sounds of our voices, and of resuscitating the same from mechanical records long after the speaker has passed away. In the arts it plays already an important part through the creation by Jacobi of the galvano-plastic process, and in further extension of the same principle it is rapidly becoming an important agent in the carrying out of metallurgical processes upon a large scale. It has now appeared as the formidable rival of gas and oil for the production of light, and, unlike those inferior agents, it asserts its higher nature in rivalling solar light for the production of photographic images; and finally it enters the ranks as a rival of the steam-engine for the transmission and utilisation of mechanical power.

Who could doubt under these circumstances that there remains an ample field for the exercise of the ingenuity and enterprise of the members of that Society I have just had the honour of addressing?
ON THE UTILISATION OF HEAT AND OTHER NATURAL FORCES.

A Lecture delivered in the City Hall, Glasgow, on Thursday, 14th March, 1878, under the auspices of the Glasgow Science Lectures Association,

BY C. WILLIAM SIEMENS, D.C.L., F.R.S., C.E.*

The supremacy which man enjoys over the animate and inanimate creation, and for which Divine Authority may be quoted, cannot be said to be the result of his superior muscular development, for amongst the members of the animal kingdom there are many which are his superiors in strength, agility, swiftness, and in natural aptitude to provide themselves against the vicissitudes of cold and hunger. Who has not looked with a feeling akin to envy upon the deer in watching its swift progress to the mountain top, or on the eagle soaring majestically aloft, while feeling his own insufficiency of power to play lightly with the force of gravity.

The compensating advantage in our favour is the intelligence with which we are enabled to call forces of nature not our own into requisition to do our behests. Man in his most primitive condition already commences to exercise his mastery over nature, by having recourse to the sling and the arrow for reaching his prey, by taking advantage of animal power to draw the plough, and when in exchanging his commodities for those of neighbouring people, both his merchandise and himself are carried by beasts of burthen, who tamely submit their superior muscular energy to his will.

At another stage we find man utilising the inanimate forces of nature by causing the falling stream to give motion to the millstone, or by calling into requisition the force of the wind for propelling him along the surface of the waters; and following his progress step by step, we finally arrive at our own condition of social existence, in which we are dependent upon the power of

steam for propelling us both by land and sea at a speed rivalling that of our friends the deer and the eagle, and for accomplishing for us the innumerable purposes of grinding, spinning, pumping, and lifting, upon which our material well-being now depends. It would not be too much to say that the power of man consists really in his ability to direct the forces of nature, and that the degree of civilisation to which he has attained is commensurate with his command of those forces. It is therefore no idle question on which I intend to address you this evening, and I feel much oppressed with the weight of matter which I have to bring before you, although I shall not attempt to deal with more than a few points, to which I hope to be able to attract your interest.

In order to understand the forces of nature, and to direct their application, it is necessary that we should at least have a general conception of their origin. The time was not long ago when the forces in nature appeared to us as spasmodic and unconnected, when the energy of the wind and of the falling stream, the energy displayed in vegetation and in muscular action, the force of heat and the almost unknown force of electricity appeared to have no connection with one another, and seemed to be beyond the reach of human calculation.

The probability of connecting-links between the different forces of nature has, however, presented itself to some of the greatest minds of different ages; thus, Aristotle, "considered the first principle in nature to be a unity of all its manifestations, and the manifestations themselves he reduced always to motion as their foundation." Again, in Lord Bacon's "Aphorisms," the chapter on "The First Vintages of the Force of Heat" contains the following remarkable passage:—"From the instances taken collectively, as well as singly, the nature whose limit is heat appears to be motion." And further on, "But that the very essence of heat, or the substantial self of heat, is motion, and nothing else limited," &c. Bacon fails, however, in his attempts to prove his philosophy, by confounding the visible motion of heating water, or of fire, with the intrinsic motion of the particles that manifests itself as heat.

Count Rumford, in 1798, made the first important advance to connect heat with mechanical force, supporting his theory by means of experiments which were intended to determine the actual
numerical relation between them, and we observe with surprise how near his experimental results approached to the now-accepted determination of the mechanical equivalent of heat.

Sir Humphrey Davy caused the fusion of two pieces of ice by friction, and thus virtually proved the identity of heat and motion, though he failed to give expression to that view.

Carnot, in 1824, sought to determine how heat produced mechanical work; and although, in one respect, he appears to have receded from the views already advanced by others before him, in speaking of heat as a subtle fluid, he makes the remarkable statement that the greatest possible work an engine can perform is a function of the temperatures between which it works, and not of the nature of the substance employed. He also was the first to draw attention to the important fact that in working a caloric engine some heat must necessarily descend from a higher to a lower point of temperature, whereas another portion disappears in the operation.

The next and most important step in the advancement of this branch of science we owe to the independent investigation of three discoverers—viz., Grove of London, Mayer of Heilbronn, and Joule of Manchester—three men whose modes of thought differed very widely from each other, but who each of them pronounced distinctly the complete identity of all physical forces, proving their mutual convertibility coupled with complete indestructibility. To Dr. Joule we owe, moreover, the determination of the numerical equivalent in units of heat by which mechanical effect is measured.

But although the mechanical equivalents of heat, as well as those of electricity and chemical affinity, were thus absolutely established, much remained to be accomplished to assign to the new theory its actual signification. This was done independently and by different methods by Professor Clausius in Germany, and by your own illustrious townsmen, Rankine and Sir William Thomson, in this country. The two former, starting from different hypotheses, determined the general equation of thermodynamics which expresses the relation between heat and mechanical energy under all circumstances; while the latter, in building upon the basis of Carnot and Joule, solved some important new problems in thermodynamics, and extended analogous principles to electricity
and magnetism, thereby creating what may justly be termed a new science. Other names, including those of Seguin, Helmholtz, and Tait, should not be passed over without mention.

The popular volume entitled "Heat a Mode of Motion," which was produced in 1863 by Professor Tyndall, also did valuable service by introducing to the larger scientific public a knowledge of this most important new branch of science, and by terminating for ever the view which had generally prevailed up to that time, according to which heat and electricity were regarded as subtle fluids or imponderable substances. According to present views, all the agencies in nature may be defined as energy, varying only in their outward manifestations, as heat or as electricity, as chemical affinity or as mechanical effect, and presenting themselves as sensible or kinetic energy, or as dormant or potential energy.

Thus, when I lift a pound weight one foot high, muscular kinetic energy is exercised, causing a certain consumption of the potential energy resident in the muscle of the arm; in suspending it, the force thus exerted becomes so much stored up, or potential energy, which may at any time be called into requisition for the accomplishment of various purposes. Thus, if attached to a string passing over a pulley, it may be made to impart motion to a train of wheels for driving a clock, or to accomplish any other kind of mechanical work. Again, if allowed to drop from its elevated position upon a plate of glass, it may produce the mechanical effect of breaking the sheet of glass into fragments, causing at the same time considerable sound, whilst, if allowed to fall upon a sheet of lead, it will cause an indentation without producing appreciable sound; but if in this instance we could have measured the temperature of the lead before it was struck, and again immediately after, we should be able to detect a certain increase of heat, the amount of which is absolutely determined by Joule's equivalent; thus, if the piece of lead were one pound in weight and were equally heated throughout, by the shock of the falling weight of 1 lb. through 1 foot, 772 repetitions of the same would produce heat sufficient to raise its temperature 34°13 Fahr., which would again be equivalent to the heating of one pound of water 1° Fahr., or to the unit of heat. Or our potential force of one foot-pound could be utilised to produce magnetism and an
electric current by means of a machine (the dynamo-electric machine) which I shall have occasion to describe to you presently, which electric current may in its turn be utilised to produce light such as at present illuminates this hall. By means of the same dynamo-electric apparatus our unit of force could be utilised to cause the separation of chemical compounds, accomplishing, for instance, the deposit of copper of definite amount from its solution.

It may be said generally that without energy both in its kinetic and potential forms it would be impossible to imagine the very existence of life, of vegetation, and indeed of material creation. It is by molecular or potential energy that the particles of all matter, whether solid, liquid, or gaseous, are maintained in their relative position; it is by an augmentation of this form of energy that ice is changed into water, and by a further augmentation that water is changed into steam or vapour, giving rise through its withdrawal to rainfall, with all its attendant benefits, to vegetation; whilst it is by the potential energy residing in coal that we derive warmth, cook our food, and work our factories.

Whence, it may be asked, is all this energy derived? Is it that our earth constitutes herself a mine of potential energy, which we have only to tap and utilise for our purposes? A little examination into this question will convince us that we have no such store to fall back upon, and that, excepting the coal, there is nothing within our earth to yield us a supply of energy. The water of the ocean is the result of the combustion of hydrogen which may have taken place at some early period of the earth's history, when it must have given rise to an enormous generation of heat; enough, perhaps, to constitute our planet a luminary body; but this combustion having been once accomplished, this energy is irrecoverably lost to us, excepting the small remnant which prevents the water from assuming the solid form, and which is unavailable for our purposes.

If we examine the solid constituents of the earth, such as the siliceous or calcareous rocks, we shall find that they also are the result of former combustion; in the case of the mountain limestone we find that, on heating it, it separates into two substances, —calcic oxide, a solid, and carbonic acid, a gaseous body. In examining each of these constituents we find that they also are
the results of combustion, the one of the metal calcium, and the
other of the metalloid carbon; a combustion which must also
have been accomplished at an early period of the earth's history.
Other rocks we find to be the product of combustion of aluminium,
magnesium, silicon, and other chemical elements; and only com-
paratively rare substances, such as gold, platinum, and copper,
besides native sulphur and pyrites, may still be looked upon as
stores of potential energy. Excepting these, and the important
deposits of coal, the earth may indeed be likened to a ball of
cinder, whose energy has long been spent and dissipated into
space, and which is dependent for its supply of energy upon
external sources. Without such external supply, the water upon
its surface would be turned into solid ice, its animal and vegetable
kingdom must soon come to an end, rain must cease to fall, and
the very winds must cease to blow. It is not now difficult to
conceive whence the all-vivifying energy to which we owe our
existence is derived; it is from our great luminary—the Sun.

It has been justly remarked that poetic vision sometimes goes
beyond the conception of the sober mind, and there never, per-
haps, lived a poet who was more remarkable for such distant vision
than Goethe, who, in his famous tragedy of "Faust," has accumu-
lated an almost inexhaustible store for thoughtful meditation.
Faust, in his eagerness for knowledge, conjures up into his presence
a spirit, which reveals itself to him as the Spirit of the Earth in
the following remarkable words, according to the translation of
Mr. Theodore Martin:

"In the currents of life, in action's storm,
I wander and I wave;
Everywhere I be!
Birth and the grave,
An infinite sea;
A web ever growing,
A life ever glowing.
Thus at Time's whizzing loom I spin,
And weave the living vesture that God is mantled in."

Surely Goethe was free from vulgar superstition, and must have
conceived that his Spirit of the Earth represented an entity
capable of precise definition, whenever science had sufficiently
advanced to render such a definition possible. Such an advance
has since been made, and Goethe's Spirit of the Earth presents
itself to us as the all-animating, all-vivifying solar ray, by which our earth is clad, and to which we owe our material existence.

The coal itself, which yields us so important a supply of energy, is no exception to this rule, being only the result of vegetation in former ages, when the ray of the sun separated carbon from carbonic acid of the atmosphere in the leaves of plants in the same manner in which it does to-day, and thus made for us a store of accumulated carbon, or, metaphorically speaking, of accumulated sunbeams which may be called large, but which, in view of our ever-increasing requirements, must become exhausted, not indeed in our lifetime, but in the lifetime of those who follow us in comparatively few generations to come.

According to the Report of the Coal Commissioners, published in 1871, there were then nearly 150,000,000,000 of tons of coal available in Great Britain. The present rate of consumption is about 132,000,000 of tons annually, and statistics show that there is a mean annual increase in the output of $3\frac{1}{2}$ millions of tons, and a calculation at this rate of increase would give 250 years as the life of our coal-fields. It must be borne in mind, however, that long before the last ton of coal is brought to the surface, the effect of its gradual failure will have made itself painfully manifest. Districts whose industry is most active and populations largest, will first experience the change, and it behoves us to consider in good time what resources, if any, we shall have to fall back upon.

I have shown that the universal source of energy is the sun, but there is one important exception, namely, the force of the tidal wave. This is of cosmical origin, depending upon the acquired rotation of the earth, as influenced by the local attraction exercised upon it by the moon and the sun, and, if utilised, would tend to a gradual reduction in the course of ages of the earth’s rotative velocity. The amount of available energy represented by this source is vast indeed, but cannot be utilised to a large extent, except in comparatively few localities and at great inconvenience and expense.

For all practical purposes we depend upon the solar ray past and present for our supply of useful energy, and when we shall have consumed the stores produced in former ages, we must be content to live with it from hand to mouth. This condition of things may satisfy the negro in Central Africa or the agriculturist of Southern
Europe, who lives on the fruit of the land, but cannot but appear highly unsatisfactory to an audience such as I have the honour of addressing.

The sun makes his appearance to the inhabitants of Glasgow at somewhat rare intervals, I am told, and it might be supposed from this fact that his action is correspondingly unimportant to their well-being. Such is not, however, the case, as it can easily be proved that the action of the solar ray is as potential in its results at Glasgow as in Central Africa. The very clouds that so frequently obstruct the direct rays of the sun are the result of his evaporative effect exercised upon the Atlantic Ocean. The steam raised there by the sun's heat condenses when driven by the prevailing south-west wind against your elevated shores, and, in condensing, produces a temperature which makes your northern climate as temperate almost as that of Southern Europe. You are furnished at the same time with an abundance of rain water, which, as I shall presently show, could be made serviceable for a supply of mechanical power, and even of heat and light, to an amount vastly superior to the total energy you now derive from coal.

These observations may suffice to define generally our present standpoint of scientific knowledge regarding energy in its different forms. It is not my purpose to penetrate deeper into this new branch of science, which we owe to the illustrious persons whose names I have mentioned, but my task is the more humble, though, perhaps, not less useful one of considering some of the applications of this science for our material wants. It is in this direction that my individual efforts have been exerted ever since the year 1846, when, fired up by the first announcement of the labours of Carnot, Grove, Joule, and Mayer, I conceived the possibility of realising at least a portion of the economical results revealed to us by scientific research.

An inquiry into the economical results of the caloric motors of the day, by the light of the Dynamical Theory of Heat, revealed to me the fact that the best steam engine of that day yielded only about \( \frac{1}{10} \) part of the mechanical effect of the heat consumed, the remaining \( \frac{9}{10} \) being lost in the form of heated products of combustion passing away up the chimney, and in heating the water inside the condenser. It appeared as though the great inheritance bequeathed to us by Watt, had nearly accomplished its mission,
and that we had reached another starting-point in applied science commensurate to the one then just accomplished in pure science.

It was evident, that in order to produce greater results, higher temperatures had to be resorted to, and it was equally evident, that inasmuch as the range of the elastic fluid giving motion to a working piston was necessarily limited, it would not be possible to convert the whole of the heat that had been employed in producing the highly heated elastic medium into onward motion of the piston, and that, therefore, a method had to be devised for storing the residue of the heat contained in the elastic medium after the accomplishment of each stroke of the engine. Such an appliance presented itself ready-made in the regenerator, or heat recuperator, as it might be more appropriately called, a contrivance which had been suggested as far back as 1817 by the Rev. Robert Stirling, of Dundee, and which was afterwards applied to a heated air engine by his brother, Mr. James Stirling.

I will not inflict on you a detailed description of the engine resulting from these reflections, nor an account of the innumerable difficulties and disappointments to which they led. Suffice it to say that I obtained economical results sufficient to prove the correctness of the principles upon which I had gone to work, but the complete practical realisation of those principles (involving, as it does, the use of steam or air very highly heated under pressure) is a matter which has yet to be achieved, as the endeavours of James Stirling, Ericsson, and other pioneers in the same field, have not led to any more satisfactory results than my own.

On the other hand, the steam-engine constructed upon the general principles laid down by James Watt has undergone some important changes; these consist of improved modes of firing, improved construction of boilers, the introduction of surface condensation, and such modifications in the construction of the engine itself as enable us to carry into effect the expansive action of steam to a much greater extent than formerly. These improvements have been introduced more particularly into the marine-engine, a class of engines which fifteen years ago compared unfavourably as regards economical results with land-engines, particularly with such as were used for pumping water, known as the Cornish engine, and for giving motion to large factories, for
which the double cylinder, or Woolff engine, had come largely into use. It is due in great measure to the energies of one of your naval constructors, the late Mr. John Elder, that a more economical marine engine has been brought into use in the shape of a modification of Woolff's engine, in which the crank of a high-pressure cylinder is placed at right angles to that of the low-pressure or expansive cylinder, whereby the important advantage is realised that a single pair of cylinders produces a continuity of driving power throughout the revolution of the engine-shaft.

The economical results obtained through the introduction of these improvements are strikingly illustrated by the fact that one-horse-power is now produced with an expenditure of 2 lbs. of coal per hour, whereas in the most economical marine-engines fifteen years ago double the amount was employed.

The calorific effect residing in one pound of pure carbon, if burnt under the most favourable circumstances (producing carbonic acid as the result of combustion), is 14,000 heat units; but common coal, containing an average amount of ash, moisture, and absorbed carbonic acid, may be taken at 12,000 units with perfect combustion. These represent \(12,000 \times 772 = 9,264,000\) ft. lbs. of force; and the two pounds of coal consumed per horse-power represent twice that amount, or \(18,528,000\) ft. lbs., whereas one horse-power is represented by \(33,000 \times 60 = 1,980,000\) ft. lbs. per hour. This comparison brings us to the conclusion that the best steam-engine of the day utilises only about one-ninth part of the heat producible by the combustion of the fuel employed.

But it must be remembered that although force may be converted entirely into its equivalent of heat, heat cannot be converted into force without loss, through heat descending from a point of higher energy or temperature to a lower point, the amount of force realisable being dependent upon the range between the maximum and minimum temperatures, or in the case of an elastic fluid engine, the temperature before and after expansion.

An engine capable of developing one horse-power with two pounds of coal per hour, is worked with a pressure of 60 pounds above the atmosphere, or 74·7 pounds on the square inch, with a corresponding initial temperature of 307° Fahr., and a pressure in the condenser of 1 pound on the square inch, corresponding to 105° Fahr.; we find, by taking the ratio of the difference of these
numbers to that of the greater given in absolute degrees of temperature, that the efficiency of the steam is 
\[
\frac{307 - 105}{307 + 461} = \frac{202}{768}
\]

But we must also consider the loss of effect carried away by the heated products of combustion. The temperature of the fire may be taken at 2500°, and that of the chimney at 500° Fahr., above the atmospheric temperature, and the ratio of the difference of these numbers to the greater gives 
\[
\frac{2500 - 500}{2500} = \frac{4}{5}
\]
as the efficiency of the furnace, which agrees with that of the best regulated furnaces worked with chimney draught.

By the multiplication together of these ratios we obtain the combined theoretical efficiency of 
\[
\frac{202}{768} \times \frac{4}{5} = \frac{808}{3840} = \frac{2}{9}
\]
(approximately) of the steam and furnace worked upon the best known and approved principles.

Thus it is shown that the best steam-engines now constructed are capable of realising \(\frac{2}{9}\) of the heat generated in the combustion of the fuel under the boiler, whilst the remaining \(\frac{7}{9}\) form the margin for future improvement,—a large margin, it must be owned, and one that can be dealt with only by increasing the range of temperatures, the most perfect engine being one in which the temperature ranges from that produced in combustion, say, 3000° Fahr., to the minimum temperature producible in a condenser.

The production of mechanical work is, however, not the only, nor indeed, the most important employment of fuel; its largest consumption takes place in the smelting and re-heating of metals and other substances. Here, again, the actual results obtained are very much below those indicated by scientific inquiry.

Great improvements have, indeed, been effected in blast furnace economy by the introduction of the hot blast by Nielson. Yet, if we consider the conversion of iron ore into finished products, such as wrought iron or steel, as a connected process, we find that there remains a very large margin for improvement; and ultimate economical results can only be looked for, I venture to think, when the several operations now employed are replaced by a direct or single process of conversion.

In order to heat a pound of iron to the welding point (say,
2,700° Fahr.), the number of heat units absorbed by the iron does not exceed, according to the best authorities, about 900, which would be producible with about \( \frac{900}{12000} = 0.075 \) lb. of coal.

In an ordinary furnace, the coal burned to heat a ton of iron to the welding point amounts to about 12 cwt., or 6 lb. of coal per pound of iron, making the actual consumption eight times that indicated by theory.

Again, in melting a ton of steel in pots the number of heat units actually absorbed by the metal may be roughly estimated at about 1,800 units per pound weight, whereas the fuel actually consumed to melt a ton of mild steel in pots amounts to 3 tons in the dense form of coke, or \( 3 \times 12,000 = 36,000 \) units per pound of steel melted.

Here we find that the actual consumption exceeds the theoretical in the ratio of 20:1,—without taking into consideration the loss of effect which had already taken place in converting the coal into coke.

Here is a field for effecting a saving in fuel which has particularly occupied my attention for a number of years, and, with your permission, I will give you a description of the means resorted to by myself and my brother, Frederick Siemens, who is associated with me in these improvements, to accomplish more economical results.

These consist in the combination of an apparatus for the entire conversion of fuel into unrefined gas, with a furnace constructed upon the regenerative principle, suitable for the combustion of such gaseous fuel.

The gas-producer, Fig. 1, Plate 3, is a rectangular fire-brick chamber, one side, B, inclined at an angle of from 45° to 60°, and provided with a grate, C, at the foot, through which passes a regulated quantity of air. Fuel is filled in through a hopper, A, at the top of the incline, and carbonic acid gas is the first result of combustion taking place at the foot of the producers. The carbonic acid gas thus produced, in passing through the thick stratum of incandescent fuel above, is converted into carbonic oxide, while some of the surplus heat distils the hydrocarbons in the fuel on the incline. Below the grate water is supplied in limited quantity, E, which is decomposed into its elements by heat which would

\[ \text{Vol. III.} \]
otherwise be lost by radiation into the atmosphere, and thus enriches the gas by the addition of hydrogen and the formation of carbonic oxide free from nitrogen. This mixture of gases passes up a brick stack, H, and is then carried through a horizontal "elevated cooling tube," J, wherein a certain amount of the energy of sensible heat is transformed into that of pressure, in which form it is required for two reasons: firstly, that there may be no leakage of air into the gas flue; and, secondly, that the gas may be delivered with a slight outward pressure at the furnace. The furnace consists of the regenerators, valves, and heating chamber. The regenerators are four chambers, C, E, Fig. 2, Plate 3, containing fire-bricks so arranged as to allow air or gas to pass through them: these fire-bricks will be heated by hot gas, and will heat cool air or gas passing through the chambers. The regenerators are divided into pairs of two, which are connected with special reversing valves, so arranged that the gas-regenerator of the admission pair is connected with the gas-producer, and the air-regenerator with the atmosphere, while the products of combustion pass through the exit regenerators to the chimney. The reversing valves are arranged like four-way cocks, so that by throwing over the flaps the admission regenerators may become exit regenerators, and vice versa. The heating chamber, D, is placed above the regenerators, and there are two sets of ports leading from it to the two pairs of regenerators.

When the furnace is in action, and at a certain high temperature, air enters the air-regenerator from the atmosphere, and gas the gas-regenerator from the producer; these currents are heated as they traverse the brickwork of their respective regenerators, and finally combine in the furnace, adding the heat of the brickwork through which they have passed to that of chemical combination or combustion. The flame produced having done its work in the heating chamber, the products of combustion pass down the exit regenerators, which they heat to a high temperature.

After a certain time, generally half an hour, the direction of the currents is reversed by means of the reversing valves, the exit regenerators becoming those of admission; and thus each pair of regenerators is alternately employed to heat the entering air and gas, and to cool the products of combustion, which finally leave the chimney at a comparatively low temperature.
By this arrangement of furnace great economy is attained, great cleanliness of working and purity of flame; but it has been principally valuable, as owing to the great heat obtainable, it has enabled metallurgical processes to be effected, which cannot be attempted in ordinary furnaces. The temperature is limited theoretically by the point of dissociation (or the point at which the energy of chemical affinity is overcome by that of sensible heat), and practically by the resistance to fusion offered by the refractory materials employed in the construction of the furnace. The economy is proved by the fact that a ton of iron can be heated to the welding point with 7 cwts. of coal; and a ton of steel melted with 12 cwts., whilst from 2 to 3 tons of coke were formerly employed to produce the same effect.

Having thus dealt with the two principal applications of coal to useful purposes, I pass over its manifold other applications for domestic and general uses, and ask you to accompany me to the consideration of that other great store of energy, the tidal wave. In order to utilise this, large basins or reservoirs would have to be provided along the shore of the tidal sea or estuary, to be filled with tidal water during the flood, and to be discharged during the ebb of the tide. The energy of the inflowing and outflowing stream of water can best be utilised by means of such turbine or vortex-wheel as we owe to Professor James Thomson, and is a matter with which I need not detain you at present. What I wish to show is, what is the amount of power recoverable with a given area of tidal basin, and a given rise or fall of tide.

Suppose the actual rise of tide to be 12 feet, 8 feet would be available during half the time of the rise or fall, which would be equivalent to an effective head of 4 feet during the twenty hours, what is the power that can be utilised per acre of surface? An acre of ground contains 43,560 square feet, and the weight of sea water is 64 lbs. per cubic foot; multiplying these numbers into the height of fall, and dividing by the equivalent of 1 horse-power, we obtain 5'6 horse-power as the effective energy of an acre of impounded sea water. Considering the great cost of constructing sea walls to form these tidal basins, and considering also the value of the foreshores in estuaries, or protected portions of the seashore, where alone such constructions would be practicable, it will be at once apparent that the utilisation of the tidal wave is
both costly and restricted in its application. Although the force is apparently obtained without expenditure, the intermittance of the supply, the interest upon the outlay, the cost of maintenance, and the tendency for such basins to silt up are drawbacks of such serious nature that we may dismiss the question of the utilisation of this source of natural energy from serious consideration.

But what about the utilisation of the sources of energy depending upon the solar ray from day to day. It has been calculated that the total calorific effect produced by solar rays upon the surface of this globe would be sufficient in amount to evaporate annually an ocean of boiling water covering the whole surface to the depth of 14 feet, or to melt a stratum of ice of upwards of 100 feet in thickness.

In order to produce the same calorific effect by means of a theoretically perfect furnace, we must consider what quantity of water is represented by a depth of 14 feet over the surface of the earth. The earth's mean diameter is about 42,000,000 feet in round numbers, and its mean circumference is 132,000,000 feet, and the multiplication of these numbers gives its surface as $5,500,000,000,000,000$ of square feet. If we multiply this by the depth of 14 feet, and by the density of water, 62.4, we obtain $77,000,000,000,000,000$ of cubic feet, equal to nearly $5,000,000,000,000,000,000$ of pounds of water.

The heat which evaporates a pound of water, in a perfect boiler, is about 1000 heat units, so that a pound of coal will evaporate 12 lbs. of water, and a ton of coal about 27,000 lbs. We shall therefore require, taking only round numbers, about $180,000,000,000,000$ of tons of coal per annum to perform the effect of the sun's rays upon the earth's surface. This quantity is about 660,000 times as great as the total quantity of coal raised annually throughout the world.

These figures prove that after all we are not so entirely dependent upon the solar energy of former days, represented by coal, as we have been apt to suppose; but that, on the contrary, a vastly superior supply of solar energy comes to us, year by year, by direct radiation, which at the present time is actively employed in producing summer and winter, the fertilising rain, the gentle winds, the raging storm, and all those other natural effects which we behold, but which we have not yet had occasion to utilise for our
SIR WILLIAM SIEMENS, F.R.S.

specific purposes, except to a very small extent. The application of natural forces has, indeed, yielded in recent times to what may be called the artificial employment of coal; the ancient water-wheel has in many cases gone to ruin, windmills no longer crowd the elevated ground near our towns and villages, and the steam funnel, with its flag of suffocating smoke, has superseded, to a great extent, the more graceful but less certain sail for the propulsion of our vessels. This change has been the natural consequence of the abundant supply of coal which we now enjoy; but this supply, as I have endeavoured to show, is not without limit, and the time will come when man will have to revert to those natural forces upon which he has for the present turned his back.

It would, however, be wrong to suppose that a resumption of the use of natural forces would throw us back to the time of the windmill and the primitive water-wheel which used to give motion to isolated establishments. We shall have learned to store, to transport, and to utilise these forces in a manner adapted to our superior requirements; and who knows whether the time may not come when our descendants in the third or fourth generation will look back upon the indiscriminate users of coal with something like the same feeling that we look upon the users of flint and bronze implements. Indeed, without waiting for the extinction of our coal-fields, it appears to me not improbable that natural forces will be resorted to simply on account of their comparative cheapness and convenience of application.

When little more than a twelvemonth ago I visited the great falls of Niagara, I was particularly struck with the extraordinary amount of force which is lost, as far as the useful purposes of man are concerned. 100,000,000 of tons of water fall there every hour from a vertical height of 150 feet, which represents an aggregate of 16,800,000 horse-power, producing as their effect no other result than to raise the temperature of the water at the foot of the fall

$$\frac{150}{772} = \frac{1}{5} \text{ Fah.}$$

In order to reproduce the power of 16,800,000 horses, or, in other words, to pump back the water from below to above the fall, would require an annual expenditure of not less than 266,000,000 of tons of coal, calculated at an average consumption of 4 lbs. of coal per horse-power per hour:
which amount is equivalent to the total coal consumption of the world."

In stating these facts in my inaugural address on assuming the presidency of the Iron and Steel Institute, I ventured to express the opinion that in order to utilise natural forces of this description at distant towns and centres of industry the electric conductor might be resorted to. This view was at that time unsupported by experimental data such as I have been able since then to collect, and before concluding this lecture I propose to bring some of the results of these further inquiries before your notice.

Our knowledge of electric force is, as you are aware, of very recent origin. The frictional electrical machine and the galvanic battery have been utilised for producing slight effects at great distances, thus giving rise to one of the great institutions of the present age, the Electric Telegraph. We have hitherto failed, however, to produce by means of electricity, effects in any way commensurate with those produced through the combustion and distillation of coal, which provide us with the means of driving our factories and lighting our towns with gas. It can be demonstrated, indeed, that the galvanic battery, which is dependent for its development of energy on the combustion of zinc, could never rival the effects due to the combustion of coal economically, for the simple reason that it takes 12 pounds of coal to separate a pound of zinc from its ores, while the amount of energy liberated in the combustion or oxidation of a pound of zinc is represented by 1400 heat units, whereas that by the combustion of a pound of ordinary coal is represented by 12,000 similar units.

The great discovery by Faraday of the induced current has enabled us, however, to produce electricity by the expenditure of force, and by a particular arrangement of a rotative armature and electro-magnets (which is chiefly due to my brother, Dr. Werner Siemens), the current so produced may be accumulated and directed in such a manner as to produce continuous currents, more powerful in their quantitative effects than could be accomplished by batteries or any other means.

Very powerful currents indeed are produced by means of these machines, Plate 4, properly called Dynamo-Electric, by the expenditure of mechanical force only, in imparting rotative motion to an
armature or keeper of cylindrical form surrounded by insulated wires, laid longitudinally upon the cylinder, and revolving with it in the magnetic field due to the polar surfaces of electro-magnets, the coils of which are excited by the very current set up through rotation in the wire upon the armature.

Thus an accumulative principle of action and reaction is inaugurated not altogether dissimilar in principle to the accumulative action already described to you in reference to the regenerative gas furnace, and as in the gas furnace temperatures can be produced limited only by the point of dissociation of combustible matter, so the intensity of electrical action producible in the dynamo-electric machine is limited only by the point of ultimate magnetisation of which iron is capable. As a matter of fact and experiment, a dynamo-electric machine such as is actually employed at the Lizard Lighthouse, weighing altogether 3 cwts. 3 qrs., is capable of converting 3-3 horse-power into electrical energy, which energy is employed for the production of an electric light equal to 4138 candle-power. The smaller machine, which I have placed before you, weighs only 2 cwts. 2 qrs., converts 2 horse-power into electrical energy, which energy may be employed for the production of an electric light equal to 1250 candles, or for producing mechanical force capable of being utilised at a distance for giving motion to machinery, for pumping water, or any other useful purpose. Experiments have shown that the amount of mechanical force that may thus be recovered is equal, or nearly equal, to one-half the force expended in the original production of the current. The diagrams placed upon the wall may serve to give you a better idea of the construction of these machines.

Let us suppose that at some central station 100 horse-power of steam or water power was employed to give motion to several dynamo-electric machines of the dimensions found most convenient in practice, and that by means of metallic conductors of suitable dimensions the electric current produced at the central station was conducted to a number of halls or factories requiring to be lighted, or to utilise mechanical power. If illumination were the only object in view, the total amount of light that could be thus produced would be equal to 125,000 candle-power. This would be equivalent to 6250 Argand burners, each of 20 candle-power, at a
consumption per burner of 6 cubic feet of gas per hour, or a total consumption of 37,500 cubic feet of gas to produce the same effect of light. This would require 3½ tons of coal, and the electric light about as many hundredweights.

It would be fallacious to suppose, however, that in resorting to the electric light we should be satisfied with anything like the candle-power that now satisfies us in using gas, even as we are not now satisfied with the light of lamps and candles since we have become accustomed to gas-lighting. There is this further inconvenience connected with the electric light, that its rays are so intense that they must not reach our eyes without having first been softened down, either by the interposition of some semi-transparent substance, such as ground glass, or by directing the light against screens, or against the ceiling of the room, as was suggested by the Duke of Sutherland, so as to illuminate by reflection only. In making due allowance for these losses of effect there remains, however, ample margin in favour of the electric light, to make it cheaper, and certainly more brilliant than gaslight. Its practical application for large halls and places where powerful light effects are required, will therefore be a question only of time, while for domestic purposes gaslight will long continue to hold its own, owing to the greater facility which it offers of subdividing the effects of light, and of accommodating its intensity to immediate requirements by simply opening and closing an ordinary tap.

My present object, however, is not to discuss the relative merits of the two modes of illumination, but simply to show that power derived from a distant source is capable of being utilised for the production of light of a very brilliant character, a light which is comparable with solar light in showing every object in its true colour, and in producing similar chemical effects, such as the taking of photographic images.

If mechanical force is required to be distributed, the arrangements are in every respect similar to those for the distribution of electric light, and it has been proved experimentally that the amount of power recovered at the distant station is nearly equal to half the power employed at the central station.

At first sight this loss of power may be considered large, but if we compare the cost of producing a limited amount of power by the magneto-electric machine, and by a gas or steam engine, it
will be found that the magneto-electric machine recommends itself, not only by its cleanliness and by the ease with which it can be turned on and off at any moment, but that it is the cheaper machine as far as regards the consumption of coal. In working a small gas or steam engine, the consumption of fuel cannot be taken at less than 8 pounds per horse-power per hour, whereas in working a 100 horse-power steam engine on economical principles, 2, or say 2·5, pounds per hour of coal suffice to produce 1 horse-power. Suppose that 45 per cent. of the power available at the central station is reproduced at the distant one, the amount of coal per hour consumed at the distant station would be

\[
2.5 \times \frac{100}{45} = \frac{250}{45} \text{is 5·6 lbs., or 30 per cent. less than if a gas or steam engine were directly employed.}
\]

The principal objection that has been raised by electricians to the conveyance of power to distances of miles, as here proposed, is on account of the apparently rapid increase in the size of the conductor required with increase of distance. In order that the magneto-electrical machine may work under the most favourable conditions, it should have an internal resistance depending in a great measure upon the nature of the work to be performed, but not exceeding for quantitative effects one ohm or unit of resistance. If the resistance is greater, a notable proportion of the power expended will be converted into heat in the conductors, causing both loss of effect and great inconvenience. By another law, the electrical resistance of the circuit exterior to the machine should be somewhat, but not much, larger than the internal resistance, say 1½ unit; the external resistance is composed of two elements, namely, the conductor and the resistance of the electric lamp, or electro-magnetic engine, which latter may be taken as amounting also to one unit, leaving only half a unit available for the conductor. These conditions determine really the size of the conductor for any distance to which the current has to be conveyed.

Suppose the distance to be half a mile, a copper wire of 0·23 inch diameter will produce the half unit resistance to be desired, which is already a wire of considerable dimensions for the purpose of working a single lamp. If the distance be doubled, wire of the same thickness would give twice the electrical resistance, and in order to reduce it again to half a unit, its sectional area must be
doubled; we have thus a conductor of double length and sectional area, and therefore of four times the weight, and relying upon this calculation it is argued that the weight of the conductor must increase as the square of the distance: so that a conductor of 30 miles' length would require to be \((60)^2 = 3600\) times the weight of the half-mile conductor, and this enormous increase in weight would certainly be required if the object to be accomplished was the working of one electric lamp by a dynamo-electric machine.

My critics have, however, fallen into the error of overlooking the fact that half a unit resistance is the same for a circuit capable of working one lamp as it is for working 100 or 1000 lamps. Electricity is not conducted upon the conditions appertaining to a pipe conveying a ponderable fluid, the resistance of which increases with the square of the velocity of flow: it is, on the contrary, a matter of indifference what amount of energy is transmitted through an electric conductor, the only limit is imposed by the fact that in transmitting electrical energy the conductor itself retains a certain amount proportional to that transmitted, which makes its appearance therein in the form of heat. If this heat was allowed to accumulate, the electrical resistance of the conductor would increase in proportion to such increase, and a point might be reached where fusion of the wire would ensue.

I will now connect the spiral of platinum wire I hold in my hand with the dynamo-electrical machine which is working a hundred yards off, and you will discover in a moment that the wire is red-hot, owing to the amount of electricity that has been passed through a wire of so small a sectional area.

The real power of transmission of an electric current depends, therefore, upon its capability to discharge its heat to surrounding objects, and it will be readily conceived that a wire of sixty times the sectional area and sixty times the length of another wire is capable of radiating away \(60 \sqrt{60} = 460\) times as much heat per hour as the smaller conductor, and that 460 machines or lights may be supplied through it without causing inconvenience.

When, some weeks ago, I had occasion to use this argument before the Institution of Civil Engineers, your President,* who happened to be at the meeting, immediately recognised its force, and, with the fertility of mind for which he is so remarkable,

* Sir William Thomson.
there and then suggested a means by which the transmitting power of a large electrical conductor might be almost indefinitely increased by giving it the form of a hollow tube through which water might be made to flow. It is evident that cold water flowing through such a conductor would prevent an inconvenient accumulation of heat in the metal, and it would not be difficult to introduce and discharge the flowing water at intervals from the pipe without interfering with the necessary insulation of the conductor from the earth.

Our last experiment proved that intense heat can be generated in the electric conductor, and I now propose to bring before you another simple experiment, to show how readily the heat so generated may be employed for heating water. I will immerse the spiral coil of platinum wire which I hold in my hand in a glass jar containing about two pints of water, and after closing the electric circuit you will perceive, in the course of a minute or two, that the water is brought to the boiling point, nor would this mode of heating water in small quantities be expensive if currents were laid on to our houses from dynamo-electric machines, and who knows whether, in the electrical age towards which we seem to be gravitating, the apparatus before you may not be the common coffee machine of the day.

After this digression, let us return for a moment to my proposal of last year to convey 1000 horse-power a distance of 30 miles through a conductor 3 inches diameter.

The electrical resistance of this conductor would be \( \frac{18}{2} \) of a unit, and supposing that the total resistance in circuit was made \( 2 \frac{1}{2} \) units, which, as I before stated, gives a favourable working condition, it follows that \( \frac{18}{2 \times 5} \times 1000 = 72 \) horse-power would be expended in heating the conductor.

This would represent about 15 lbs. of coal per hour, a quantity quite insufficient to raise a mass of 1900 tons of copper, with a surface of 132,000 square feet, to a sensibly heated condition. So far from admitting therefore that I have overstated my case regarding the capability of my large electrical conductor, I am convinced, on the contrary, that its sectional area might be safely reduced to one-half that previously given (or its diameter to 2 inches), whereby its cost would also be reduced to one-half.
It would not be necessary to seek on the other side of the Atlantic for an application of this mode of transmitting the natural force of falling water, as there is perhaps no country where this force abounds to a greater extent than on the west coast of Scotland, with its elevated lands and heavy rainfalls. You have already conducted the water of one of your high-level lochs to Glasgow, by means of a gigantic tube, and how much easier would it be to pass the water in its descent from elevated lands through turbines, and to transmit the vast amount of force that might thus be collected, by means of stout metallic conductors, to towns and villages for the supply of light and mechanical power!

Practical difficulties would, no doubt, have to be contended with, regarding chiefly the proper distribution of the main current over its numerous branches. This subject has latterly occupied my attention in some degree, and admits, I believe, of a satisfactory solution.

It is not my desire, however, to occupy your attention with matters of practical detail of this kind, nor to enlarge further upon the advantageous applications that could be made of the electricity produced by natural forces for other purposes, such as the separation of copper and other metals from their combinations.

Much might be said, also, regarding the utilisation of the irregular force of the wind, which represents an enormous aggregate of available energy capable of collection and distribution in countries where other sources of energy may be wanting.

A number of windmills, such as may be constantly seen working in Holland for the drainage of the land might, for instance, be employed to raise water, by pumping, to an elevated lake or reservoir, whence the power could be drawn off by means of hydraulic motors when required, and might be conducted electrically to centres of habitation.

Other modes of utilising solar energy, either in the form of the direct ray or in other modified forms, might be added to the illustrations I have selected. In dwelling probably too much upon these, I fear to have taxed your patience, and to have laid myself open to the reproach of having betrayed a preference for those branches of the general subject with which I have been professionally or otherwise connected. I do not deny such a charge, but plead for my excuse that those are the very branches upon which
I may possess some right to speak, with some chance of engaging your interest.

Whether or not I have been in the least degree successful in accomplishing this is a question which you will judge, I hope, rather by my desire to discharge the duty I had undertaken than by the standard furnished you by my predecessors in this place.

THE MICROPHONE.*

At a discussion upon Mr. William Preece's paper on the microphone, which took place before the Society of Telegraph Engineers on Thursday last, the Duke of Argyll called attention to the important part which that invention was likely to play in physiological research. As chairman of the meeting I took occasion to refer to the intimate connection between the microphone and its two elder sisters, the telephone and the phonograph, in conjunction with which it formed a discovery which would probably be hereafter regarded as one of the greatest achievements in natural science of the present century. I ventured further to draw an analogy between the action of the phonograph and the action of the brain in the exercise of memory, and with your permission I will enlarge upon this speculation to the extent of making my reasoning clear enough to submit the same to the critical test.

All impressions received by us from without, either through the tympanum of the ear, the retina of the eye, or through the sensitive nerves of the skin, are, it is generally believed by physiologists, communicated to corpuscular bodies in the brain, which lie embedded in a grey substance, the nature and precise function of which have not yet been fully explained. It would appear that the corpuscular bodies in which the sensitive nerves terminate are connected, through the medium of extremely delicate filaments, with the nervous system of volition, the reaction of the

one system upon the other being attributable to mental energy. It may be conceived that any fresh impressions received on the extremely complex sensitive network of the brain may give rise then and there to acts of volition; but how, it may be asked, can acts of volition arise from impressions that were communicated through the sensitive nerves years before, having been committed in the meantime to what we term the memory? But in order that the mind can deal with an impression previously received it seems necessary that it must have the power of reproducing the same from some material record by which the impression has been rendered permanent. Take the case of a tune that we have heard in early youth and which may not have since recurred to us. By some incident or other that tune and the words connected with it become suddenly revivified in the mind. If the tune had been sung into a phonograph it could have been reproduced at any time by releasing a spring moving the barrel of the instrument; and it seems a fair question to ask whether the grey substance of the brain may not, after all, be something analogous to a store-house of phonographic impressions representing the accumulated treasure of our knowledge and experience, to be called into requisition by the directing power of the mind in turning on, as it were, one barrel or another.

Such a hypothesis might possibly serve also to explain how in sleep, when the directing power of the mind is not active, a local disturbance in the nervous system may turn on one or more phonographic barrels at a time, and thus produce the confused images of dreamland! A powerful mind would exercise a complete control over the innumerable barrels constituting our store of knowledge, whereas in a weak mind the impressions of the past would be brought back into evidence in a confused and irregular manner. Such a supposition might also account for the more vivid recollection of impressions received in early life, when the mechanical record stored up in the brain may be supposed to have been more distinctly and indelibly rendered. In speaking of these impressions as phonographic it does not follow that they were originally conveyed through the tympanum of the ear. Mr. Willoughby Smith, at the meeting above referred to, called attention to the fact that, by substituting crystalline selenium for carbon in the microphone, a ray of sunlight directed upon the
selenium produces a noise comparable with that produced by a Nasmyth hammer; and it is quite feasible that the impressions received through the retina of the eye, and the nervous system generally, would be equally susceptible of being recorded in the cerebral storehouse. The record itself might be supposed to be of a mechanical, or, more probably, of a molecular character, the one thing important being that it must be material.

These observations are, no doubt, extremely crude, but may serve possibly to direct the attention of physiologists to a point of interest to their science; nor would it be the first occasion on which a phenomenon of inanimate nature had revealed the secrets of animate organisation.

C. William Siemens.

ADDRESS

Of C. William Siemens, D.C.L., F.R.S.,*

President of the Iron and Steel Institute, delivered at the Paris Meeting on the 16th September, 1878.

The Iron and Steel Institute has, from its very origin, assumed a somewhat cosmopolitan character. Not only has it devoted a considerable portion of its proceedings to the record of achievements in foreign countries, but it counts among its members foreign metallurgists and others connected practically with the treatment of iron and steel, who, although not able frequently to attend our meetings, appear through their adhesion to appreciate our labours. Belgium is represented upon our list by no less a personage than the enlightened King of that country, while of our other foreign members I need only mention, in this place, the well-known names of Åkermann of Sweden; Kolokoltzoff of Russia; Krupp of Essen; Harmann and Lümann of Osnabrück; Tunner of Leoben; d’Allemagne and d’Andrimont of Liège;

Éuchene and Greiner of Seraing; Tenore as representing Italy; and Ybarra, Spain; Grüner, Jordan, Schneider, de Wendel, Morel, Gautier, and Périsse, as representatives of France; and of our American members, Cooper, Holley, Burden, and Gowen. The large number of gentlemen proposed at the present meeting of the Institute, including several foreign names of distinction, proves that the general interest felt in our proceedings is not abating.

A further important step towards giving this Institute an international character was made in 1873, when we accepted the invitation of the Belgium engineers and ironmasters to hold our summer meeting at Liège. The success of that meeting, under the able presidency of my friend and predecessor in office, Mr. I. Lowthian Bell, is still fresh in the memory of all those members of the Institute who could avail themselves of the invitation.

We are now for the second time assembled upon foreign soil, having accepted the invitations kindly given us by the Institution des Ingenieurs Civils, by the Société d'Encouragement, and by the Directors of the Conservatoire des Arts et Métiers.

When at Liège, we found ourselves in the midst of a great iron-producing district, an advantage which we cannot boast of on the present occasion, inasmuch as in Paris and the Departments immediately surrounding it, iron and steel industries are conspicuous by their absence. On the other hand, we have the advantage of meeting at one of the greatest centres of intelligence in all branches of knowledge, including those in which we are particularly interested, and of finding at the Universal Exhibition opportunity of viewing the mineral and manufactured produce of nearly all civilised nations brought into juxtaposition so as to facilitate comparison between them, although allowance must, of course, be made for the limited space and imperfect arrangement appertaining to the greater part of the exhibits other than French.

Eighteen months have now elapsed since I had the honour of addressing you upon assuming the office of President of this Institution, and the present is the last time upon which the responsibility of conducting its meetings will devolve upon me.

In the address I delivered upon that former occasion, I referred to the already depressed condition of the steel and iron trade throughout the world, and but few of us would have thought at
that time, that so far from selling prices having reached their lowest point, they were only upon the middle of a descending incline. Among the causes which I then enumerated for the depression of prices, I assigned the first place to foreign competition, an opinion the merit of which you will have ample opportunity of testing at the present meeting, when we hope to discuss matters of great interest to both the British and foreign ironmaster.

The challenge given by France to the industrial world through her Universal Exhibition, and the special invitation which our Institute has received from the French engineers and metallurgists to meet them in friendly discussion of the methods adopted in both countries for the attainment of ever-improving results, shows a confidence on their part that they have matters of interest to place before us; and if any one of our members should still have any doubt in his mind regarding the recent advance in French practice, I am satisfied that the opportunities he will have of visiting some of the leading works in this country will satisfy him regarding their advanced condition.

We shall go home, I doubt not, with the conviction that we have returned from a visit to formidable rivals in the markets of the world, but we shall return home with the further conviction that those formidable rivals have behaved to us most generously in giving us access to their secrets of success, and that, in reality, we may look upon them as friends, whose rivalry is productive of that stimulus to further exertion, without which we should not probably have made those remarkable advances in the means of cheapening production, which are the characteristic features of our more recent achievements.

In the address already referred to, I ventured to express the opinion, that in the contest for cheapness upon which civilised nations were at that time engaged, England would be able to hold her own, owing to her abundant supply of fuel and of ores, coupled with her ample means of intercommunication and with her facilities for reaching the markets of the world; advantages which more than compensate for the somewhat higher rate of wages payable in England; and considering the natural aptitude of the British people to be stimulated to exertion under difficulty, as also the results revealed by recent statistics, I see no reason to
alter that opinion. England must for a long time retain the first position for massive and cheap production, whereas we shall probably find that our neighbours excel in the aptitude they evidently possess for adapting new materials to particular purposes, of which the present Exhibition furnishes us with so many striking examples. Again, whilst the English, to realise a novel proposition, make bold attempts (not always carefully matured beforehand), the French systematically study a question in all its aspects, and fortify their views by careful inquiry into the experience obtained elsewhere, before they commence operations, which are then carried out with all the economical and other advantages resulting from such an exhaustive preliminary inquiry. If we seek a cause for the remarkable aptitude of adapting means to special ends, to which I have referred, we shall probably find it in the advantages France and other Continental countries have enjoyed for at least a generation of a more extended technical education than we could boast of, and of the personal influence which has been exercised by a line of scientific writers and experimentalists, of whom I shall only mention here the honoured names of Réaumur, Ebelmen, Régnauld, Pouillet, Péclet, Thomas, and Le Châtelier, as belonging to the past, and of Deville, Grüner, Lan, Laurens, Jordan, Frémy, and Dumas, who are fortunately still among us. It is chiefly to such men as these that France owes her admirable system of technical education, which enables her to place her metallurgical establishments under the guidance of men who are scientifically qualified for the discharge of their respective duties, and for the attainment of practical results which may well excite our admiration.

Public education in France is divided into five faculties, those of literature, law, medicine, theology, and science; it is the latter only with which we are principally concerned, and in reference to which I propose to offer a few remarks. Foremost amongst the schools for technical education stands the Ecole Polytechnique with its branches, the Ecole des Mines, and the Ecole des Ponts et Chaussées, destined exclusively for the education of government, railway, and mining engineers, not to speak of the military and naval branch of the school, nor of the comparatively small number who join the Regie de Tabac, Salpêtre, &c., and the naval construction. The admission to the Ecole Polytechnique is by
competitive examination. The degree of Bachelor in Science or Literature is required for admission to the competition. This examination is a somewhat severe test of sound primary education, as it comprises the whole of arithmetic, elementary geometry, algebra, trigonometry, descriptive geometry, physics and general chemistry, and a knowledge of German. From 120 to 150 are admitted per annum, out of a number five times as great, who present themselves usually for examination. The pupils pass two years at the Ecole Polytechnique: the studies are purely scientific; they embrace the higher mathematics, mechanics, physics, chemistry, astronomy, &c. There are some 20 or 25 places in the Civil Service set apart annually by the Government for the benefit of the first students in the order of their classification at the final examinations of the Ecole Polytechnique; and as these are extremely honourable and highly prized by the students, it results in a close competition and in the attainment of a high standard.

The students who pass sufficiently high can choose to enter into the Ecole desPonts et Chaussées, or the Ecole des Mines. In these the student engineers remain three years, and receive a state allowance of £72 a year. The instruction has for its object the application of the physico-mathematical sciences to special branches of engineering. At the Ecole des Mines, for example, the course consists of geology, mineralogy, analytical chemistry, and metallurgy. Some of the students complete their practical instruction by travelling in France and abroad, at the partial expense of the State.

Of equal importance with the Ecole Polytechnique and its branches is the Ecole Centrale des Arts et Manufactures, though somewhat inferior to it as regards the curriculum of mathematical and physical knowledge. Its special object is to train engineers for private industry, and it turns out annually from 100 to 120 scholars, who can boast of having received a three years' course of general scientific education, including the higher branches of mathematics, physical science, pure and applied chemistry, geology, mechanics, metallurgy, mineralogy, and other branches of useful information, fitting them for the career of the civil engineer and of the manufacturer. This school was originally founded by an association of savans, and without connection with the state, but
since 1860 it has been placed under the direction of the Minister of Agriculture and Commerce.

It is not my intention to advocate the establishment of an Ecole Polytechnique with its superior adjuncts, the Ecole des Mines and the Ecole des Ponts et Chaussées in Great Britain, for the simple reason that we require no Government engineers to direct our public works. The Ecole Centrale differs in its organization essentially from that of the Ecole Polytechnique, insomuch as it makes no promise of employment to its students, depending for its success upon the amount and character of the technical education it may succeed in imparting to the majority of the students that pass from its walls into practical life, and it is thus one which recommends itself specially to our ideas of independent action.

The only establishment in Great Britain comparable with the Ecole Centrale as regards metallurgy is our School of Mines, which, if it were installed in a capacious building, and had other branches of knowledge added to its curriculum, might easily, under the guidance of such men as Percy, Smyth, Frankland, and Huxley, be developed into an institution which would give rise to beneficial results difficult to over-estimate.

In addition to the Ecole Centrale many other schools are established in France, foremost amongst which stand that of the Conservatoire des Arts et Métiers, where, under the able direction of General Morin and of M. Tresca, both Membres de l'Institut, an education is provided intended for the class of foremen or head workmen of the manufactories of the capital. The students have the great advantage of the admirable collection of models and specimens, which gives the Conservatoire des Arts et Métiers a world-wide reputation. The courses are public and gratuitous, and attract larger numbers from other classes than those for which they are intended; foreign professors and others who take an interest in the progress of technology being often present.

There are, besides, local schools scattered throughout the country, such as the Ecole des Mineurs de St. Etienne, intended for managers of mines, where the instruction is more elementary and more practical than that of the Ecole des Mines, and the Ecoles des Arts et Métiers at Alais, Chalons, Aix, Angers, and elsewhere, where foremen and works managers are trained.
these there are Ecoles Industrielles at Paris, Lyons, Lille, &c., and it is gratifying to observe the great attention given to such elementary education at leading works.

By way of example I will only cite the instance of Le Creusot, where the schools afford instruction to over 6000 children of both sexes of the population connected with those works, and the outlying branches. The number of teachers employed in these schools amount to 121, and although the information given to the children is strictly elementary, care is taken to impart the elements of the higher branches of knowledge to those who seem desirous and fit to rise to a higher level.

The Creusot Works taken altogether form a most interesting instance of what can be accomplished by patient industry and systematic organisation. Situated in a district possessing moderate deposits of coal of an inferior character, a meagre clay iron stone, having only a scanty population, and without possessing the advantage of natural means of communication, an establishment has been reared chiefly through the genius of the late M. E. Schneider, representing an annual production of 125,000 tons of iron and steel wrought into the forms of rails, forgings, plates, and finished engines, remarkable for their finish and general quality. Yet these works depend in a great measure for their superior ores upon a supply from the coast of Africa, and for a portion of their fuel upon the south of France, whilst their produce has to pass over some hundred miles of railway before it reaches any harbour or important market of the world.

Some of you will have the opportunity, thanks to the kind invitation of M. Henri Schneider, of visiting these remarkable works, and your attention will be especially attracted by a steam-hammer, recently erected there, which with its weight of 80 tons falling through a distance of 5 metres, is by far the most powerful tool of this description now in existence, and does excellent service, I believe, in consolidating heavy ingots of steel for the production of steel cannon, armour-plate, and other heavy forgings.

The works of Terrenoire, with which we have been made acquainted from time to time by the interesting papers of M. Gautier, the chemist of those works, furnish another instance of great results produced by a combination of intelligence and systematic management; and, thanks to the invitation of
M. Jullien, the managing director of the Terrenoire Works, those members of our Institute who wish to avail themselves of it will have an opportunity of visiting these and other remarkable works of the same industrial centre.

Another section of our body will be able to take advantage of the invitation of M. de Wendel to visit a group of works in the Meurthe and Moselle district, where an oolitic ore is worked not dissimilar in character to Cleveland ore, and it will be a matter of considerable interest to those more intimately connected with the Cleveland district to observe the points of difference in the practice of the two countries.

The papers presented to us for discussion are of a highly interesting character. Foremost amongst them stands that of M. Jordan, "On the Iron Ore Resources of France," from which we shall gather a great deal of valuable information regarding the distribution of the mineral wealth of this country, and the system and methods generally adopted for the production of those highly-finished materials and appliances that meet our view in passing through the French portion of the Exhibition. We shall have a paper from M. Marché dealing with general questions of interest regarding the application of steel, and another from our own member of Council, Mr. Adamson, giving an elaborate series of tests of that material, showing to what extent it may be relied upon in its application to the construction of boilers and for other engineering purposes. Professor Åkermann will enlighten us on the present state of iron and steel manufacture as judged from the Paris Exhibition, and there are other papers on special subjects by M. Périsse, Mr. Rothwell, and Messrs. Thomas and Gilchrist.

Bearing in mind the important communications just alluded to, I shall not venture to take up your time with any elaborate observations regarding the iron and steel industries of the country you have come to visit, and it remains for me in conclusion of these introductory remarks only to express our high sense of appreciation of the kind and hospitable manner in which we have been received, and to assure our hosts beforehand that although we occupy in a certain degree the position of rivals towards them, as we stand also as rivals of one another, we come among them animated with that kindliness of feeling and that desire to exchange knowledge and experience which does not preclude
friendly sentiments, and even admiration on our part for the achievements of our confrères. These intercommunications must lead ultimately, not only to the cheapening of the cost of production, but chiefly to the attainment of fresh starting-points in the application of iron and steel for the useful purposes of man, and through which we may hope to re-establish that balance between consumption and our increased means of production so essential to our prosperity as a class.

REMARKS AT THE ANNUAL DINNER OF THE IRON AND STEEL INSTITUTE,

*Held in the Hôtel Continental, Paris, on the 17th September, 1878.*

The Chairman,* (Dr. C. W. Siemens), said he had now the pleasure to propose, "Prosperity to the Learned Societies of France." In his introductory remarks on the previous day he had referred to the educational establishments of France so far as concerned technical education, and he pointed out that the "École Polytechnique" gave an education of the very highest order to the mining and railway engineers of that country. He also pointed out that the "École Centrale" gave an education of perhaps not quite so high an order, but still very good, to the young manufacturer, who, after he left that establishment, entered the workshop and the factory. He had also pointed to the admirable "Conservatoire des Arts et Métiers," which was so ably presided over by General Morin and by M. Tresca. In order to convey such an amount of knowledge, it was necessary that science should be cultivated, and for the cultivation of science that country also possessed establishments that might well be called the envy of the civilised world. The "Académie des Sciences," one of the five branches of the Institute of France, was an establishment which had arisen towards the end of the last century, and had attained great fame throughout the world. He need only

* Excerpt Journal of the Iron and Steel Institute, 1878, pp. 494-496.
mention such names as Lavoisier, Laplace, Ampère, and Arago, in order to remind them of so many fixed stars who had illumined the firmament of science. Modern science was in a great measure created by these men, and this country might well be proud to possess such an academy as the "Académie des Sciences." They had to-night three members of that Académie amongst them. The French Académie des Sciences corresponded to the Royal Society, with this difference, that its members were fewer in number, and it might be assumed that their quality was thus rendered more select; however that might be, he (the Chairman) thought it one of the highest distinctions he could boast of to be a Fellow of the Royal Society, and he felt additional pleasure to do honour in their name to the French Académie. Among other establishments in France for the cultivation of science, he would mention the "École des Mines," which they had that day visited under the distinguished guidance of MM. Dupont and Lan, who had so kindly taken them over that great establishment. They had, further, the "Société d'Encouragement," who had so hospitably placed their rooms at the disposal of the Institute. That institution had done a great deal of good in promoting the interests of industry, and was under the able presidency of M. Dumas, Membre de l'Académie. Then they had what, to use an Irishism, might be called a French-British Association, a body corresponding entirely with our British Association; and he was happy to say that he had the eminent President of that Society on his left, M. Frémy. Last, but not least, there was the "Société des Ingenieurs Civils," which corresponded to the English Institution of Civil Engineers, although, perhaps, in that instance, they might claim to be the older and more important body of the two, inasmuch as they represented civil engineering in all its branches. Yet the French Institution gave promise of great results, and was at this moment under the able presidency of M. Tresca, who was on his right. These were the principal scientific bodies that occurred to him at that moment, and without further comment he would propose "Prosperity to the Scientific Institutions of France," coupling with the toast the respected names of M. Frémy and M. Tresca.
REMARKS ON THE OCCASION OF THE EXCURSION OF THE IRON AND STEEL INSTITUTE TO CREUSOT.

The President* (Dr. Siemens) said he rose to thank their worthy host for the kind manner in which he had received them already, and at the same time to thank him for the kind words he had spoken with regard to his presidency. He had for many years been proud to consider himself a friend of that house. He had enjoyed the society of that house many years ago, and the more he knew of M. Henri Schneider the more admiration did he feel for him. Looking upon him from whatever point they might, he could only express by the word "admiration" the impressions they received of his character. The man who found Creusot a comparative wilderness, a small place cast away in a valley, had by his genius, his method, his system, his honesty of purpose, created an establishment there such as, he believed, the world could not boast of elsewhere. Naturally, Creusot had got its minerals and its fuel, but those minerals and that fuel put together would give very poor results indeed—the fuel was a non-binding kind of anthracite; the stone was very poor ironstone of the oolitic formation. If any ordinary person had made the attempt to produce iron there he would have relinquished it very soon; but with growing means of communication M. Schneider took advantage of all the circumstances he could. He himself had very great pleasure in going with him when he paid daily visits to inspect systematically the result from the puddling furnaces and works, and rewarded with a premium the puddling furnace which produced in that day the best set of samples. It was through such a system as that that Creusot was able to produce the marvellous results which they saw now. The ironstone had to be supplemented by ironstone from abroad—the coal of the district had to be supplemented by binding coal from the South of France. Elaborate machinery, which in those days was considered refined machinery, had to be erected to grind those coals together and burn them in an apparatus, which up to this day had not been acknowledged in England, and

which they might have good reason for not acknowledging there, but which at Creusot produced good results. They had seen that which was poor coal and poor ironstone originally produce iron and steel of the very highest quality, and in the blast furnace they got a ton of pig metal for a ton of coke, a result, he might say, which was not surpassed in England. All that was the result of the genius of their host’s father, but it required more than that; it required a man who could go forth in the world and take his position, and M. E. Schneider, as was well known, was President of the National Assembly, and it was there he made an impression and developed the power necessary to produce such results as they saw. Of M. Henri Schneider he would say only that he was the affectionate son of his father. He never knew a son of such thorough devotion as M. Henri Schneider always was—to his knowledge—to his father, and now that the great responsibility of conducting those works had been thrown upon himself, he had shown himself his father’s worthy successor. In Le Creusot today he saw no backsliding anywhere; everywhere progress, and nothing could better express the great example set by M. E. Schneider than was expressed by the beautiful statue in the pavilion, where the poor mother of the Creusot child pointed to its founder saying, “That is the man—follow him.” It was a great pleasure to him to thank their host in the name of the members of the Institute for the magnificent and princely reception he had given them. Nothing, he thought, could exceed the cordiality and the liberality of the reception which they had received, and they would go home indeed gratified beyond measure with the kindly feeling to which that visit would lead. Before proposing the health of their host, Dr. Siemens proposed the health of Madame E. Schneider.

At the dinner the members collected among themselves a subscription of 1000 francs, which was remitted to Messrs. Schneider in due course by the President, who also sent the following letter:

Paris, 23rd September, 1878.

Dear Messieurs Schneider & Company,—It would be impossible for me to express to you, in adequate terms, the feeling of
entire satisfaction with which the Members of the Iron and Steel Institute left Le Creusot on Saturday last. The enlightened system with which those gigantic works are carried on could not fail to produce a deep impression upon every one of your visitors; and I need scarcely say that your generous hospitality will long be remembered, and will do much to strengthen the friendly feeling already existing between the metallurgists of the two countries.

It was felt by us at Dijon that, before separating, some outward expression might not inappropriately be given of our appreciation of what you, and all connected with you, had done for us, and it occurred to us that this might best be accomplished by means of a complimentary subscription to the Creusot Hospital. No large subscriptions were asked for; but as every one present cheerfully responded to my proposal, the collection soon reached the amount of 2560 francs 50 cents, which I have much pleasure in forwarding you in the shape of my cheque for £102 10s., of which please to dispose in the manner you think best for the intended purpose.

In thanking you in the name of the Iron and Steel Institute for your very kind reception of them, and in thanking you for the friendly consideration shown to myself, believe me to remain, with my respectful remembrances to Madame Schneider, and very kind regards to M. Henri Schneider, very truly yours,

(Signed) C. WILLIAM SIEMENS.

Hearty cheers were given for M. Henri Schneider on leaving for Paris.

ELECTRIC LIGHTING.

TO THE EDITOR OF "THE TIMES."

SIR,—The intelligence flashed through the Atlantic cable a few days since to the effect that Mr. Edison, the ingenious inventor of
the phonograph, etc., had succeeded in dividing electric currents indefinitely for the distribution of light and power, appears to have taken the public by surprise, and has exerted a most depressing influence upon the holders of gas shares. Having given close attention to the question of electric lighting ever since 1867—when following the researches of my brother, Dr. Werner Siemens, I presented a paper to the Royal Society describing the dynamoelectric principle—I may be allowed to make a few remarks upon the novelty and probable effect of Mr. Edison’s startling announcement.

In passing an electric circuit from a main conductor into several or any number of branches, the current divides itself between those branches, according to the well-known law of Ohm, in the exact inverse ratio of the electric resistance presented by each branch. A current may thus be divided, for instance, into ten separate currents of precisely equal force, if each branch is made to consist of a wire of the same length and conductivity; but if one of these wires was again to be slit into ten wires, presenting in the aggregate the same conductivity, each of these wires would only convey 100th part of the total current. In the same way one of the minor wires might again be subdivided into branches, each of which would convey an amount of electric current which would be accurately expressed by the relative resistance of the branch in question, divided by the total resistance of all the branches put together. It would thus seem that nothing could be more easy than to divide a powerful electric current among as many branches of varying relative importance as might be desired; but in the case of electric lighting a difficulty arises in consequence of the varying resistance in each electric light or candle, due to the necessarily somewhat varying distance of the carbon points from each other, upon which the length of the luminous arc depends. In order to work a number of lights upon different branches of the same current, it is necessary to furnish each branch with a regulator so contrived that an increase of current corresponding to too near an approach of the carbon points will produce automatically an increased resistance in that branch circuit, whereas an accidental increase in the distance between the carbon points of any lamp will cause the regulator to reduce the extraneous resistance of the circuit to a
Such a mode of regulating currents was present in my mind when, in addressing the Iron and Steel Institute in March, 1877, I ventured to express my conviction that natural forces, such as represented by large waterfalls, could be utilised for the production of motive power and electric light, in towns at a distance of even 30 miles from such source, by means of a large electric conductor. This suggestion gave rise to a good deal of discussion and criticism, especially in the United States; but I replied to some of these criticisms in delivering one of the Science Lectures at Glasgow in March last, having already referred to the matter in a discussion that was held before the Institution of Civil Engineers on the 29th of January last. Having in the meantime perfected the regulator, I showed it in operation at the soirée of the Royal Society on the 19th of June, and have only been waiting to get experimental data complete, in order to bring the whole subject before one of the scientific bodies. The arrangement may be said to consist simply of a thin strip of copper or silver, say 6 inches long and half an inch broad, stretched horizontally between two supports, with a weight or spring exerting a certain pressure in the middle. The branch circuit to be regulated is passed through this strip of metal, which is thereby heated to a certain moderate extent, depending upon the amount of current passing, and upon the rate of radiation of the heat produced in the strip to surrounding objects. Suppose that when the normal condition of things obtains, the strip of metal is maintained at the temperature of, say, 100° Fahr., and suppose that by an accidental approach of the carbons of a lamp, the resistance of the circuit is suddenly decreased, an almost instantaneous increase of temperature of the thin strip will ensue, which will cause it to elongate slightly, and allow the weight resting in the middle to descend, which in its turn causes an increase in the resistance of a small rheostat, through which the branch current in question has to flow.

It will thus be seen that it is not so much the novelty of the announcement made by Mr. Edison, as the manner in which it has been conveyed to us that has alarmed a portion of the British public, and I hold that such startling announcements as these should be deprecated, as being unworthy of science and mischievous to its true progress.
Although I am strongly of opinion that electricity will gradually replace gas in many of its most important applications, as being both cheaper and more brilliant, I still hold the opinion, quoted by Mr. Northover in his letter to you of yesterday, that its application will be limited, at least during our generation, to such larger purposes as the lighting of our coasts, to naval and military signalling, to harbours, quays, warehouses and public buildings, including perhaps picture galleries and drawing rooms, where the objections to gas are already felt to the extent of banishing that means of lighting to the passages, offices and bed-rooms. I am, however, of opinion that a revolution even to the extent indicated, must be the work of time, and that while gas will undoubtedly in due course be supplanted by its more brilliant rival for the purposes just indicated, the consumption of gas will be maintained by the increasing area of application resulting from increase of towns, and by additional applications for cooking and for heating purposes, for which gas will supplant the use of solid fuel, and thus confer a new benefit upon mankind by doing away with the nuisance of smoke and ashes. If gas companies only rightly understood their interests, they would themselves take up electric lighting for those purposes for which it has the decided preference, and at the same time promote the application of gas for heating, in doing which they would clearly increase their business as lighting companies, while benefiting the public by providing them with the very best sources of heat and light.

I am, Sir, your obedient servant,

C. William Siemens.

12, Queen Anne’s Gate, Westminster, Oct. 11, 1878.

To the Editor of “The Times.”

Sir,—A letter in The Times of this day’s date by Captain J. T. Bucknill, R.E., points out certain objections to the mode of electric street-lighting suggested by me, and affords me an opportunity, with your kind permission, of explaining my views on this subject rather more fully than I have had occasion to do hitherto.
Captain Bucknill points out very forcibly that in the experiments carried out last spring at the South Foreclands by Professor Tyndall and Mr. Douglass, for the Trinity House, great loss of illuminative effect was observed to result from an increase of electrical resistance of the metallic conductor through which the current is communicated to the lamp from the dynamo-electrical machine. This loss was relatively greater in the case of the Siemens than in that of the Gramme machine, for the simple reason that the former machine had been constructed with little resistance in its own coils, the intention having been to produce quantity rather than intensity of effects. Electricians will readily follow me when I say that the internal resistance of the dynamo machine, or the size, thickness, and length of the insulated wire employed in its construction, should always be made proportionate to the external resistance, comprising the lamp and its leading wires, in order to obtain a maximum effect. It would be as wrong and wasteful to employ a dynamo machine of considerable internal resistance to work through a circuit of little resistance as it is to attempt a greater external resistance with a machine of little internal resistance, such, for instance, as would be suitable for effecting metallic precipitation.

As an example of producing electric light at a considerable distance I may here mention the interesting application by Sir William Armstrong, who lights his library at Craigside successfully with a current produced by a waterfall 1500 yards distant. A Siemens dynamo-machine of the smallest type is employed to generate the current, and this is conveyed to the lamp and back again to the machine by a copper wire of three-tenths of an inch diameter, suspended at intervals from iron posts, and representing a resistance of $1\frac{1}{2}$ units or Ohms. If a waterpipe or the metals of a railway or tramway could have been pressed into service for the return of the current, one-half of the line-resistance might have been saved, or the distance of the light from the source might have been increased to nearly 3000 yards. This would, therefore, be the limit of distance to which the light might be carried in a town, where the water and gas pipes constitute a perfect return wire for any number of electric circuits.

Sir William Armstrong now intends to put up a medium-sized dynamo-machine at the source of water power, and to utilise the
smaller machine as a motor for working the lathes and other tools at his experimental workshop during the daytime, while reserving the faculty of lighting his principal apartments in the evening.

This practical illustration of the power of the electrical conductor serves to show the possibility of application upon a large scale such as I have ventured to suggest. A true comparison between the cost of the electric current and its rival, gas, cannot be instituted until central motor stations are established in populous districts, where steam may be produced at the cheap rate of 2½ lbs. of coal per horse-power per hour, and whence radial conductors may supply the neighbourhood within, say, a mile radius, with both light and also with mechanical power for minor industrial purposes. The realisation of such a system involves the means of subdividing the electric current to a certain extent, a problem which offers no insuperable difficulties when continuous currents are used instead of the reversing currents which have hitherto been mostly resorted to for street lighting.

I do not quite follow Captain Bucknill in his argument that my plan of street illumination (by means of comparatively powerful lights placed 100 yards apart at a considerable height under metallic reflectors) involved comparatively long metallic conductors, which must result in loss of effect, for the mere raising of the light does not constitute a material increase in the length of the conductor, whereas it is well known that working with reversed currents, and the shading of the electric light when placed in the line of ordinary vision by semi-transparent glass globes cut off between 60 and 70 per cent. of the effect. It is, moreover, well known that in order to produce the electric light cheaply it should be effected in as concentrated a form as possible, the reason being that the light increases in the square ratio of the current producing it. The same reasoning points to the fact that extreme subdivision of the light for domestic purposes must be attended with great loss of effect, which loss is vastly increased if it is attempted to dispense with the electric arc and subdivide the mere glow of a wire of platinum or iridium or of a stick of carbon traversed by the current.

We have to be careful not to attempt to purchase our practical results at the expense of principles in nature which will soon
reassert themselves at a time of enlightened competition like the present.

I am, Sir, your obedient servant,

C. WILLIAM SIEMENS.

12, Queen Anne's Gate, S.W., Dec. 12, 1878.

STEEL FOR WAR PURPOSES.

To the Editor of "The Times."

Sir,—Although I have followed the discussion that has recently appeared in the columns of The Times, and in which General Younghusband, Sir J. H. Lefroy, Mr. Krupp, and Mr. Bessemer have taken part, having reference to my lecture before the Royal United Service Institution on the above subject, I have hitherto abstained from taking part in the controversy, and should much have preferred to maintain this reserve if that discussion had not somewhat drifted away from the facts.

In my lecture, and upon all previous occasions of discussing the history of modern steel manufacture, I have spoken with the greatest admiration of the Bessemer process, the achievement of which marks an epoch in the metal industry of the world; but simultaneously with the Bessemer process another process has grown up by my labours and has attained a position of its own as regards the production of certain kinds of steel—notably of those mild steels of uniform quality which are more particularly applicable for war purposes. According to published statistics for 1877 the total quantity of steel manufactured by this, the open-hearth process, was during that year 275,000 tons, and its use has since that time considerably increased, notwithstanding the present extreme depression in trade.

I have no desire to question or limit the ultimate capability of the Bessemer process as regards high and uniform qualities of steel; but Mr. Bessemer's remarks in his letter of to-day would lead the reader to infer that the steel for war purposes actually furnished by Sir Joseph Whitworth, by Krupp of Essen, and by

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the Creusot and Terrenoire Works was produced by the Bessemer process, which is an inference that would be simply inconsistent with the fact that the process with which my name is connected is employed for these purposes by the very works specially mentioned by Mr. Bessemer. With regard to Mr. Krupp’s works, all I know is that he uses my process very largely, although it is commonly reported that in casting his ordnance he still employs the crucible. Sir Joseph Whitworth, in working out his remarkable system of compressing steel in the fluid state, by means of which he has obtained unequalled results as regards the combined qualities of strength, toughness, and uniformity of material, tried, it is true, in the first instance, both steel made in crucibles and in the Bessemer converter; but, as a matter of fact, it should be stated that during the last three or four years he has used no other than open-hearth steel, and has lately erected extensive plant in accordance with my designs.

In your Money Article of to-day you again refer to an interesting trial recently made by Messrs. Boleckow, Vaughan and Co., of Middlesborough, who appear to have succeeded in producing Bessemer metal from Cleveland pig in adapting to their Bessemer converter Mr. Thomas’s lime lining. The success of this process will depend upon the question whether such a lining can be made to stand in practical working and upon the percentage of phosphorus that can be removed through the action of such basic lining; but I confess that my own efforts in 1868 to adapt a basic lining of alumina, magnesia, or lime to the metal chamber of my furnace proved unavailing. One great difficulty I encountered with these linings was that when defective they could not be mended at the end of an operation by the introduction of additional quantities of the same material, which in the case of a silica lining, combine readily with the old material under the influence of intense heat. The mere fact of producing steel from Cleveland material is, however, no novelty, and has been practised to some extent by the use of the open-hearth process; large contracts having for some years been carried out for converting old iron rails into steel rails by some of my licensees.

I am, sir, your obedient servant,

C. WILLIAM SIEMENS.

12, Queen Anne's Gate, S.W., March 19, 1879.
To the Editor of "The Times."

Sir,—Since writing my letter to you under the above heading yesterday I have been informed that Sir Joseph Whitworth and Co. still continue the use of pots in melting steel for tools and other particular purposes, and I shall feel obliged if you will give a place for this correction of my previous statement in your next impression.

I am, sir, your obedient servant,

C. William Siemens.

12, Queen Anne's Gate, Westminster, S.W., March 20, 1879.

REMARKS

Of C. W. Siemens, D.C.L., F.R.S.,

On quitting the Chair of the Iron and Steel Institute.

The President * (Dr. Siemens), in acknowledging the vote of thanks to the President and Council for their services during the past year, said he wished to make a few parting remarks before leaving the chair and handing into it his successor—a gentleman who was so well known to them that he need not say a word in his commendation. What concerned him (Dr. Siemens) more immediately was to give, in a few words, an account of his stewardship during the last two years. Those two years had been years of singular difficulty, not only to the iron trade generally, but to the Institute as well. When he first took the chair they had lost their Foreign Secretary, and immediately after he had assumed office they also lost their General Secretary—a gentleman who had been at the foundation of the Society, and who seemed to be an integral and inseparable part of it. This conjunction of unfortunate circumstances rendered the management of the affairs of the Institute a matter of greater difficulty to those who remained

behind; and he thought that the Institute had proved its vitality in having passed through such a crisis without suffering in any way, and he might now boldly assert that during the last two years its prosperity and influence had been steadily increasing. At the time when, two years ago, he assumed the office of President, the number of members appearing on their books was 946, and at that moment the number did not exceed 941. It seemed thus to follow that the Institute had been going back as far as numbers were concerned; but it must be remembered that two years ago their list of members was not in a very satisfactory condition. Names had been continued on the list which ought to have been erased. Gentlemen had been elected almost without having been sufficiently consulted, and had utterly neglected to pay their subscriptions or to attend to the business of the Institute. The Council thought that the time had arrived when such names should be withdrawn from the register, and a considerable number of names had been accordingly removed. That number had been since recovered to within five, and they had that day candidates on their register (including the newly elected members) amounting to fifty, so that, if all the gentlemen were elected whose names had been passed by the Council, their number would come up to 998, or within two of a thousand. It was a notable fact that the Society had existed exactly ten years, and at the end of that time it counted 1,000 members, thus showing ten years of continued advance and prosperity. As regarded the papers read during the last two years, he should not enlarge upon their merits, but it was well known that they had been of a very interesting character. Twenty-four papers in all had been read, and that day there were presented to them eleven additional papers of more than average interest. They had especially two subjects to discuss which were of paramount interest to every one concerned with steel—namely its production, and its application. Therefore he might say that the Institute had a large balance at its bankers; not its bankers in the ordinary sense of the word, but its intellectual bankers, in the shape of papers to be discussed. The two general autumn meetings which had occurred during his tenure of office had also been of considerable interest. At the Newcastle meeting the attendance had, perhaps, been the largest on record, and the meeting at Paris was one of great interest to all
those who availed themselves of the invitation received from that city. They had had associated with them the leading scientific men and metallurgists of France, and they had been invited to visit its most important works, and had been shewn an amount of cordial hospitality such as they could not soon forget. (Hear, hear.) He had, therefore, great satisfaction in resigning his office that day, and in saying that, at any rate, the Institute had not suffered during the time he had held the honourable position of President. (Hear, hear.) He owed this to those who had supported him more than to his own individual efforts, although those efforts, whatever their shortcomings, had been most cordially given. The President-elect was a gentleman who was well known to them for his great practical knowledge. He had been one of those who had founded the prosperity of the great Cleveland iron district. But although some years ago he professed chiefly that kind of knowledge which they called practical—the knowledge obtained by observation—a remarkable change, he noticed, had of late come over him. He (the President-elect), now spoke of a hundredth per cent. of phosphorus and carbon in steel, as though he had just emerged from the laboratory of the School of Mines, and he had proved in his own person the great importance of the change wrought in the opinions of practical metallurgists through the operations of the Iron and Steel Institute. After all there was no essential difference between knowledge obtained by observation and knowledge obtained through study, and it seemed absurd for one man to say "I prefer one method of obtaining knowledge," and for another to say "I prefer knowledge obtained in another way." It was only the conjunction of study and observation that constituted perfect knowledge, or such knowledge as was productive of useful results. It was for the extension of such knowledge that the Institute existed, and for such knowledge it had done good service. He had great pleasure in introducing into the chair his successor, their President-elect, Mr. Williams. (Cheers.)
ON TECHNICAL EDUCATION.*

An Address delivered at the Distribution of Prizes, &c., to Students of the Belgrave Mechanics' Institute, Tunbridge Wells, on the 9th December, 1879,

BY C. WILLIAM SIEMENS, F.R.S.

DR. SIEMENS, having expressed the great pleasure it had afforded him to distribute the prizes, said that when their chairman told them he (Dr. Siemens) would deliver an interesting and instructive address on the arts and sciences, he reckoned rather without his host.

He had not attended that evening to enlighten them, but had come amongst them on account of the deep interest he felt in the development of science and art. It was with a view of showing the sympathy he felt with them in their doings there that he responded to the invitation to attend and distribute the prizes.

He must congratulate first of all the managers of that school of science and art on the very excellent results which had been laid before them that evening, and next the managers who directed the classes and organisations of an institution like this, the teachers deserved praise for the assiduity and zeal they had displayed in bringing their students forward to such a point as to come out in the general competition with such excellent results. And while it was most gratifying to the management, they must not leave out their very zealous and excellent secretary (Mr. Skillen), who deserved a considerable amount of praise.

But really congratulation was deserved most by those students who had taken the prizes. It must not only be a gratification—a very great gratification—to them to feel they had done their duty, and had given proof that they really had striven for good results, but he would congratulate them chiefly on account of the solid nature of the information which they had attained, and which was capital for them to start life with—capital

which was better than any other that could be handed down to
them— a capital that would ever increase and always produce
good fruits.

Science and art schools had in recent years been greatly
developed, and one would think that development was most
natural in the great centres of industry such as Manchester,
Birmingham, Liverpool, and such like places. But it was most
gratifying to find in a secluded town like Tunbridge Wells, where
manufacture was not carried on in such a prominent manner as in
the great towns he had mentioned, that the work of instruction
in science and art went on steadily, showed year by year better
results, and brought forth fruit. When he spoke of fruits he
did not mean pounds, shillings, and pence only, but fruits which
would be more permanent than that.

The time was, indeed, when this county of Kent was an
industrial centre, and when the iron smelting of the country was
done chiefly in Kent and the neighbouring county of Sussex.
How little industry was thought of 300 years ago might be
gathered from the fact that in Queen Elizabeth’s time an Act
was passed for the purpose of putting down iron smelting in this
county, inasmuch as it was regarded simply as a nuisance, as it
used up a great deal of timber from the forests, and interfered
consequently with deer hunting, which was then one of the great
national pastimes.

The consequence of that Act was that iron smelting lingered
and lingered till two centuries later, when Dudley, a plain
common sense man, conceived the idea of smelting iron by
means of stone coal, as it was then called, instead of wood. He
put the coal into an oven, and burnt it into coke, with which
he smelted the iron, and found that it performed the operation
just as well as charcoal. This laid the foundation of that mighty
industry of this country, which was now one of the chief sources
of our national wealth.

It was not, however, till little more than a century ago that a
mighty impulse was given to another great industry in Lancashire
by Compton and Arkwright, who first developed mechanical cotton
spinning. Now, instead of a million persons using spinning
wheels, there was one machine in Manchester which would perform
an equal amount of work.
This gave rise to another mighty impulse, which tended to make this country the workshop of the world. It was probably the greatest of all the mighty impulses to which he could allude. He alluded to what was done by Newcomen, also a man of this neighbourhood, and after him came Watt, who completed the steam engine, which revolutionised the whole civilised world.

To the three great inventions already mentioned, might be added that by Cort, of converting cast iron into wrought iron by the quick process of puddling and rolling instead of by the slow process of flushing fires and hammers. This produced an outlet and great development to the system introduced by Dudley.

It was through these inventions that England became the greatest industrial producing country of the world; but another race of men were required to give application to these great discoveries. These were Fletcher and Bell, who first placed a steam engine on a ship and propelled that ship over the ocean to all parts of the world; and next came a man whose name would be known to the end of the world—George Stephenson, a colliery workman—who saw that this steam engine could be put on wheels, and carry loads on wheels from one end of the country to the other. These were the two inventions which had given us the steam engine in a practical form, and had so developed it that it passed goods and passengers from place to place in much less time and with much less expenditure of labour and money than could be done under the systems previously in vogue.

Now it might be said that the men he had mentioned were none of them scientific men, that they were men who had risen from the ranks, who by their indomitable perseverance, their genius, and their self-tuition had accomplished these extraordinary results, and it might be asked why should we then trouble ourselves much about technical education when, without it, such results had been produced; and it might be said that surely without it we might go on prospering and keep our foremost position among nations. Such arguments would be very fallacious. A man of genius made his way in whatever position he might be placed, and the very difficulties he had to encounter in early life were the hard discipline and education of mind, which enabled him to battle with and conquer the
still greater difficulties which crossed his path later on in life. He did not think he need further combat the arguments he had referred to.

What the great men he had mentioned had produced in the shape of steam engines, railways, steam navigation, surely these inventions and the various works for the production of iron, cotton, fabrics, and so on, all require intelligent supervision, and such intelligent supervision could not be given by those who were ignorant, but by persons who must have knowledge of the processes which were being carried on. If the persons in charge had not the necessary knowledge, the comfort, happiness, and even the lives of Her Majesty’s liege subjects would be sacrificed in various ways. It would not therefore be safe for them to trust themselves, their lives, convenience and comfort to illiterate persons—to persons without knowledge of the processes they had to superintend and direct. It was there where technical education became a necessity.

He would go even further, and say that this education had been for some length of time neglected in this country. We had been content with our position, and had rather allowed things to go on as they were, until we saw on the other side of the channel that the nations of the continent had established schools for higher and lower education, and had by that means produced classes of men eminently qualified for superintending their railways, their telegraphs, and other works, and by dint of that intelligence and information, they had been able to raise up a very powerful competition.

It would be wrong to suppose that the natural wealth of coal, iron, and such other products were confined to this island. Nothing of the sort. In other countries there were vast deposits of these minerals. In the United States there were deposits of coal, perhaps ten times more important in volume than ours, and the ironstone was infinitely more important also. Therefore the race of competition had truly set in between nation and nation, and it was a competition and warfare that redounded to the honour and profit of all parties concerned, and for one he hoped the time was not far distant when civilised nations would confine their warfare to the production of means for the comfort and development of the human species, instead of excelling one another in the thick-
ness of their armour-plates and the perfection of their engines for the destruction of one another.

These institutions, therefore, for the spread of science and art education had become an absolute necessity, and having been once taken up in this country, not under the absolute superintendence of the Government, but by the aid of the Government, with a certain amount of supervision they were sure to lead to greater results than if they had simply followed the lead of some continental nations who looked to their governments only for the establishment of such schools.

There was one point which he might perhaps be allowed to call attention to, and that was the education of the schoolmasters themselves. No doubt there were many excellent schoolmasters busy now in the different schools of art and science, but he thought that something would have to be done to produce teachers of really high efficiency in greater numbers. It was there that the shoe pinched at the present time. It was one thing to know a subject sufficiently well to pass an examination in it, but it was quite another thing to be able to teach that art or science to others. In order to do so, teachers must not only know absolutely what they taught, but they must know also what relation there was between that branch of science and other sciences. A teacher must in fact be a man of general education. There was, he thought, still much room for improvement in this respect.

The first prizes he had to present were given to young ladies—and these were, he thought, the very best prizes of all, seeing that they were gained in a national competition in London. They were art prizes, but they knew also that young ladies had taken prizes for electricity and magnetism, and other branches of science which showed how capable they were of grappling with science as well as art. The interest that ladies took in the present day in all branches of education was moreover shown by the fact that the school board in London was now composed of two thirds gentlemen and one third ladies. This showed also that the ladies were perfectly capable of discharging many duties which were confined formerly entirely to men.

Referring to the working of telegraphic machines, he said he believed that young women were quicker than men at that work,
and he thought it a great pity that the Post Office authorities at present discourage the employment of young ladies in the telegraph service. One would almost think from the number of students in electricity and magnetism that the art of attraction was peculiarly there. He did not think this was so, but there was no getting away from the fact that the telegraphic art was a sphere in which there was a great field for the exercise of ability.

We were now, it might be thought, at the end of discovery; we had steam engines and gas lighting and railways, the electric telegraph, and everything except flying. He did not believe in our ability to fly, but they need never fear that they were coming to the end of discovery and invention.

There were new branches of science coming very near to the surface at this moment, one of which, personally, he took a great deal of interest in, and which was attracting a good deal of attention, and that was lighting by electricity. He believed that electricity was destined not only to become the most powerful luminant that could come into competition with gas without doing away with the necessity for it, but electricity was also destined to perform other very important functions for us. By electricity we could convey motive power from one place to another, with the least amount of loss, and the greatest amount of comfort, and so fully convinced was he of the applicability of electricity for that purpose that three years ago, when president of the Iron and Steel Institute, in his address to the members, he gave a calculation of the power which was lost through great waterfalls not being utilised.

Shortly before that time he had stood under the falls of Niagara, and after his first feelings of astonishment and wonder at the greatness of the falls, he went into a calculation as to the power the fall of water there really represented. He was astonished to find that the force lost at this one place was equal to the force of all the coal raised throughout the world. That was to say that if the whole of the coal raised annually throughout the world—260 million tons—was brought to the place and consumed in boilers the engines which all the boilers would work would be just about sufficient to raise the water up again. They would see that a force was here lost that was equal to all the energy we laboriously took from the mines of this and other countries, and it showed
that even if our coal supplies came to an end, as in course of time they would, we should not be altogether left without resources, but should be able to utilise those numerous forces in nature, which we now hardly looked at, but which in time would perhaps be the mainstay of our existence. Of course with such a change there would come a great variety of new arts and new industries, to employ those powers in this and that direction, and there would be ever new fields opening out for the exercise of their intelligence, which was after all the greatest gift they had received from their Creator.

What he might say was that it constituted the condition of civilised man. No doubt we had a moral elevation given by religion, art, and letters, but after all we could not exist without the material domination of the world. In the earliest times man lived only a little removed from the natural condition of the animal. He, however, soon gained some efficiency, such as using the bow and arrow, and making animals subservient to him and employing them for draught and other purposes. Then he tilled the ground, grew corn and similar products, and step by step advanced until we had arrived at the present state of society, in which man no longer was made to do the drudgery of work which devolved on him formerly. There had also taken place a great advance of mental activity, and we were, he contended, on the threshold of that period when the great forces of nature would be more fully employed, and when man would rise to the position which he believed we were destined to hold.

He thanked them for the patience with which they had listened to the few remarks he had made, and before sitting down he begged again to congratulate the institution on the sound position it seemed to be in, and the good progress everything seemed to have made.

A vote of thanks to Dr. Siemens for his address was carried with acclamation.

Dr. Siemens, in acknowledging the compliment paid him, said he thanked them very much for the kind manner in which the vote of thanks had been proposed and seconded, and also for the kind way in which they had adopted it. He was a comparative stranger in this neighbourhood. Rather more than thirty years
ago he came to this country a stranger, and finding there was
great scope for activity in the pursuits he so much loved and
liked, he made this country his home. He had made a great
many dear friends, and his efforts to advance applied science had
always been so cordially accepted, and had gained him so many
friends amongst all classes that he had adopted England as his
country, and hoped to live and die here. He had secured a resi-
dence for the summer months in this particular neighbourhood,
and he hoped, as his work in the active pursuits of life became
more and more accomplished and drew to a close, he should have
more leisure to spend amongst them. It was a particular gratifi-
cation to him to be present amongst them that evening, and to
see the activity which was going on in the development of
scientific subjects, and also in the pursuits of art. He could not
help thinking that the interest shown augured well for the future.
Again he thanked them very much for the compliment they had
paid him.

ELECTRICITY AND GAS.

TO THE EDITOR OF "THE TIMES."

SIR,—Mr. W. H. Preece, in addressing you under the title of
"Electricity in Collieries" on the 28th ult., points out, very
properly I think, that the employment of the electric light would
not be without danger in coal mines, because both the electric arc
and an accidental spark between conductors would be liable to fire
a gaseous explosive compound. When examined before the Royal
Commission on accidents in mines, I gave evidence to this effect
suggesting only an indirect application of the electric light, by
which, if successful, the chance of accident would be minimized. I
am not prepared however to follow Mr. Preece in his assertion that
electric light generally and under ordinary circumstances is an
illuminant dangerous to life and property; his statements in this
respect have actually caused unnecessary alarm to those who have
trusted electricity for the illumination of public buildings. Mr.
Preece says that "if a mere crack or pinhole were to occur in an insulating coating the currents would escape to earth, generating heat and producing fire," emphasizing this statement by asserting that it is not a chimical one, but the result of practical information of his own. Now, the dynamo-electric current is powerful in the sense of doing a large amount of work, but its intensity is so moderate that it is only by rubbing the two unprotected conductors against one another that vivid sparks are produced. The interposition of a shaving of wood or other inflammable substance would in itself supply a sufficient insulating separator to prevent the spark, and I challenge Mr. Preece, notwithstanding his well-known skill as an experimenter, to the production of an igneous discharge through a mere pinhole in the insulating covering of one or other of the conductors. In practically arranging electric lights for public buildings the insulated conductors are entirely separate, and the likelihood of danger to buildings is absolutely removed by the precautions taken. Mr. Preece's reference to the unfortunate musician and Russian sailor who appear to have been struck dead by electric discharges while assisting to put up electric lights, is somewhat sensational. They must have been predisposed to succumb to an electric shock, and must have grasped firmly the two unprotected leading wires with moist hands; for I and many other persons have frequently touched both poles of a powerful dynamo machine without feeling any the worse for it. At the same time there are dangers connected with the establishment of this, as of almost any apparatus or machinery, which do not in any way apply to the user not set upon courting danger. Mr. Preece also charges the electric light with being cold in appearance, but in reality "the greatest source of heat which science possesses." Now, I quite agree with him in this latter proposition, and have, indeed, constructed an electric furnace for fusing highly refractory materials; but I wish to guard against the inference that because the electric arc is hot, electric light must necessarily heat rooms in which it is employed to anything like the same extent as gas or, indeed, any other illuminant. The following simple calculation, based upon actual experiment, will show what is the relative heating effect of the two sources of light within a room. To produce 4000 candle-power by electricity requires a current of 34 Webers, which again represents 130 heat units per
minute. To produce the same amount of light by gas takes
200 Argand burners, consuming 16 cubic feet of 20-candle gas
per minute, which consumption represents 15,000 heat units.
Some additional heat will be produced in the electric arc, however,
by the combustion of the carbon electrodes, which consumption
amounts to 6.3 grains of carbon per minute, and will produce in
combustion 12.5 heat units. The total amount of heat produced
by the electric arc is, therefore, 130 + 12.5 = 142.5 units per
minute, or rather less than 1 per cent. of the heat developed with
the same amount of light by means of gas. Gas light produces,
moreover, the further inconvenience of displacing the oxygen of
the air by carbonic acid, and by a minor, but still very sensible
amount of sulphurous acid.

If this calculation militates against gas as an illuminating agent,
it proves, on the other hand, its great value as a heating agent;
and just now, when so much is said about the smoke nuisance, I
may be allowed to add a few words on that subject. For upwards
of twenty years I have been actively engaged upon the develop-
ment of a system of working furnaces for the manufacture of
iron, steel, glass, &c., by means of gas fuel produced in a simple
gas-generating apparatus. Some thousands of these gas producers
are in operation, and furnish daily proof that gas may be used
with economical results; and the smoky factory chimney,
where it still exists, proves simply a disregard for principles of
economy. In the year 1858 I was anxious to take a further step
in the same direction in proposing to supply towns with heating
gas, and, having induced the Town Council of Birmingham to
support my plans, measures were taken to obtain Parliamentary
power to carry them into effect. It was intended to separate the
two constituents of coal by a comparatively inexpensive method,
supplying gas of low illuminating, but high heating power to
consumers at a cheap rate, and reserving the coke for use in loco-
motive engines and stoves, for which purpose it is eminently better
suited than raw fuel. Unfortunately, the bill was thrown out by
a Committee of the House of Lords, in consequence of the oppo-
sition of the existing gas companies, and the proposal has remained
in abeyance ever since. While it is admitted by many that gas
fuel can be used advantageously for heating furnaces, there still
exists great objection to its use upon the domestic hearth, which
is one of the largest sources of consumption of raw coal, and certainly the cause of a great amount of smoke in our metropolis. The gas fireplace sometimes used does not meet with public favour, owing to its uncheerful appearance, great consumption of gas, and, most of all, from the smell which frequently results from its use. It is said to produce a "dry" heat—a term which, to my mind, conveys no definite meaning, seeing that the heat produced by an open fireplace is purely radiated heat, precluding the idea of moisture; but I have observed that in the usual gas-grates, consisting of a number of gas jets spread over the grate, and covered in with pumice or asbestos, the heavy gases resulting from the combustion descend through the grate bars, and thus find their way into the apartment.

I have lately constructed in my own house gas-grates that are certainly free from the defect just named, and which are at the same time economical and cheerful in their appearance. The arrangement consists in substituting for the fire-grate below a solid plate, so as to exclude all communication with the atmosphere, except through the front bars. A gas-pipe perforated above with a certain number of small holes is connected to the ordinary gas service. The grate is filled with ordinary gas-coke or anthracite, banked up well towards the back. In this way a cheerful fire can be kindled at any time by opening the gas-tap and putting a lighted match to the grate. The gas flames, acting only in front of the grate, soon cause the surface of the coke to glow, without depriving the beholder of the cheerful appearance of the flame. In the course of half-an-hour the surface of the heap of coke is fairly red hot, throwing out fully as much heat as an ordinary fire, while not a particle of flame or smoke reaches the chimney; the combustion of the gas prevents the rapid consumption of coke in front, and the absence of air its consumption towards the back of the fire. When fairly ignited the gas may be almost turned off because the coke, once well heated, continues its glow by slow combustion with the atmosphere. An ordinary grate may be converted into a coke gas-grate as just described at a very trifling cost, and will be found convenient and inexpensive in its use even when using illuminating gas at 3s. 6d. per thousand cubic feet. Its economy may be materially increased by a sort of regenerative arrangement, by which the heat gradually accumulating at the
back of the fire is utilized to supply the gas flame with a current of hot air—an arrangement which it would take too much space to describe, but which I shall be happy to place at the disposal of the association recently formed with the laudable object of improving our winter atmosphere.

I am, sir, your obedient servant,

C. WILLIAM SIEMENS.

12, QUEEN ANNE'S GATE, S.W., NOV. 2, 1880.

TELEGRAPH WIRES.

TO THE EDITOR OF "THE TIMES."

SIR,—Among the causes of danger and inconvenience which the snowstorm of yesterday has created, none will be felt more keenly by the public than the partial interruption of the telegraphic communication throughout the country, and it may be interesting to inquire whether such occasional interruption of telegraphic traffic is a necessary evil connected with this great achievement of recent times, or is attributable to preventable causes. It would not be difficult to prove that such interruptions are entirely preventable by a reconstruction of our telegraphic system in a more permanent manner. This would involve considerable expenditure, it is true, but an expenditure that would very soon recoup itself through a greatly reduced cost of maintenance. There would be immunity, moreover, from those causes of interruption, great and small, which constitute a daily source of trouble to the operator, and which, upon such occasions as yesterday, throw us suddenly back to the condition of the pre-telegraphic age. By the substitution of underground for suspended line wires, the causes of uncertainty attaching still to the land telegraphic system of the day would be entirely removed, together with the danger and unsightliness inseparable from tall wooden poles strained to the utmost by their load of suspended wires, placed along our railways and public thoroughfares. Proof is not wanting in favour of an
underground system of land telegraphy. When, in the year 1846, the Prussian Government decided upon the construction of electric telegraphs it adopted an underground system, which did not prove practically successful, owing to a want of experience in insulating the conductors, and in protecting them against the attacks of animals and of gradual decay. The German Government, nothing daunted by the comparative failure of these early experiments, decided five years ago to resort again to the underground system for the principal lines of communication throughout the country. So complete has been their success that, after having laid down some 8000 miles of underground insulated wire, they have resolved upon a considerable further extension. The plan adopted in Germany consists in enclosing seven or more insulated conductors within a core of moist hemp, surrounded by a complete sheath of iron wire, which again, is covered with a layer of hemp yarn, impregnated with a protecting compound. These land cables are wound upon drums at the sheathing works, and after being subjected to careful electrical tests are paid out into trenches 3 feet deep, and covered up.

I may state, I think, without fear of contradiction, that on these 8000 miles of underground wires, part of which have now been down for five years, no expenditure for maintenance has been incurred, and, judging by the perfect condition of the cables, it is not likely that any repair will be required for many years to come. Taking this immunity from decay and also from wear and tear into account, I am convinced that the underground system is not only the most perfect, but will also prove to be the cheapest in the end, and an occurrence like that of yesterday furnishes perhaps a fitting opportunity of calling, through your courtesy, public attention to this important matter.

I am, sir, your obedient servant,

C. William Siemens.

12, Queen Anne's Gate, January 19, 1881.
GAS AND ELECTRICITY AS HEATING AGENTS,

A Lecture delivered at Glasgow on Thursday, 27th January, 1881, under the auspices of the Glasgow Science Lectures Association.

BY C. WILLIAM SIEMENS, D.C.L., LL.D., F.R.S.

On the 14th of March, 1878, I had the honour of addressing you "On the Utilization of Heat and other Natural Forces." I then showed that the different forms of energy which Nature has provided for our uses, have their origin, with the single exception of the tidal wave, in solar radiation; that the forces of wind and water, of heat and electricity, are attributable to this source, and that coal forms only a seeming and not a real exception to the rule,—being the embodiment of a fractional portion of the solar energy of former geological ages.

On the present occasion I wish to confine myself to one branch only of the general subject, namely, the production of heat energy. I shall endeavour to prove that for all ordinary purposes of heating and melting, gaseous fuel should be resorted to, both for the sake of economy, and in order to do away with that bugbear of the present day, the smoke nuisance, but that for the attainment of extreme temperatures the electric arc possesses advantages, unrivalled by any other known source of heat.

Carbonaceous material such as coal or wood is practically inert to oxygen at ordinary temperatures; but if wood is heated to 295° C. (593° Fahr.), or coal to 326° C. (617° Fahr.), according to experiments by M. Marbach, combination takes place between the fuel and the oxygen of the atmosphere, giving rise to the phenomenon of combustion. It is not necessary to raise the whole of the combustible material to this temperature, in order to continue the action; the very act of combustion when once set in, gives rise to a development of heat more than sufficient to prepare additional carbonaceous matter, and additional air for entering into combination; thus a match suffices to ignite a shaving, and this in its turn to set fire to a building.

The first effect of combustion is therefore to heat the combus-
tible and the air necessary to sustain combustion to the temperature of ignition, but in dealing with the combustible called coal other preparatory work has to be accomplished besides mere heating in order to sustain combustion. The following is an analysis taken from Dr. Percy's work on "Fuel" of a coal from the Newcastle district:—

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>81.41</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>2.05</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>5.83</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.74</td>
</tr>
<tr>
<td>Oxygen</td>
<td>7.90</td>
</tr>
<tr>
<td>Ash</td>
<td>2.07</td>
</tr>
</tbody>
</table>

which shows at a glance that nearly 16 per cent. of the total weight of the fuel consists of such permanent gases as hydrogen, oxygen, and nitrogen. These gases are partly occluded or absorbed within the coal, and are partly combined with carbon, forming such volatile compounds as the hydrocarbons and ammonia, so that when coal is subjected to heat in a closed retort, as much as 34 per cent. in weight passes away from the retort in a gaseous condition; a portion of this condenses again in the form of water, tar, and ammoniacal liquor, and the rest passes into the gas mains as illuminating gas, a mixture mainly of marsh gas (CH₄), olefiant gas (C₂H₄), and acetylene (C₂H₂). The result of the distillation of a ton of coal will be as follows, from data with which Mr. Alfred Upward has kindly supplied me:—

<table>
<thead>
<tr>
<th>Product</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coke</td>
<td>13.60</td>
</tr>
<tr>
<td>Tar</td>
<td>1.20</td>
</tr>
<tr>
<td>Ammoniacal liquor</td>
<td>1.45</td>
</tr>
<tr>
<td>Gas</td>
<td>3.15</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>0.18</td>
</tr>
<tr>
<td>Sulphur removed by purifying</td>
<td>0.30</td>
</tr>
<tr>
<td>Loss</td>
<td>0.12</td>
</tr>
</tbody>
</table>

So great is the loss of heat sustained in an ordinary coal fire, in consequence of this internal work of volatilization, that such a fire is scarcely applicable for the production of intense temperature effects; and it has been found necessary to deprive the coal in the first place of its volatile constituents (to convert it into coke) in order to make it suitable for the blast furnace, for steel melting, and for many other purposes where a clear intense heat is required,
In the ordinary coke oven the whole of the volatile constituents are lost, and each 100 lbs. of coal yield only 66 lbs. of coke, including the earthy constituents which on a large average may be taken at 6 lbs., leaving a balance of 60 lbs. of solid carbon. In burning these 60 lbs. of pure carbon, 220 lbs. of carbonic anhydride (CO₂) are produced, and in this combination 60 \times 14,500 = 870,000 heat units (according to accurate determinations by Favre and Silbermann, Dulong, and Andrews) are produced.

The 34 per cent. of volatile matter driven off yield, when the condensible vapours of water, ammonia, and tar, are separated, about 16 lbs. of pure combustible gas (being equal to about 10,000 cubic feet per ton of coal), which in combustion produce about 16 \times 22,000 = 352,000 heat units. The escape of these gases from the coke-oven constitutes a very serious loss, which may be prevented, to a great extent at least, if the decarburization is effected in retorts. The total heat producible from each 100 lbs. of coal is in that case 870,000 + 352,000 = 1,222,000, or 12,220 units per lb. of coal. Deduction must, however, be made from this, for the heat required to volatilize 34 lbs. of volatile matter in every 100 lbs. of coal used, and also to heat the coke to redness, or to say 1000° Fahr. Considering the multiplicity of gases and vapours produced, it would be tedious to give the details of this calculation, the result of which would approximate to 60,000 heat units, or 600 units per lb. of coal treated. We thus arrive at 12,200 - 600 = 11,600 heat units as the maximum result to be obtained from 1 lb. of best coal. Considering, however, that the coal commonly used for industrial purposes contains a larger quantity of ashes and water than has been here assumed, a reduction of say 10 per cent. is necessary, and the calorific power of ordinary coal may fairly be taken at 10,500 units per lb.

In comparing these figures with those obtained in actual practice, it will be found that the margin for improvement is large indeed. Thus in our best steam engines we obtain one actual HP. with an expenditure of 2 lbs. of coal per hour (the best results on record being 1.5 lb. of coal per indicated HP.). A HP. represents 33,000 \times 60 = 1,980,000 foot-lbs. per hour, which is \( \frac{1,980,000}{2} = 990,000 \) foot-lbs., or units of force, per lb. of fuel. Dr. Joule has shown us that 772 foot-lbs. represent one unit of heat, and
1 lb. of coal therefore produces \( \frac{990,000}{772} = 1282 \) units of heat, instead of 10,500, or only one-eighth part of the utmost possible effect.

To melt steel in pots in the old-fashioned way still practised largely at Sheffield, 2\(\frac{1}{2}\) tons of best Durham coke are consumed per ton of cast steel produced. The latent and sensible heat really absorbed within a pound of steel in the operation, does not exceed 1,800 units, whereas 2\(\frac{1}{2}\) lbs. of coke are capable of producing 18,050 \(\times\) 2.5 = 32,625 units, or 18 times the amount actually utilized.

In domestic applications the waste of fuel is also exceedingly great, but it is not easy to give precise figures representing this loss, owing to the manifold purposes to be accomplished, such as cooking and the heating and ventilating of apartments. If ventilation might be neglected, close stoves such as are used in Russia would unquestionably furnish the most economical mode of heating our apartments; but health and comfort are after all of equal importance with economy, and these are best secured by means of an open chimney. Not only does the open chimney give rise to an active circulation of air through our rooms, which is a necessity for our well-being, but heat is supplied to them by radiation from incandescent material instead of by conduction from stove surfaces; in the one case the walls and furniture of the room absorb the luminous heat rays, and yield them back to the transparent air, whilst, in the latter case, the air is the first recipient of the stove heat, and the walls of the room remain comparatively cold and damp, giving rise to an unpleasant musty atmosphere, and to dry rot or other mouldy growth. The adversaries of the open fire-place say that it gives warmth on only one side, but this one-sided radiant heat produces upon the denizens of this somewhat humid country, and indeed upon all unprejudiced people, a particularly agreeable sensation; which is proof I think of its healthful influence. The hot radiant fire imitates indeed the sun in its effect on man and matter, and before discarding it on the score of wastefulness and smokiness, we should try hard I think to cure it of its admitted imperfections.

If incandescent solid matter is the main source of radiant heat, why, it may be asked do we not resort at once to coke for our
domestic fuel? The reasons are twofold; coke is most difficult to light, and when lighted looks cheerless without the lively flickering flame.

The true solution consists, I venture to submit, in the combined application of solid and gaseous fuel brought thoroughly under control, by first separating these two constituents of coal. I am bold enough to go so far as to say that raw coal should not be used as fuel for any purpose whatsoever, and that the first step toward the judicious and economic production of heat is the gas retort or gas producer, in which coal is converted either entirely into gas, or into gas and coke, as is the case at our ordinary gas works.

When in the early part of the present winter London was visited by one of its densest fogs, many minds were directed towards finding a remedy for such a state of things. In my own case it has resulted in an arrangement of fire-grate which has met with a considerable amount of favour and practical success (there being some two hundred now in operation), and I do not hesitate to recommend it to you also for adoption.

One arrangement of this grate is represented in Figure 1, Plate 5. The iron dead plate $c$ is riveted to a stout copper plate $a$ facing the back of the fire-grate, and extending five inches both upwards and downwards from the point of junction. The dead plate $c$ stops short about an inch behind the bottom bar of the grate to make room for a half-inch gas-pipe $f$, which is perforated with holes of about one-sixteenth of an inch diameter placed at distances of one and a half inch along the inner side of its upper surface, at an angle of about 50° from the vertical. This pipe rests upon a lower plate $d$, which is bent downwards towards the back so as to provide a vertical and horizontal channel of about one inch in breadth between the two plates. A trap-door $e$, held up by a spring, or counterweight, is provided for the discharge of ashes falling into the horizontal channel. The vertical channel is occupied by a strip of sheet copper $b$ about four inches deep, bent in and out like a lady's frill and riveted to the copper back piece. Copper being an excellent conductor of heat, and this piece presenting (if not less than a quarter of an inch thick) a considerable sectional conductive area, transfers the heat from the back of the grate to the frill-work in the vertical channel. An air current is
set up by this heat, which, after passing along the horizontal channel, impinges on the line of gas flames and greatly increases their brilliancy. So great is the heat imparted to the air by this simple arrangement, that a piece of lead of about half a pound in weight introduced through the trap-door into this channel melted in five minutes, proving a temperature exceeding 619° Fahr. or 326° C. The abstraction of heat from the back has moreover the advantage of retarding the combustion of the coke there while promoting it in front of the grate.

The sketch represents a fireplace at my office, in a room of 7,200 cubic feet capacity facing the north. I always found it difficult during cold weather to keep this room at 60° Fahr. with a coal fire, but it has been easily maintained at that temperature since the grate has been altered to the gas-coke grate just described.

In order to test the question of economy, the gas consumed in the grate is passed through a Parkinson’s 10-light dry gasmeter, and the coke used is carefully weighed.

The result of 66 days’ campaign of eight hours each, has been a consumption of 4100 cubic feet of gas, 1112 lbs. of coke and 581 lbs. of smokeless coal (the fuel remaining in the grate being in each case put to the debit of the following day). Calculating the gas at the average London price of 3s. 6d. per 1000 cubic feet, the coke at 18s. a ton, and the coal at 20s. a ton, the account stands thus:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4100 cubic feet of gas at 3s. 6d. per thousand</td>
<td>0 14 4</td>
</tr>
<tr>
<td>1112 lbs. coke at 18s. a ton</td>
<td>0 9 0</td>
</tr>
<tr>
<td>581 lbs. smokeless coal at 20s. a ton</td>
<td>0 5 2</td>
</tr>
<tr>
<td>Total</td>
<td>1 8 6</td>
</tr>
</tbody>
</table>

or a cost of 0.518d. per hour. In its former condition as a coal-grate the consumption exceeded generally two and a half large scuttles a day, weighing 19 lbs. each, or 47 lbs. of coal, which at 23s. a ton equals 5.7d. for nine hours, being 0.633d. per hour. This result shows that the coke-gas fire, as here described, is not only a warmer but a cheaper fire than its predecessor; with the advantages in its favour that it is lit without necessitating the
trouble of laying the fire, as it is called, and that it keeps alight without requiring to be stirred, that it is thoroughly smokeless, and that the gas can be put off or on at any moment, which in most cases means considerable economy.

A second and more economical arrangement as regards first cost is shown in Figure 2, Plate 5, and consists of two parts which are simply added to the existing grate, viz. —the gas-pipe $d$ with a single row of holes about $\frac{1}{8}$ inch diameter, 1·5 inch apart along the upper side inclining inward, and an angular plate $a$, of cast iron, with projecting ribs $b$, extending from front to back on its under side, which serve the purpose of providing the heating surface produced by the copper plate and frill-work in my first arrangement. In using iron instead of copper it is necessary however to increase the thickness of these plates and ribs in the inverse ratio of the conductivity of the two metals, or as regards the back plate, from $\frac{1}{2}$ to $\frac{3}{4}$ inch, according to Sir William Thomson's most recent determination. This would be a very inconvenient thickness, and in order to reduce it the construction is altered so as to let the conducting ribs run horizontally rather than vertically.

An inclined plate $d$ fastened to the lower grate bar, directs the incoming air upon the heating surfaces and provides at the same time a support for the angular and ribbed plate which is simply dropped into its firm position, between it and the back of the grate.

The front edge of the horizontal plate has vandyked openings $c$, forming a narrow grating, through which the ashes produced by the combustion of the coke or anthracite in the front part of the grate discharge themselves down the incline towards the back of the hearth, where an open ash-pan may be placed for their reception.

In adapting the arrangement to existing grates, the ordinary grating may be retained to support the angular plate which has in that case its lower ribs cut short, to the level of the horizontal grate.

But, it may be asked, are you sure that the coke and gas grate you advocate will do away with fogs and smoke? My answer is, that it will certainly do away with smoke, because the products of combustion passing away into the chimney are perfectly transparent. Mr. Aitken has, however, lately proved, in an interesting
paper read before the Royal Society of Edinburgh, that even with perfect combustion a microscopic dust is sent up into the atmosphere, each particle of which may form a molecule of fog. We have evidence indeed, that the whole universe is filled with dust, and this is, according to Professor Tyndall, a fortunate circumstance, for without dust we should not have a blue but a pitch black sky, and on our earth we should be, according to Mr. Aitken, without rain, and should have to live in a perpetual vapour bath. The gas fires would contribute, it appears, to this invisible dust, and we should, no doubt, continue to have fogs, but these would be white fogs, which would not choke and blacken us. It seems, moreover, reasonable to suppose, that perfect combustion cannot contribute materially to the formation of even microscopic dust, and that with the suppression of smoke our town atmosphere would become as clear at any rate as that of Philadelphia and other American cities where anthracite is the fuel used.

Granted the cure of smoke, it might still be questioned whether such a plan as here proposed could be carried out, on so large a scale as to affect our atmosphere, with the existing mains and other plant of the gasworks. If gas had to be depended upon entirely for the production of the necessary heat, as is the case with an ordinary gas and asbestos grate, it could easily be proved that the existing gas mains would not go far to supply the demand; each grate would consume from 50 to 100 cubic feet an hour, representing in each house a consumption exceeding many times the supply to the gaslights. My experiments prove, however, that an average consumption of from 6 to 8 cubic feet of gas per hour, suffices to work a coke-gas grate, on the plan here proposed. This is about the consumption of a large Argand burner, and therefore within the limits of ordinary supply.

But independently of the practical question of supply it is desirable on the score of economy to rely upon solid carbon chiefly for the production of radiant heat for the following reason:—

1000 cubic feet of ordinary illuminating gas weigh 34 lbs., and the heat developed in their combustion amounts to about $34 \times 22,000 = 748,000$ heat units. One pound of solid coke develops in combustion, say, 13,400 heat units (assuming 8 per
cent. of incombustible admixture) and it requires \( \frac{748,000}{13,400} = 56 \text{ lbs.} \),
or just half a hundredweight, of this coke to produce the same
heating effect as 1000 cubic feet of gas. But 1000 cubic feet of
gas cost on an average 3s. 6d., and half a hundredweight of coke
not more than 6d. (at 20s. a ton), or only one-seventh part of the
price of gas.

If heating gas could be supplied at a much cheaper rate than
at present, it would in many cases be advantageous to substitute
incombustible matter, such as balls of asbestos for coke or anthra-
cite. The consumption of gas would in that case have to be
increased very considerably, but the economical principle involved
(that of heating the air of combustion by conduction from the
back of the grate) would still apply, and would produce economical
results as compared with those obtained by the gas-asbestos
arrangements hitherto used.

To illustrate the efficiency of this mode of heating the incoming
air by what would otherwise be waste heat, I will show you
another application of the same principle which I have made
very recently to the combustion of gas for illuminating purposes.

Gas engineers were formerly under the impression that a supply
of cold air was favourable to the production of a brilliant flame.
This is a misconception, which was very general also as regards
the combustion of solid fuel in furnaces, until it was disproved by
Stirling, by Nielson, and by the introduction of the regenerative
gas furnace. The "duplex burner" owes its brilliancy to the
heating effect of the one burner upon the other; and my brother,
Mr. Frederick Siemens, has quite recently constructed a burner in
which the flame of the gas is reversed in its action in order
to heat in its descent the ascending current of flame-supporting
air.

By the application of the principle of conduction before
described, I obtain the hot-air current in a most simple manner
without interfering with the free action of the flame. The con-
struction of my burner will be seen from the accompanying Figure 3,
Plate 5: \( a \) is an ordinary Argand burner, taking its supply of
gas through the vertical copper tube \( b \). This copper pipe ter-
minates in a rod \( c \) of highly conductive copper, which passes
upward through the burner, and two or three additional conduc-
tive rods $d$ project upward from the circumference of the copper chamber or tube $b$. The rods are coated with platinum or nickel to prevent oxidation when heated (almost to redness) by the heat of the flame. The tube $b$ is perforated on its circumference, and surrounded with several layers of wire gauze $e$ presenting a considerable aggregate surface. Its bottom surface is formed of a perforated disk covered with a similar thickness of wire gauze $f$, through which the external air finds access to the burner, and in so doing becomes considerably heated.

The waste heat of the flame, or that portion of the heat produced in combustion which is not utilized as luminous rays, serves to heat the air by which combustion of the gas is supported to some $500^\circ$ or $600^\circ$ Fahr., giving rise to a more brilliant flame, and consequently to a greatly increased output of light for a given consumption of gas.

But not only the quantity of light but its quality is improved by the higher temperature attained. It may appear surprising, but it is a fact susceptible of accurate proof, that the light obtained in consumption of a given amount of gas is thus increased by some 40 per cent., and in this large proportion the deleterious influences connected with gas lighting may be diminished. Gas will thus be better able to hold its position against its more brilliant rival the electric arc, except for such large applications as the lighting of public halls, and places, of harbours, railway stations, warehouses, &c., for which the latter is pre-eminently suited. Add to these improved applications of gas the ever-increasing ones for heating purposes, and I have only to express regret that I am not a gas shareholder.

If gas is to be largely employed, however, for heating purposes, it will have to come down in price; and considering that heating gas need not be highly purified, or possessed of high illuminating power, the time will come, I believe, when we shall have two services; and as in many towns two systems of gas mains already exist, it would only be necessary to appropriate the one for illuminating and the other for heating gas. The ordinary retorts could be used for the production of both descriptions of gas, it being well known that even ordinary coal will give up gases of high illuminating power during a certain portion of the time occupied in their entire distillation. The gases emitted from
the retort when first charged are to a great extent occluded gases of low illuminating power such as fire-damp or marsh gas, and these should be turned into the heating mains. In the course of half-an-hour these occluded gases, together with the aqueous and other vapours will have left the coal, which is then in the best condition to evolve olefiant gas and other gases rich in carbon, and therefore of high illuminating power. The period during which such illuminating gases are emitted extends over probably two hours, after which the retorts should again be connected with the heating gas mains, until the end of the process. By this method of working, the illuminating gas supplied, say in London, from Newcastle coal, would probably exceed 20 candle-power, instead of being 16 as at present, whereby the objectionable effects of gas lighting would be greatly diminished, and there would be, say, an equal volume of heating gas available, consisting for the most part of marsh gas, which although greatly inferior to olefiant gas in illuminating effect would be actually more suitable for heating purposes, because less liable to produce soot in its combustion.

The total cost of production would not be increased by this separation of the gases, and the price might, with advantage both to the supplier and to the consumer, be so adjusted that the latter, while paying for his illuminating gas an increased price proportionate to the increase of illuminating power, would be furnished with heating gas at a greatly reduced cost; for the heating gas could be reduced in price in a much larger proportion than the illuminating gas need be raised, because it would not require the same purification from sulphur which renders illuminating gas comparatively costly. The enormous increase of consumption would moreover enable the gas companies to reduce prices all round very considerably without interfering with their comfortable revenues.

For such large applications of heating gas as to the working of furnaces and boilers, simpler means than the retort can be found for its production. It is now exactly twenty years since I brought out, with my brother, Frederick Siemens, the regenerative gas furnace, which is so largely used in the manufacture of steel, iron, glass, &c., that I need not describe it in detail on this occasion. The effects produced through its introduction into extensive practice are sufficiently apparent to speak for themselves. The glass
works of former days were perhaps the greatest of all producers of smoke. St. Helens, and other centres of glass manufacture used to be under a perpetual black cloud, whereas at the present time it would be hardly possible to say whether the chimneys that still remain were emitting any products of combustion at all. The furnaces of iron and steel works were also thought incurable as regards smoke, but a glance at the large steel works at Hallside, belonging to the Steel Company of Scotland, will convince you that the production of smoke is no longer an essential condition to the working of those metals. Sir Henry Bessemer, in his late address in the City of London, alluded in the most kindly manner to what I have done towards the economy of fuel by means of these furnaces, and he certainly did not overstate the case in saying that in melting steel by means of the regenerative gas furnace one ton of small coal accomplished the work of two tons of Durham coke. His testimony I look upon as being particularly valuable, coming as it does from the originator of the world-famed Bessemer process in acknowledgment of a process which he might regard as a rival to his own. Armed with such testimony, I may be permitted to state that the total saving effected by the use of the regenerative gas furnace amounts to some millions of tons of coal per annum, proving that the abatement of the intolerable smoke nuisance need not be advocated solely upon public or philanthropic grounds, but may be also sustained by an appeal to an enlightened self-interest.

It is this large experience in the applications of gaseous fuel which gives me, perhaps, some right to speak on the subject of heating gas, both for domestic and other purposes. In the year 1863 I succeeded in interesting the Town Council of Birmingham in the question, and they applied to Parliament for power to supply that city with a separate service of heating gas; but the project was unfortunately nipped in the bud through loss of their Bill in Parliament. Time, in fact, was not then ripe for the project, but I believe that before long the gasworks themselves will be tempted to take the matter up.

The gas producer now used in connection with the regenerative gas furnace yields a comparatively poor gas, and it has been my endeavour for some time to construct a gas producer which, without losing the simplicity of the first should be capable of yielding a
heating gas of superior calorific power. It consists, Fig. 4, Plate 6, of a wrought-iron cylindrical chamber $a$, truncated downwards, and lined with brickwork. The fuel to be converted into gas is introduced through a hopper $b$, and the cinder and ashes work out through the orifice at the bottom. Instead of a grating for the introduction of atmospheric air a current of heated air is brought in, either through the hopper or through the orifice at the bottom, and is discharged into the centre of the mass of fuel; the effect is the generation of a very intense heat at that point. The fuel, after its descent through the hopper, arrives gradually at this region of intense heat $c$, and when subjected to it, parts with its gaseous constituents. At the point of maximum heat the carbon is consumed, producing carbonic anhydride, which, in passing through the considerable thickness of fuel surrounding this portion, takes up a second equivalent of carbon, and becomes changed into carbonic oxide. Here also the earthy constituents are for the most part separated in a fused or semi-fused condition, and in descending gradually reach the orifice at the bottom, whence they are removed from time to time. Air enters through the bottom orifice to some extent, causing the entire consumption of any carbonaceous matter, which may have got past the zone of greatest heat; water is also here introduced in a hollow tray $d$, and after evaporation by the heat of the hot clinkers, passes upwards through the incandescent mass, and is converted by decomposition into carbonic oxide and hydrogen gas. The exit orifices $e$ for the gases are placed all round, near the circumference of the chamber, ascending upwards into an annular space $f$, whence they are taken through pipes to the furnace or other destination.

The advantage of this modus operandi consists in the intensity of the heat produced within the centre of the mass, whereby the whole of the fuel is converted into combustible gases, with the least amount of nitrogen. The hydrocarbons formed in the upper portion of the apparatus have to descend through the hotter fuel below, and in so doing, the tar and other vapours mixed up with them are decomposed, and furnish combustible gases of a permanent character.

The orifice at the bottom of the apparatus may be enlarged, and so arranged that, instead of ashes only being produced, coke may be withdrawn, and in this way a continuous coke oven may
be constructed, which is at the same time a gas producer, or in other words an apparatus in which both the solid and gaseous constituents of the coal are fully converted.

The intense heat in the very centre of a large mass of fuel has for its result a very rapid distillation, and thus one gas producer does the work of two or three gas producers of the type hitherto employed; this more concentrated action will moreover allow of the introduction of gaseous fuel, where want of space and considerations of economy have hitherto militated against it, and in favour of the ordinary coal furnace.

It has been already proved that steam boilers can be worked economically on land with gaseous fuel, and there is no reason that I know of why the same mode of working should not also be applied to marine boilers. The marine engine has within the last fifteen years been improved to an extent which is truly surprising: the consumption of coal, which at the commencement of that period was never less than 8 lbs. per h.p., has been reduced by expansive working in compound cylinders to 2 lbs. or even less per actual h.p. The mode of firing marine boilers has, however, remained the same as it was in the days of Watt and Fulton. In crossing the Atlantic one may see a considerable number of men incessantly employed in the close stoke-hole of the vessel opening the fire-doors and throwing in fuel. Each charge gives rise to the development of heavy clouds of black smoke issuing from the chimney, to the great annoyance and discomfort of the passengers on deck. If, instead of this, the fuel were to be discharged mechanically into one or more gas producers, the gaseous fuel produced would maintain the boilers at a very uniform heat, without necessitating the almost superhuman toil of the fireman; no smoke or dust would be emitted from the chimney, and a large saving of fuel would be effected.

This change would be specially appreciated by the numerous tourists visiting the Western Highlands. Speaking from my own experience on one occasion, I may say that the pleasure of a trip on the beautiful Loch Lomond was very seriously marred in consequence of the fumigation which my fellow-passengers and myself had to endure.

The change from the use of solid to gaseous fuel would be the prelude probably to another, and still more important change
namely the entire suppression of the steam boiler. We are already in possession of gas engines working at moderate expense as compared with small steam engines, even when supplied with the comparatively expensive gas from our town gas mains, and all that will be required is an extension of the principle of operation already established. It can be easily demonstrated upon purely dynamical principles that a gas engine is capable of realizing a higher proportion of the heat developed in combustion than can ever be expected from a steam engine, for the simple reason that the range of temperature attained in the cylinder of the gas engine greatly exceeds that of the steam engine, and that expansive action of the explosive mixture of gas and air can be carried to the utmost limits. According to well-known dynamical laws, the duty realized in an engine depends upon the value of $\frac{t - t'}{t}$, $t$ being the initial, and $t'$ the final temperature of the expanding gases, stated in absolute degrees of temperature, which in the case of a well-designed gas engine would attain the highest conceivable value. The realization of such a plan would of course involve many important considerations, and may be looked upon as one of those subjects the accomplishment of which may be left for the energy and inventive power of the rising generation of engineers.

Before leaving this branch of the subject I wish to call attention to a favourite suggestion which I had occasion to make some years ago. It consists in placing gas producers at the bottom of the coal mines themselves, so that instead of having to raise the coal by mechanical power, the combustible gases ascending from the depth of the mine to the surface would acquire by virtue of their low specific gravity such an onward pressure that they could be conducted in tubes to distances of many miles, thus saving the cost of raising and transporting the solid fuel.

Glasgow with its adjoining coal-fields appears to me a particularly favourable locality for putting such a plan to a practical trial, and the well-known enterprise of its inhabitants makes me sanguine of its accomplishment. When thus supplied with gaseous fuel, the town would not only be able to boast of a clear atmosphere, but the streets would be relieved of the most objectionable portion of the daily traffic.

*SIR WILLIAM SIEMENS, F.R.S.*
I now approach another and the last portion of my address, the attainment of very intense degrees of heat either for effecting fusion or chemical decomposition. Although by means of the combustion of either solid or gaseous fuel heats are produced which suffice for all ordinary purposes, there is a limit imposed upon the degree of temperature attainable by any furnace depending upon combustion. It has been shown by Bunsen and by St. Claire Deville, that at certain temperatures the chemical affinity between oxygen on the one hand and carbon and hydrogen on the other absolutely ceases, and that if the products of combustion \( \text{CO}_2 \) and \( \text{H}_2\text{O} \) be exposed to such a degree of temperature they would fall to pieces into their constituent elements. This point of dissociation, as it is called, is influenced by pressure, but has been found for \( \text{CO}_2 \) under atmospheric pressure to be 2600° C. (or 4700° Fahr.). But long before this extreme point has been arrived at, combustion is greatly retarded and the limit is reached when the losses of heat by radiation from the furnace balance its production by combustion.

To electricity we must look for the attainment of a temperature above that of dissociation, and we have evidence of the early application of the electric arc to such a purpose. In 1807 Sir Humphrey Davy succeeded in decomposing potash by means of an electric current from a Wollaston battery of 400 elements, and in 1810 he surprised the members of the Royal Institution by the brilliant electric arc produced between carbon points through the same agency.

Magneto-electric and dynamo-electric currents allow of the production of the electric arc much more readily and economically than by the use of Sir Humphrey Davy’s gigantic battery, and Messrs. Huggins, Lockyer, Liveing, and other physicists have taken advantage of the comparatively new method to advance astronomical and chemical research with the aid of spectrum analysis.

My object is now to show that the heat of the electric arc is not only available within a focus or extremely contracted space, but that it is capable of producing such larger effects as will render it useful in the arts for fusing platinum, iridium, steel, or iron, or for effecting such reactions or decompositions as require for their accomplishment an intense degree of heat, coupled with freedom
from the disturbing influences inseparable from a furnace worked by the combustion of carbonaceous material.

The apparatus which I employ to effect the electro-fusion of such material as iron or platinum was brought before the Society of Telegraph Engineers at their special meeting held on the 3rd of June last, and is represented in Fig. 5, Plate 7, of the accompanying drawings. It consists of an ordinary crucible \( a \) of plumbago or other highly refractory material, placed in a metallic jacket or outer casing \( b \), the intervening space being filled up with pounded charcoal or other bad conductor of heat. A hole is pierced through the bottom of the crucible for the admission of a rod \( c \) of iron, platinum, or such dense carbon as is used in electric illumination. The cover of the crucible is also pierced for the reception of the negative electrode \( d \), by preference a cylinder of compressed carbon of comparatively large dimensions. At one end of a beam supported at its centre is suspended the negative electrode \( d \) by means of a strip of copper, or other good conductor of electricity, the other end of the beam being attached to a hollow cylinder \( e \) of soft iron free to move vertically within a solenoid coil of wire \( f \), presenting a total resistance of about 50 units or ohms. By means of a sliding weight \( g \) the preponderance of the beam in the direction of the solenoid can be varied so as to balance the magnetic force with which the hollow iron cylinder is drawn into the coil. One end of the solenoid coil is connected with the positive, and the other with the negative pole of the electric arc, and, being a coil of high resistance, its attractive force on the iron cylinder is proportional to the electro-motive force between the two electrodes, or, in other words, to the electrical resistance of the arc itself.

The resistance of the arc was determined and fixed at will within the limits of the source of power, by sliding the weight upon the beam. If the resistance of the arc should increase from any cause, the current passing through the solenoid would gain in strength, and the magnetic force overcoming the counteracting weight, would cause the negative electrode to descend deeper into the crucible; whereas, if the resistance of the arc should fall below the desired limit, the weight would drive back the iron cylinder within the coils, and the length of the arc would increase, until the balance between the forces engaged had been re-established.
Experiments with long solenoid coils have shown that the attractive force exerted upon the iron cylinder is subject only to slight variation within a length of several inches, which circumstance allows of a working range to that extent of nearly uniform action on the electric arc.

This automatic adjustment of the arc is of great importance to the attainment of advantageous results in the process of electric fusion; without it the resistance of the arc would rapidly diminish with increase of temperature of the heated atmosphere within the crucible, and heat would be developed in the dynamo-electric machine to the prejudice of the electric furnace. The sudden sinking or change in electrical resistance of the material undergoing fusion would, on the other hand, cause sudden increase in the resistance of the arc, with a likelihood of its extinction, if such self-adjusting action did not take place.

Another important element of success in electric fusion consists in constituting the material to be fused the positive pole of the electric arc. It is well known that it is at the positive pole, that the heat is principally developed, and fusion of the material constituting the positive pole takes place even before the crucible itself is heated up to the same degree. This principle of action is, of course, applicable only to the melting of metals and other electrical conductors, such as metallic oxides, which constitute the materials generally operated upon in metallurgical processes. In operating upon non-conductive earth or upon streams of gases, it becomes necessary to provide a non-destructible positive pole, such as is supplied by the use of a pool of fused platinum, or iridium, or by a plumbago crucible. In working the electric furnace, some time is taken up in the first instance in raising the temperature of the crucible to a considerable degree, but it is surprising how rapidly an accumulation of heat takes place. In using a pair of dynamo-machines capable of producing seventy webers of current with an expenditure of 7-horse power, and which, when used for purposes of illumination, produced a light of 12,000 candles, a crucible of about eight inches in depth, immersed in a non-conductive material, has its temperature raised to a white heat in fifteen minutes, and 4 lbs. of steel are fused within another fifteen minutes, successive fusions being effected in somewhat diminishing intervals of time. The process can be carried on on
a still larger scale by increasing the power of the dynamo-machines and the size of the crucibles.

The purely chemical reaction intended to be carried into effect within the crucible, might be interfered with through the detachment of particles from the dense carbon used for the negative pole, although its consumption within a neutral atmosphere is exceedingly slow. To prevent this I have used, both in this connection and in the construction of electric lamps, a water pole, or tube of copper, through which a current of water circulates, so that it yields no substance to the arc. It consists simply of a stout copper cylinder closed at the lower end, having an inner tube penetrating to near the bottom for the passage of a current of water into the cylinder, which water enters and is discharged by means of flexible india rubber tubing. This tubing being of non-conductive material, and its sectional area small, the escape of current from the pole to the reservoir is so slight that it may be neglected. On the other hand, some loss of heat is incurred through conduction, with the use of the water pole, but this loss diminishes with the increasing heat of the furnace, inasmuch as the arc becomes longer, and the pole is retired more and more into the crucible cover.

In the experiments which I shall now place before you, the current which has supplied the one electric lamp in the centre of the hall will be diverted by means of a commutator through the electric furnace. After it has been active for five minutes to warm the crucible, I shall charge the furnace with 8 lbs. of broken steel files, which I shall endeavour to melt and pour out into an ingot mould before your eyes.

By some obvious modifications of this electric furnace it can be made available for a variety of other purposes where intense heat is required combined with immunity from disturbing chemical actions. By piercing a number of radial holes through the sides of the chamber, and introducing the ends of wires through the same, an excellent means is provided of heating those wire ends very rapidly, without burning them, for the purpose of welding them together. The electrical furnace will also be found useful, I believe, in the hands of the chemist to effect those reactions between gaseous bodies which require the employment of temperatures far exceeding the hitherto available limits, and will
thus increase the means at his disposal for the attainment of either scientific or practical ends.

I have endeavoured to compress within the limited space of a single lecture, subject-matter that might occupy the close attention of the student for weeks or months, and I may therefore be pardoned if I have failed to convey to you more than a very rough outline of what may be accomplished by the judicious use of gaseous fuel, and of the electric current, as heating agents. The one purpose that has been foremost in my mind in preparing this lecture, has been to make war upon the smoky chimney, which, so far from being a necessity under any circumstances whatever, should be regarded only as a remnant of that stage of our industrial and social progress, which, satisfied with the attainment of certain ends, could afford to neglect the economical and sanitary conditions under which those ends were accomplished.

The Exhibition which has lately been held in this city of appliances for heating and illuminating by means of gas and electricity—in which your President, my esteemed friend, Sir William Thomson, took so prominent a part, as he does in everything tending towards the advancement of human knowledge and well-being—proves how deep is the interest felt amongst you in those very questions with which I have had to deal this evening.

And so I thought you might not be disinclined to give attention once more to a particular view of the question, which happens to be the result of the independent labour of one who may claim at any rate to have given a life-long consideration to the subject.
REMARKS AT THE ANNUAL FESTIVAL OF THE IRON, HARDWARE AND METAL TRADES PENSION SOCIETY,

Held on the 1st June, 1881,

BY DR. C. W. SIEMENS, Chairman.

The Chairman rose and said: The toast which I have to propose to you is "Success to the Iron, Hardware, and Metal Trades Pension Society." The old proverb says "Charity begins at home," but this is not saying that charity should end at home, but only begin there. Speaking of charity, I may, perhaps, mention that this word seems to have been rejected from the Scriptures in the newly revised version, but I hope the sentiment has not been taken away because they have substituted a word which perhaps more completely represents what is meant. The word substituted is love. Love we know commences at home. There is no love more efficacious than that shown by one member of a family towards another. It not only benefits a family, but benefits a country at large, perhaps more than any other form of charity. When a family is thus constituted one member will not allow another to fall low, but will endeavour to keep, not only one member, but all the members, above water in a way that would appear marvellous to those who have not tried it. The next form of love is that bestowed between members of workmen's associations. Perhaps the most intimate association of love was that found in the workshops between master (or employer) and employed. Unfortunately, and, I say very unfortunately, that spirit which has existed in olden has been lost sight of in modern times; but I hope the time is not far distant when it will be reinstated in all its former efficacy. At the time of the ancient guilds the members of a trade were like one family: the master met the men, not on terms of equality, he was the master, but he took a deep interest in the welfare of his workmen, and he would not allow a man to go astray without making a strong effort to bring him back to his duty; and, if he would not do so, he would call on the guild to bring him back to a sense of his duty. This custom is impossible at the present time. It is now impossible for a master to exercise that supervision over an employé which was possible formerly; but, notwithstanding,
the master can reach the employé in another way. It is a matter
of great congratulation to see at many large works benefit
societies established in which the workmen share all alike; and, as
example is perhaps always worth more than mere argument, I
would on this occasion mention the pension fund, which it occurred
to me, in connection with my own co-partners, to establish at the
works with which I am connected. Eight years ago we established
such a fund at our telegraph works at Woolwich, and the principle
we adopted was somewhat of a novel character; but having been
for eight years very successful, I think it might not be disagree-
able to bring the facts before you. At the time we commenced
we paid into the pension fund £1,847. This fund is maintained
by annual subscriptions, not by the workmen, but by the em-
ployers, who every year pay 1 per cent. of the amount of wages
they give to the workmen into this fund, out of which pensions
are paid to any workmen who are disabled from age or other cause,
and in the event of the death of a workman a pension is paid to
his widow or orphans. The amount of this pension depends in a
great measure on the length of time during which a man has
served the firm and the number of individuals to be provided for.
This fund is administered by one representative of the firm, who
presides over the committee of management. A permanent secretary
is also appointed by the firm, and six employés are elected to represent
the workmen. The fund has been found amply sufficient to pro-
vide for all those who have been disabled and would otherwise
have been without resources during their illness. More than that,
capital has accumulated from £1,800 to nearly £5,000, at which
it stands at the present time. It may be said "Why should a man
benefit from a fund to which he does not contribute?" Well, I
think we acted wisely in not making them contribute, because, in
virtue of that provision, we, and not the men, are masters of the
fund. If a man discharges himself he takes with him no right to
the fund, and it is only in case he remains in the service that he
acquires an accumulating interest in the fund, and thus he
"affectionates" himself towards his employers and towards the
concern. By giving this additional amount of 1 per cent. we get
better service and work, and I believe that in a similar way a much
better feeling might be established. The fund with which we deal
here this evening is also based upon the "home" principle. The
iron trade of this country is, perhaps, not only the largest indus-
try in the kingdom, but in the whole world, and therefore if a 
feeling of good fellowship can be established in such a trade, 
amongst those who devote lifelong toil and energy to the advance-
ment of that trade, I am quite certain a vast amount of good will 
be done; and more than the value of the actual money paid will be 
the feeling that will be engrafted in the breast of the man who, 
perhaps, seeing an increasing family about him, and feeling his 
health failing, and the knowledge that, although his own efforts 
are insufficient to provide amply for the widow and children who 
will be left by him, there is a fund like that in connection with this 
Society, which will come to the assistance of the widow in the time 
of bereavement, that feeling alone, I say, will keep a man up, 
and make him a more useful worker than would be the case if his 
heart had sunk. Gentlemen, it is charity, or love, like this that 
is productive of a great amount of good, in fact, anything that will 
keep a man from that final abomination, the workhouse, is a great 
benefit. I hope the time will come when the union workhouse 
will no longer exist, and when no man will need to go there. It is 
by mutual support between those who ought to have a fellow-
feeling towards one another that such a result can be brought 
about, and that great happiness will result. This fund has already 
produced most beneficial results. It distributes every year more 
than £3,000 in pensions to those most deserving of it; but con-
sidering the vast proportions of this trade a much larger sphere of 
action is possible, and should be aimed at. Our object needs only 
to be known to be more widely patronised and better supported. 
It is now my pleasurable duty to support the efforts made by those 
who have led this movement for nearly 40 years, and to urge you 
to come forward and make the amount of the benefit bestowed by 
this Society an ever-increasing one, so that those who are the 
recipients may be even more in number, and made more glad on 
account of the great benefits you bestow on them. Gentlemen, 
I need not add many more words. You all understand what our 
object is, you all approve of it, and you all see the necessity for 
active support; therefore I now call upon you to drink success to 
the Iron, Hardware, and Metal Trades Pension Society, with all 
due honours.
ADDRESS OF C. WILLIAM SIEMENS, Honorary President of the Meeting of the Société des Ingénieurs Civils, held at the Exposition d'Électricité, on the 23rd September, 1881.

M. LE PRÉSIDENT * a prononcé ensuite le discours suivant:

Messieurs, grâce à votre aimable invitation, je me trouve dans ce moment dans une position bien honorable, pour laquelle je vous offre mes remerciements sincères.

Cette position m'impose pourtant un devoir, que je me sens peu capable de remplir, attendu que ma connaissance de votre langue est trop limitée et que le temps m'a manqué pour préparer un discours, tel que j'aurais voulu vous l'adresser. Aussi, je compte sur votre indulgence qui, je l'espère, ira même au delà de votre courtoisie.

En vous adressant cependant quelques mots, avant que vous mettiez à votre œuvre d'examen soigneux, permettez-moi de vous féliciter sur le succès éclatant de cette Exposition, œuvre française, qui fera époque dans l'histoire du progrès intellectuel et industriel. Cette réunion remarquable de tout ce qui représente le progrès dans cette branche la plus jeune de l'industrie, a déjà attiré à Paris le Congrès international d'électricité, composé des hommes les plus illustres dans les sciences physiques de tous les pays civilisés. Ce Congrès semble destiné à fournir des bases solides pour le développement futur de l'électricité, soit comme science, soit dans son application à l'industrie.

Je vous félicite encore, Messieurs les membres de la Société des Ingénieurs civils, d'avoir reconnu l'importance de cette Exposition, par rapport à votre profession et d'avoir institué ces séances-visites, qui vous donneront des occasions précieuses de vérifier les déclarations théoriques, par les expériences et même par une pratique comparative.

Messieurs, il est inutile d'insister devant vous sur le rôle important que l'électricité va jouer dans presque toutes les branches de l'industrie.

Vous savez ce qui a été accompli par la télégaphie électrique, et quelle influence bienfaisante l’introduction des divers systèmes de signaux a eu sur nos chemins de fer. Aujourd’hui, quand tous les pays du monde se couvrent de plus en plus de réseaux de voies ferrées, et que de plus, le nombre et la rapidité des trains qui les parcourent augmentent de jour en jour, le télégaphie électrique est une nécessité absolue ; et cependant l’Exposition nous fait sentir que même dans cette application, la plus ancienne, il reste encore bien des progrès à faire.

Le membre le plus jeune dans la famille de l’électricité, c’est le téléphone ; cet instrument à la fois extrêmement simple et ingénieux, qui combine, dans sa simplicité, toutes les lois les plus compliquées de l’électricité, se présente dans l’enceinte de ce palais dans un état de perfectionnement vraiment étonnant. Ceux qui ont déjà eu occasion d’entendre ici, dans ce bâtiment, les sons compliqués de l’Opéra, ont dû juger et apprécier quel énorme progrès nous avons devant nous, et il me semble que nous ne sommes pas encore au bout dans cette direction remarquable.

Hier soir, M. Mercadier nous a entretenus (les Membres de la Société des Électriciens Anglais) de nouvelles recherches extrêmement intéressantes, qui augmentent de beaucoup le nombre de phones que nous avons déjà. Au téléphone, au microphone et au photophone, M. Mercadier a ajouté le radiophone, le thermophone et l’électrophone ; tous ces appareils qui, du reste, sont extrêmement simples dans leurs détails, se rapportent à des influences primaires et de différents genres. Dans l’un, le téléphone, c’est la vibration de l’air qui est cause de la transmission des sons, de la voix. Dans le photophone, c’est le sélénium qui, par sa propriété remarquable de changer sa conductibilité à mesure que la lumière plus ou moins intense le frappe, fait fonctionner l’appareil. C’est un appareil qui a déjà été présenté par M. Bell, il y a un an. Le microphone, imaginé d’abord par MM. Hughes et Edison, est un appareil qui nous donne la faculté d’augmenter merveilleusement l’importance des signaux transmis par le fil électrophone. M. Mercadier ajoute des phones qui reçoivent la force motrice par les rayons de la chaleur, ou bien de la couleur, dans le spectre de la lumière électrique.

En nous adressant à une autre branche des objets exposés dans cette enceinte, nous trouvons la lumière électrique, qui occupe une
place considérable dans cette exposition. Il est évident que la lumière électrique n'est plus un essai, c'est une réalité bien positive, soit que la lumière électrique se présente sous la forme de grands foyers de 500 à 10,000 bougies ou de 50 à 1,000 carceils, soit qu'elle se présente sous une forme plus ou moins divisée, comme lumière produite par des courants de sens contraire, des courants alternatifs, ou comme une petite lumière produite par le carbone incandescent, comme dans les appareils de MM. Swan, Edison, Maxim, Lane Fox; tout cela démontre que l'électricité est applicable à l'éclairage non seulement de nos places publiques et de nos rues, mais aussi des grands appartements et même des petits, tels que salles à manger et autres. Et, comme suite de cette application, il y a cet immense avantage en faveur de l'électricité, c'est qu'il n'y a pas de produits de combustion; quoique la source de lumière, dans la lampe électrique, soit même beaucoup plus chaude que la source du bec de gaz; cependant, suivant le calcul que j'ai fait, la quantité de chaleur produite pour une quantité donnée de lumière produite, est théoriquement d'environ 10 pour 100 de celle que produirait le gaz pour la même intensité lumineuse, c'est-à-dire que, pour donner une lumière voulue, nous aurions, par le gaz, une production de chaleur dix fois plus considérable que par la lumière électrique.

Outre cela, il y a la question des produits de la combustion qui vicient l'atmosphère, et dont la lumière électrique est exempte.

Cependant, je ne suis pas de ceux qui disent que le gaz est tout à fait éclipsé, et que les usines à gaz n'ont plus qu'à fermer leur établissement. Je crois, au contraire, que nous sommes au début d'une période d'augmentation énorme de l'usage du gaz. Quand il s'agit d'obtenir la lumière par le gaz, nous trouvons qu'un mètre cube de gaz brûlé dans un bec ne produit qu'un dixième de la lumière totale qui se produirait si le même mètre cube de gaz était brûlé dans une machine; ou autrement que la combustion du gaz dans un moteur donnerait une énergie de lumière dix fois plus considérable que si le même mètre cube de gaz était brûlé dans un bec. Cela démontre que la véritable place, pour le gaz, est l'intérieur des cylindres et non pas le bec. En faisant ce changement, le gaz nous sera nécessaire comme auparavant; seulement, nous aurons une lumière beaucoup plus intense à meilleur marché. (Applaudissements.)
Il y a plusieurs autres applications pour le gaz qui, je l’espère, feront leur chemin, maintenant que l’attention des ingénieurs et des consommateurs de gaz est dirigée dans cette voie. Le gaz est le combustible le plus avantageux: 1 kilogramme de gaz produit six fois plus de calorique que 1 kilogramme de houille. Si l’on veut obtenir le même degré de chaleur avec un minimum de combustible, il est donc plus avantageux de se servir du gaz que d’un combustible solide.

En outre, le gaz ne produit pas d’ordures, il ne produit pas de cendres, il ne produit pas de fumée. Il y a encore un autre avantage: le transport du gaz est meilleur marché que le transport de tout autre combustible; il est plus commode, surtout dans nos rues déjà trop encombrées par le trafic ordinaire. Le combustible, il faut l’apporter de l’embarcadère à la maison, le descendre à la cave, et ensuite le porter encore de la cave dans l’appartement, puis après porter les cendres au dehors: tout cela représente une dépense totale énorme, si on la multiplie par le nombre des maisons, dans un grand centre comme Paris, par exemple; tandis que le gaz, une fois établi, n’a pas tous ces inconvénients et coûte très peu: on n’a à s’occuper que de l’entretien des tuyaux, qui durent bien longtemps. Je crois donc qu’à l’avenir la consommation du gaz ira graduellement de plus en plus en augmentant; tandis que, pour l’éclairage de nos grands appartements et de nos rues, la lumière électrique sera la lumière ordinairement employée, le gaz prendra la position plus modeste de donner la lumière à nos passages, nos cuisines, nos petits appartements; pour tous ces besoins accessoires, le gaz a un grand avantage: on peut ouvrir le robinet à moitié, au quart, et à réduire ainsi la consommation du gaz, en diminuant, suivant les besoins, l’intensité de la lumière.

Une autre application de la force de l’énergie électrique, qui n’est pas encore aussi développée que la lumière électrique, mais qui, je crois, jouera un rôle plus important, c’est la transmission de la force motrice par l’électricité. Vous savez que, dernièrement, des efforts ont été faits dans plusieurs directions pour transmettre la force motrice d’un endroit à un autre au moyen du fil électrique. Il y a, dans ce bâtiment, une foule d’applications qui montrent les moyens qui se présentent à l’ingénieur pour employer ce nouveau moteur à diverses applications. Nous avons non seulement des machines de toute espèce mises en mouvement par le
courant électrique, nous avons aussi un chemin de fer qui marche avec une machine dynamo-électrique et qui démontre qu'auzii, pour la locomotion, ce moteur sera applicable.

Je dois dire qu'il ne faut pas s'imaginer que pour nos grands chemins de fer, la machine à vapeur sera jamais remplacée par le moteur électrique; ce n'est que pour les tramways et les petits chemins qu'on pourrait transporter la force d'un centre dans un autre par la voie de l'électricité.

Dans la transmission de la force motrice par l'électricité, il y a nécessairement une perte: cette perte s'élève à peu près à 50 pour 100; nous avons obtenu jusqu'à 60 et 70 pour 100 de rendement; mais, en pratique, il ne sera pas sage de dire que la force obtenue à l'extrémité d'une ligne de deux kilomètres de longueur, par exemple, sera plus de 50 pour 100. Mais ce résultat n'est nullement défavorable; les 50 pour 100 ne représentent pas seulement les forces perdues dans la machine électrique, mais l'ensemble des forces perdues dans la transmission.

Dans une machine électrique, la force perdue n'est que d'un dixième, c'est-à-dire qu'une machine dynamo-électrique donne dans le courant 90 pour 100 du travail fourni par le moteur. Mais pour transmettre la force motrice par un moyen mécanique, pour transporter cette force, il y a des pertes dans la transmission. Il y a d'abord une perte dans les conducteurs, il y en a une seconde dans le frottement, dans les couissinets. Il y a une troisième perte dans l'échauffement des fils; une quatrième, dans la transmission du courant électrique, et une cinquième perte pour transmettre cette force dans la machine pour donner son effet utile. Ces cinq sources de perte ne représentent que 50 pour 100 de la force totale: cela veut dire qu'il n'y a pas de perte énorme dans aucun de ces points.

Mais si on veut transmettre une force motrice par l'hydraulique ou l'air comprimé, on doit dépenser au moins les 50 pour 100; mais il y a cet avantage dans la transmission électrique, que cette perte ne dépend pas autant de la distance; on peut très bien faire transmettre une force électrique à une distance de 10, 20 kilomètres, à travers un conducteur d'une certaine importance, sans augmenter les pertes; et il y a cet avantage encore, que le fil électrique, pour transmettre la force, est très bon marché, en comparaison des tuyaux à air ou des tuyaux hydrauliques.
Je puis mentionner ici une application que j’ai faite dernièrement dans ma petite ferme d’Angleterre. J’ai un moteur central pour faire travailler la ferme. Ce moteur à vapeur donne le mouvement, soit à des machines, dans une partie de la ferme, pour faire couper le foin, le bois ; soit, dans un autre endroit, un kilomètre plus loin, pour pomper l’eau. Je dois aussi appliquer la même force pour labourer, application, du reste, déjà faite en France, sous le contrôle de M. Tresca, qui a publié des résultats très intéressants. Quoique je perde 50 pour 100 de transmission, je trouve encore de grands avantages dans ce système : je brûle beaucoup moins de charbon qu’en mettant des petites machines partout pour faire le travail. Ma machine marche toute la journée, à présent pour utiliser toutes les forces, la pompe plus loin commence à marcher, personne ne s’en occupe, c’est dans un endroit fermé à clef, et on pompe l’eau à un kilomètre plus loin. Il n’y a qu’un seul homme qui fait tout le travail et qui s’occupe des chevaux et des soins de la ferme. C’est une économie remarquable.

Pour employer la même force pendant la nuit, j’ai fait une application qui a excité un peu l’intérêt des savants : c’est d’étudier l’influence de la lumière électrique sur la végétation. Je puis avoir des pêches, des fraises et autres fruits annuels, l’hiver, autant que pendant l’été : c’est un fait bien remarquable, et je crois que, jusqu’à présent, ce n’est qu’un essai ; le temps viendra où les horticulteurs en tireront un grand parti, surtout si on combine l’horticulture avec l’agriculture.

On peut encore utiliser la chaleur de la vapeur perdue, qui se condense dans un calorifère, et obtenir, par ce calorifère, le chauffage de la maison, de sorte qu’on ne perd rien.

Par la lumière électrique, on peut produire des fruits, en hiver, d’un arôme tout à fait exceptionnel, et je suis bien aise de voir dans ce bâtiment, un essai qui s’est produit dans cette même direction. J’ai observé qu’une erreur, qui avait été faite, a été rectifiée depuis deux jours. On avait mis les foyers électriques à nu et j’ai constaté, comme je l’ai dit dans le mémoire que j’ai présenté sur ce sujet, que la lumière électrique, quoiqu’elle puisse être très utile pour l’agriculture, a un effet détruisant pour la plante, quand celle-ci y est exposée directement. Ce sont les rayons de haute intensité, ultra-violets, qui ont cet effet destructeur.
J'ai constaté, en mettant devant une plante opposée à un foyer électrique un morceau de verre couvrant la plante à moitié, j'ai constaté, dis-je, que le verre transparent absorbe tous les rayons ultra-violets, qui sont nuisibles pour les plantes ; et je ne doute pas que dans ce bâtiment, on n'observe une grande différence dans les résultats qu'on obtiendra, maintenant qu'on s'est aperçu de cette erreur et qu'on a recouvert les foyers électriques par un globe transparent.

Une autre question bien intéressante pour le physiologiste botanique, c'était de savoir si une plante peut travailler toujours, jour et nuit. L'opinion des botanistes était plutôt en faveur de la nécessité d'un sommeil pour la plante ; mais les résultats obtenus, qui s'étendent déjà à deux années, démontrent que la plante n'a pas besoin de repos, sauf le repos d'hiver, et que, par exemple, des pois plantés aujourd'hui, peuvent pousser, atteindre leur complet développement et produire des pois mûrs, sans aucun repos.

Messieurs, je crains d'être resté trop longtemps (Non! non!) sur cette utile application dans laquelle j'ai cru qu'il y avait un intérêt spécial, mais je l'ai expliqué avec tant de détails pour démontrer que l'énergie électrique s'applique presque partout, et que, par elle, une nouvelle voie s'ouvre à l'ingénieur pour diriger les forces de la nature dans un sens qui n'était pas connu auparavant ; j'ai voulu montrer que nous avons devant nous un travail énorme, mais énormément intéressant à accomplir. Je dois féliciter votre Société du pas que vous avez fait et de la résolution que vous avez prise d'étudier ces phénomènes intéressants et nouveaux. (Applaudissements prolongés).
SCIENCE AND INDUSTRY.

An Address delivered to the Birmingham and Midland Institute in the Town Hall, Birmingham, on the 20th October, 1881.

BY C. WILLIAM SIEMENS, D.C.L., I.L.D., F.R.S., President.

CONSIDERING the high position in literature and science of my predecessors in this Chair, I feel that I have been bold indeed in accepting the distinguished office of President of the Midland Institute during the current year. I shall not attempt to rival my predecessors in those literary or philosophic flights which befitted their powers, but shall confine myself to certain suggestive remarks flowing from personal experience of men and matter, which may prove of some interest to an audience consisting in the main of persons who, like myself, are intent upon combining science with practical aims, but who, unlike myself, have the best part of their career still before them.

In venturing to express my views regarding the very popular question of technical education, I shall run considerable risk of disappointing some of its most ardent advocates, who may have looked upon me, a foreigner by birth, as a staunch supporter, if not as the living embodiment, of that particular form of education that the Polytechnicum of Germany and other Continental countries imparts to the aspiring engineer and manufacturer, but which, in my opinion, leaves much to be desired, and is certainly inapplicable to the condition of things which we find in this country.

The subject of education, and of science education in particular, is one the practical and national importance of which it would be difficult to over-estimate. It is well known that the Continental nations have in some respects stolen a march upon us in providing for the education of the young engineer, the architect, the manufacturer, and the craftsman. Colleges of higher and lower degree abound where both science and practical processes are taught, whereas amongst us the teaching of the latter has been looked
on hitherto as professional or trade knowledge to be acquired during lengthy periods of pupilage or apprenticeship.

The more ardent advocates of the Continental method of technical education go so far as to think that the irksome system of apprenticeship should give way entirely to technical teaching within the college walls, whereby it is assumed that much time could be saved and a better knowledge be imparted. Having had some experience of young men brought up at these technical schools, I am bound to say that I have not been favourably impressed with the results produced by that system. The practical knowledge acquired at those establishments is wanting in what may be called the commercial element, that is of due regard to cost of production, of which the teacher himself must be comparatively ignorant, as otherwise we should probably find him employed at the factory or the engineer's office, instead of in the schoolroom.

The young polytechnic student is apt to look on the machine or process which he has studied, not as one of many solutions of a practical problem influenced by ever-varying external circumstances, but as something representing an absolute condition of things almost as completely proved and established as a first principle in nature, or a proposition of Euclid; he is very proud of this positive knowledge and impatient of any suggestion aiming at the accomplishment of the same object by means not sanctioned by his authoritative text-book. He is apt to be a dogmatist, a splendid man for coming out first-class in a competitive examination, and likely enough to make a good official in a Government administration, but most unlikely to venture for himself on such new embodiments of first principles of nature as are essential to the accomplishment of improved results, and as have animated our Watts, our Cromptons, our Corts, and our Bessemeres in enriching the world with new processes.

On the Continent, where the Governments themselves are largely engaged in trade and enterprise, where railways, mines, and factories are State establishments, it was necessary to create a large staff of men educated to the point of being able to assume at once a position of some authority in the ranks of rigid organisation, and such men are provided by the polytechnic schools. Our Indian Govern-
ment being similarly situated had to resort to similar means, and to establish Cooper’s Hill Engineering College.

In this country, where happily the great commercial interests, with one exception, are still in private hands, educational establishments on the Continental model would be, I consider, inappropriate. The object a young man has in view is not the attainment of a snug position in a Government establishment, but to be fitted by his education for the great battle of life, in which he will be judged, not by the answers he can give to certain set questions in his competitive examination, but rather by the faculty he may have acquired of realising useful results under even adverse circumstances and conditions.

The time was, not long ago, when the opinion prevailed in this country that useful knowledge could only be attained in the workshop; that a lad, after having mastered the three R’s at a primary school, had to be bound to a manufacturer or craftsman for a period of seven years, where his time was occupied in routine work or in mechanical repetitions of one and the same operation, causing him to give up thinking altogether, and to become what was dignified by the appellation of “practical man”—a man of notions, with a supreme contempt of theory or science. The reign of this practical man par excellence is happily drawing to a close; for those who wish to treasure up his memory, I would recommend a lucid description of him by my friend Sir Frederick Bramwell in his presidential address to the Mechanical Section of the British Association in 1872 (which may be found in the Transactions of that year). Since then Sir Frederick Bramwell has done much to hasten the burial of the character he describes, in making himself the principal promoter of that splendid endowment, the City and Guilds of London Institute, which, under wise direction, cannot fail to exercise a very important influence on the educational development of the country.

Having now spoken, somewhat disparagingly, I fear, of both the old English system and of the more recent Continental system of technical education, I shall be asked, no doubt, what in my opinion should be the plan adopted in preparing the mechanical engineer, the manufacturer, and the artisan of the future, for their respective careers. The answer to such a question is one involved in much difficulty, scarcely admitting of universal solution. There
are, however, certain principles of general application, which, I submit, should never be lost sight of. Moral education being provided for, the main object in teaching the young should be to strengthen their power of memory, and after that their reasoning faculty. The first is most appropriately accomplished by the conventional three R’s, and by the teaching of geography, history, and languages, both ancient and modern; and the second by mathematics, logic, and the natural sciences. Sir John Lubbock, in addressing you some years ago from this chair, forcibly called attention to the necessity of combining both literary and scientific education in our grammar schools, suggesting that at least ten hours a week should be given up to the teaching of science.

Such a system of education has since been established at Eton, where (as reported in Nature some weeks ago) all pupils attend science classes, and are said to be very fond of what they are pleased to call the “stinks” (in allusion to the chemical laboratory); whereas at other grammar schools a “modern side” has been added to the establishment, where science is taught to those only who elect not to go in for a classical career, whilst the classical scholars remain untaught in science as before. I am of opinion that the Eton system is the better of the two, for I cannot regard an education to be complete that does not combine literary with scientific training; the one gives the polish and the other the fibre and practical direction to the understanding. A Birmingham manufacturer by no means despises polish to make his goods tempting in the market, but he would hardly like to offer them composed entirely of lacquer and polish without that solid fibre in the interior that is necessary to fit them for practical usage; such internal fibre may in our case be likened to the knowledge of useful information such as modern languages and natural science, without which the classical polish must be devoid of the power to produce useful results, which after all is the standard to be aimed at.

The man of classics, the Bishop, the Statesman, and the Judge of the future, educated at Eton, will be none the worse for standing upon an educational foundation comprising “stinks” in its composition, whereas the man of practical pursuits will be all the better for his early literary culture.

But it may be urged that the time available for study is too
short to admit of both, and that one or other must therefore be chosen. I should venture to doubt the sufficiency of this objection, being of opinion that the study of the one kind of knowledge qualifies the mind the better for the other, in the same way as in after life recreative exercise of mind and body is resorted to in order to relieve the drudgery of daily duty.

The usefulness of science teaching depends of course to a great extent upon the teacher, and upon the system adopted. Science taught as it were by rote is of comparatively little value in after life; to be beneficial it should be practical, impressing the mind vividly with the simplicity and the beauty of the laws of nature, and for this purpose each statement of a law should be followed up by ocular demonstration, nay by active co-operation on the part of the student in the experiment. For this purpose no school ought to be without its chemical, its physical, and its mechanical laboratories, where students could test for themselves chemical reactions, verify physical laws, and ascertain the mechanical properties of materials used in construction. Nor do these laboratories necessarily involve a large expenditure for apparatus, the most instructive apparatus being that which is built up in the simplest possible manner by means of pulleys, cords, wires, prisms, and glass tubes, and, if possible, by calling into requisition the constructive ingenuity of the student himself.

Only after the student has attained a thorough knowledge of first principles will it be desirable to introduce him to elaborate instruments such as telescopes, polariscopes, electrometers, and delicate weighing machines wherewith to attain numerical results and to commence original research. For this reason very complete laboratories are of great importance at the Universities and superior colleges, where exact science and independent research should take the place of mere tuition of first principles.

After first principles have been taught at school, the university on the one hand and the workshop aided by study on the other hand are requisite to impart that special knowledge necessary for the profession or business to be followed in after life. In this respect the German university—that glorious institution for the development of independent thought—offers advantages much more commendable for imitation than the technical school, and it is a significant fact that while the thirty universities of Germany
continue to increase both as regards number of students and high state of efficiency, the purely technical colleges, almost without exception, have during the last ten years been steadily receding; whereas the provincial "Gewerbe Schule" has, under the progressive Minister Von Falk, been modified so as to approximate its curriculum to that of the "Gymnasium" or grammar school.

In some technical schools mechanical workshops are provided, in which students may work at the lathe, the vice, and the planing machine, and where they are allowed to construct small steam engines or other pieces of machinery. I doubt very much whether these toy steam engines are such as would satisfy a mechanical engineer in real practice, and think that both the money of the institution and the time of the student could be much better employed, if, instead of imitating practical engineering, he were made to experiment with testing machines in order to obtain a thorough insight into the mechanical nature of materials, their absolute strength, their elastic limits, and the effects produced upon them by the processes of annealing, tempering, and welding. University College, London, has taken a lead in this respect under the able direction of Professor Kennedy, and its example will, I hope, be followed by other colleges.

As regards middle class education, it must be borne in mind that, at the age of sixteen, the lad is expected to enter upon practical life, and it has been held that under these circumstances at any rate it is best to confine the teaching to as many subjects only as can be followed up to a point of efficiency and have reference to future application. It is thus that the distinction between the German Gymnasium or Grammar School and the Real Schule or Technical School has arisen—a distinction which, though sanctioned to some extent in this country also by the institution of the "modern side," I should much like to see abolished.

But I shall be told that it is impossible to teach everything properly within the time, and shall be reminded of the proverb that says, "A little knowledge is a dangerous thing." I, for one, do not believe in this proverb, which I consider erroneous, and mischievous in its application. Referring to myself as an example, I am sorry to state that I had not the advantage of being taught Greek at school beyond the mere letters of the alphabet—my early
education having, indeed, been irregular, and cut short much too soon—which surely is the minimum of knowledge that could possibly be possessed of that language. Yet even this amount of knowledge of Greek has stood me in good stead, because it has enabled me at any rate to use those letters in mathematical formulæ, and on a push to puzzle out some of those Greek names which are given to scientific instruments. In this case at least, exceedingly little knowledge has proved no danger but a considerable advantage to me, and it would not be difficult to multiply examples to the same effect. A little knowledge of a modern language will be best appreciated by an English person who, speaking no language but his own, has occasion to go abroad. Arriving at his destination he finds that he is unable to make the railway porter understand what conveyance he intends to take, and where he intends to go; his perplexity will be still greater when on entering a restaurant, say at Paris, he is presented with a bill of fare extending over several pages, from which to select his dinner. In despair he points at random to some of the enumerations of dishes, and finds to his discomfiture that the one is presented to him in the form of a pâté of snails, another as a preparation of legs of frogs, and the third as water ice with which to appease an appetite quite equal to roast beef, potatoes, and cheese.

In physical science a little knowledge may be a matter of the greatest importance to an artisan when he is called upon to set a machine to work, and is stopped by some such accidental cause as the accumulation of air below a valve, or unequal expansion due to a local source of heat. The knowledge of a few fundamental laws of physical science will at once enable him to divine the cause of difficulty, which has only to be recognized in order to be removed. I should, therefore, be disposed to reverse the proverb, and to say that "A little knowledge is an excellent thing," only it must be understood that this little is fundamental knowledge; that it is not the knowledge of the conceited pretender who has committed to memory a few scraps of information on a particular subject; who quotes a Greek author without having learned as much of the language as I have; who speaks of planetary perturbations without having a knowledge of the fundamental law of gravitation; or who pretends to know all about steam engines.
without having the least knowledge of the laws of heat, of elasticity, or of dynamics involved in their action.

On the whole I am inclined to agree with Lord Brougham, who, himself a great lawyer and a lover of science, gave origin to the pithy expression, "Try to know something about everything, and everything about something." It would be hard, indeed, to realise the latter portion of his saying, but it would be difficult to know even a good deal about something without knowing at least something about a great many other things.

The question of education becomes even more difficult when we approach the condition of the artisan who needs to send his boy into the mine or factory at the tender age of twelve. I am of opinion that fourteen years should be the minimum age at which lads should be admitted into works, in order that they may have had not less than four years of judicious training at elementary or Board schools, where, in addition to the purely elementary subjects, at least so much of general history, easy mathematics, and natural science should be inculcated as to implant, if possible, the desire to acquire more of those subjects in after life. School education, whether followed up to one point or another, can after all do no more than lay a foundation and implant, if possible, a desire in the mind of the student to follow up the subjects taught in maturer years, with the experience of life present to give a practical direction to his studies.

In order to aid him in these endeavours, such bodies as the Midland Institute must prove to be of great service, with its science classes and lectures open to all who thirst after knowledge and who want to understand more particularly the scientific principles involved in their occupations. Technical education such as this is indeed indispensable if this country is to maintain the supremacy won for it by men of exceptional genius, enterprise, and perseverance, but which without it can hardly be expected to withstand in the long run the competition of foreign nations, with cheaper labour and a higher standard of general education in their favour. The English system of technical education has this advantage over the system established elsewhere, that it is not governmental but essentially spontaneous and self-supporting, and will therefore shape itself into the mould best suited to the free and vigorous development of trade itself.
The system of pupilage or apprenticeship will still be necessary, but instead of involving the sacrifice of seven of the most important years of a young man's life, half that time, or say three years, will be found amply sufficient to give to the lad imbued with first principles the practical knowledge necessary for his trade. The employer would be amply compensated for the shorter time of gratuitous service by a corresponding improvement in its quality. He should be expected to see to it that during the term of his authority the pupil attended Saturday and evening classes where, in addition to general subjects, the principles underlying the operations of his business of spinning, dyeing, paper-making, or metal-working are taught by competent persons.

It is important that the teacher himself should not be a mere specialist, but a man capable of generalising and of calling to his aid other branches of science and general knowledge, that he should be, in short, a well-educated person. It is difficult, I believe, as yet to find a sufficient number of teachers equal to such a standard, and in order to supply this deficiency normal schools will have to be established upon a much larger scale than has hitherto been the case. It is satisfactory to learn that South Kensington is coming to the rescue in converting its Science School into a Normal School for the education of science teachers, only it is to be hoped that literary subjects will be added to their curriculum.

The importance of a higher education of the working classes will be appreciated by all who have watched the rapid strides with which one branch of industry after another undergoes fundamental change, by which the mere craft-skill acquired yesterday becomes obsolete to-day, when a new process, involving entirely new modes of operation, takes the place of a previous one. Nor is there any promise of stability in the process of to-day, which may be again superseded to-morrow by something more nearly approaching ultimate perfection.

To those who still have some confidence in the stability of things as they exist in arts and manufactures, I would strongly recommend a trip to Paris, where they will still be in time to visit the International Exhibition of Electricity. That form of energy known as the electric current was nothing more than the philosopher's delight forty years ago; its first practical applica-
tion may be traced to this good town of Birmingham, where Mr. George Elkington, utilising the discoveries of Davy, Faraday, and Jacobi, had established a practical process of electro-plating in 1842.

It affords me great satisfaction to be able to state that I had something to do with that first practical application of electricity: for in March of the following year, 1843, I presented myself before Mr. Elkington with an improvement on his processes which he adopted, and in so doing gave me my first start in practical life. Considering the moral lesson involved, it may interest you, perhaps, if I divert for a few minutes from my subject in order to relate a personal incident connected with this my first appearance amongst you.

When the electrotype process first became known it excited a very general interest, and although I was only a young student of Göttingen under twenty years of age, who had just entered upon his practical career with a mechanical engineer, I joined my brother, Werner Siemens, then a young lieutenant of artillery in the Prussian service, in his endeavours to accomplish electro-gilding, the first impulse in this direction having been given by Professor C. Himly, then of Göttingen. After attaining some promising results, a spirit of enterprise came over me so strong that I tore myself away from the narrow circumstances surrounding me, and landed at the East End of London with only a few pounds in my pocket and without friends, but with an ardent confidence of ultimate success within my breast.

I expected to find some office in which inventions were examined into, and rewarded if found meritorious, but no one could direct me to such a place. In walking along Finsbury Pavement I saw written up in large letters "So and so" (I forget the name), "Undertaker," and the thought struck me that this must be the place I was in quest of; at any rate, I thought that a person advertising himself as an "undertaker" would not refuse to look into my invention with a view of obtaining for me the sought-for recognition or reward. On entering the place I soon convinced myself, however, that I came decidedly too soon for the kind of enterprise here contemplated, and finding myself confronted with the proprietor of the establishment, I covered my retreat by what he must have thought a very lame excuse. By dint of perseverance I found my way to the patent office of
Messrs. Poole and Carpmael, who received me kindly and provided me with a letter of introduction to Mr. Elkington. Armed with this letter, I proceeded to Birmingham to plead my cause before your townsman.

In looking back to that time, I wonder at the patience with which Mr. Elkington listened to what I had to say, being very young, and scarcely able to find English words to convey my meaning. After showing me what he was doing already in the way of electro-plating, Mr. Elkington sent me back to London in order to read some patents of his own, asking me to return if, after perusal, I still thought I could teach him anything. To my great disappointment I found that the chemical solutions I had been using were actually mentioned in one of his patents, although in a manner that would hardly have sufficed to enable a third person to obtain practical results.

On my return to Birmingham I frankly stated what I had found, and with this frankness I evidently gained the favour of another townsman of yours, Mr. Josiah Mason, who had just joined Mr. Elkington in business, and whose name as Sir Josiah Mason will ever be remembered for his munificent endowment of education. It was agreed that I should not be judged by the novelty of my invention, but by the results which I promised, namely, of being able to deposit with a smooth surface 30 dwt. of silver upon a dish-cover, the crystalline structure of the deposit having theretofore been a source of difficulty. In this I succeeded, and I was able to return to my native country and my mechanical engineering a comparative Croesus.

But it was not for long, as in the following year I again landed in the Thames with another invention, worked out also with my brother, namely, the Chronometric Governor, which, though less successful, commercially speaking, than the first, obtained for me the advantage of bringing me into contact with the engineering world, and of fixing me permanently in this country. This invention was in course of time applied by Sir George Airy, the then Astronomer Royal, for regulating the motion of his great transit and touch recording instrument at the Royal Observatory, where it still continues to be employed.

Another early subject of mine, the anastatic printing process, found favour with Faraday, "the great and the good," who made
it the subject of a Friday evening lecture at the Royal Institution. These two circumstances combined obtained for me an entry into scientific circles, and helped to sustain me in difficulty until, by dint of a certain determination to win, I was able to advance step by step up to this place of honour situated within a gunshot of the scene of my earliest success in life, but separated from it by the time of a generation. But notwithstanding the lapse of time, my heart still beats quick each time I come back to the scene of this, the determining incident of my life.

At the time I am speaking of, the electric telegraph was occupying the minds of the philosophers of different countries, but it was not until the year 1846 that the first practical line of telegraph was established between Paddington and Slough, where it soon gained notoriety in preventing the escape from justice of a great criminal. It is unnecessary for me to insist upon the enormous results that have been achieved by this great modern innovation, which goes even beyond the poetic vision of Shakespeare himself, who in the extravagance of his "Midsummer Night's Dream" makes Puck "encircle the earth in forty minutes," a rate of communication which would nowadays hardly satisfy the City merchants who expect Calcutta and New York to respond to their calls much more promptly than that.

The telegraph has found its simplest but most remarkable development in the telephone, which although shadowed forth by Riess in 1862, was only reduced to anything like a practical shape by Graham Bell in 1876, and subsequently extended by Edison, Hughes, and others.

This latter invention appeared at first particularly unpromising of practical results. The currents set up through the vibrations of a metallic diaphragm facing the poles of a magnet are so feeble, and the rate of succession of currents necessary to produce sound (represented by 440 vibrations per second to produce the note fundamental la) was so very much beyond anything met with in telegraphy, that it was difficult to conceive how such a succession of distinct currents with the infinite variety of strength and quality necessary to reproduce speech, could be transmitted through a line wire many miles in length, and could reproduce mechanically the same sounds at the receiving end. Yet the telephone has become a practical reality, and its ultimate powers
are illustrated in a very remarkable manner at the Paris Exhibition.

There, in a certain room, you may listen of an evening one minute to the performance going on at the Great Opera House, the next minute to an air sung at the Opéra Comique, and again the next minute to the well-known voices of the principal actors of the Théâtre Français. The novelty of this particular arrangement consists in having each receiving telephone connected separately to a transmitting telephone, fixed in front of the footlights towards the two sides of the stage, whereby an acoustic effect is produced that may almost be called stereoscopic; you actually hear when the actor turns his or her head from one side to the other, and are able to separate most distinctly the several voices, as well as the orchestral instruments when concerted music is being produced. Nor are the sounds in any way distorted or disagreeable, or too low to be enjoyable, but loud and full, producing an agreeable impression even on the musical ear. The person with his ears to the two receiving telephones imagines himself in a mysterious dreamland of sound, but remove the instruments only half an inch from the ear, and all has departed, no sweet sounds of music are heard, but in their stead the speaking voice of the person anxious to take your place at the auditory. I leave it to your imagination to picture the innumerable applications which this new power of man in directing the forces of nature may ultimately lead to.

The most striking feature upon entering the Paris Exhibition in the evening is the blaze of electric light that makes the interior of that large building even brighter than by daylight; nor is the effect of this illumination marred by the flickering, fizzing, and colour changing of the earlier attempts in this direction. The character of the lights comprises a range from the central arc of 10,000 candle power, to the incandescent lamp of only 15 candles, equalling the light only of an ordinary gas burner, and the grouping and shading of some of these lights are such as to produce effects extremely agreeable to the eye. Who would venture to say, after this display, and after the practical applications that have been made of the electric light in the City of London, at several of our docks and harbours, at works, halls, and theatres, that it is not a practical illuminant destined to work as great a change as
gas-lighting did before it, thirty years ago, when it was inaugurated at the Soho Works not many miles away from this hall?

But, although I predict a great future for electric light as being the most brilliant, the cheapest, and the least objectionable from a sanitary point of view of all illuminants, I do not agree with those who consider that the days of gas must therefore be numbered.

In addressing the British Association of Gas Managers in this town a few months ago, I called attention to certain means by which gas of much higher illuminating power might be obtained from the ordinary retorts, if only, at the same time, the gas companies or corporations could be induced to supply at a reduced rate heating gas, of which we so much stand in need; and how, by certain improvements in the burners themselves, the illuminating power of a given quantity of gas might be still further augmented. Gas companies have for many years enjoyed the sweets of their monopoly position, which position is generally speaking not productive of desire for change. The electric light has furnished for them the incentive to advance, and the effect of that incentive has told already, I am glad to observe, in a very striking manner upon the street illumination of this immediate neighbourhood.

The time is not far distant, I believe, when gaseous fuel will almost entirely take the place of solid fuel for heating, for obtaining motive power, and for the domestic grate; and if gas companies and corporations rightly understand their mission, they will take timely steps to supply, separately, heating gas at a greatly reduced cost, the demand for which would soon be tenfold the gas consumption of the present day. The economy and the comfort which would accrue to the inhabitants of large towns by such a change would be great indeed, and it would, amongst other things, effect a radical cure of that great bugbear of our winter existence, a smoky atmosphere.

The third great practical illustration furnished by the Paris Exhibition has reference to the transmission of power from one place to another by means of the electric conductor. When, only five years ago, in addressing the Iron and Steel Institute, I ventured upon the assertion that the time was not distant when the great natural sources of power, such as waterfalls, would be trans-
ferred to considerable distances by means of stout electric conductors, to be there utilised for providing towns with light and motive power, I elicited an incredulous smile even from some of those most conversant with the laws of electricity. Electricity had been looked upon by them as a swift agent to flash our thoughts from country to country, but the means of producing that form of energy by the expenditure of power on the dynamoelectric machine, although known, was not yet properly appreciated. Such can scarcely now be considered the case. I could point to at least three instances in this country where power is practically transmitted to a distance by means of electricity, to be utilised for pumping water, for lighting, and for working machinery, and the Paris Exhibition furnishes additional illustration of the facility with which that transmission may be effected.

The electric railway leading from the Place de la Concorde into the Exhibition, only half a kilometer in length, does its work regularly and well, running a trip every five minutes, and conveying generally as many passengers as can be packed both inside and outside of a tramcar of ordinary dimensions. This system of propulsion will soon be in operation on a new line of railway, 6 miles long, with which I am connected, in the north of Ireland, to be extended, if successful, to a further equal distance. This will give us 12 miles of electric railway worked without expenditure of fuel, for the motive power will be obtained from a neighbouring waterfall, which at present runs to waste. Mr. W. A. Traill, the resident engineer of the line, has already commenced construction, and I hope that by next spring, visitors to the sister island may reach one of its most interesting sights, the Giant's Causeway, propelled by invisible but yet potential agency.

The experience gained by my brother in the working of the first electric railway, 2 miles in length, established by him at Lichtenfelde, near Berlin, leaves no reasonable doubt regarding the economy and certainty of this mode of propulsion, although it is not anticipated that it will supersede locomotive power upon our main trunk railways. It will have plenty of scope in relieving the toiling horses on our tramways, in working elevated railways in populous districts, and in such cases as the Metropolitan Railway, where the emission of the products of combustion causes not only the propulsion but also the suffocation of passengers.
Another application of electricity, also at any rate indicated at the Paris Exhibition, is that to agriculture and horticulture, upon which I have been practically engaged during the last two winters on my farm near Tunbridge Wells. This is neither the time nor place for me to enlarge upon this application, which should be mentioned, however, because I believe that it will ultimately exercise a considerable influence upon an important interest, besides providing a means of adding to the pleasures of country pursuits. Electro-culture by itself would be expensive, but not so if combined, as it is at Sherwood, with the utilisation of electric energy for accomplishing other objects—such as chaff- and root-cutting at one place, wood-cutting at another, and pumping of water at a third, while the waste heat of the steam at the generating station is utilised to heat the water circulating through the greenhouses, &c. In this way labour and expense are saved in many ways, and the men employed on the farm find no difficulty in working the electrical horses, no longer experimentally, but as a regularly established thing.

A somewhat special application of electricity, also shown at the Paris Exhibition, is its employment as a heating agent. For temperatures not exceeding that of a welding furnace, solid or gaseous fuel produces the desired effect at a cheaper rate than it is likely to be accomplished by electricity. When electricity is used, heat energy has in the first place to be transferred from the burning fuel to the boiler of the steam engine. The mechanical energy of the engine works the dynamo-electric machine, whence electric energy is transmitted through the conductor to the point where it is to be utilised as heat. At each intermediate stage a loss will have to be incurred, and it is therefore absolutely certain that the amount of heat finally produced in the electric arc must fall very much short of that generated by the fuel under the boiler. But the electric arc has this advantage over other sources of heat, that no waste heat need pass away from it in the shape of heated products of combustion. This loss of heat in the furnace by combustion increases with the temperature at which the work has to be accomplished, and reaches its maximum in a furnace for melting steel or platinum. Beyond this the point is soon reached where combustion ceases entirely, where, to use the scientific phrase, the point of dissociation of carbonic acid is reached; and it is for pur-
poses where such degrees of heat are required that the electric arc can be advantageously employed, and will enable us to accomplish chemical effects which have hitherto been beyond the reach of science.

My chief object in dwelling, perhaps unduly, upon these practical questions is to present to your minds in a concrete form the hopelessness of looking upon any of the practical processes of the present day as permanent, to be acquired in youth and to be the staple occupation of a lifetime.

The respectable millwright of former years had already to enlarge his scope of knowledge, and become a steam-engine builder; having made himself master of the construction of simple forms of high-pressure engines, he has had to go to school again, to study the laws of condensation and of the expansive action of steam, in order to produce an engine using only a fractional amount of the fuel which his customers were willing to expend in former years for a given effect; he now has to study the laws of electricity and understand the construction of dynamo-electric machines, in order to be able to transmit and distribute his steam power more readily than could be accomplished by means of wheels and belts. But even his condensing steam-engine with variable expansion, of which he is so justly proud to-day, will no longer be acceptable to his client to-morrow, when it will be made clear to him, by the light of thermo-dynamics, that even the best of steam-engines utilises barely a seventh part of the heat-energy residing in fuel, and that the attainment of perhaps three-fourths of that ultimate limit will be required of him.

Analogous changes threaten to invade almost every existing branch of industry, and it is necessary for every one of you to be prepared for such changes.

The practical man of former days will have to yield his place to the unbiased worker who with open mind is prepared for every forward step as it arises. For this purpose it is necessary that he should possess, beyond the mere practical knowledge of his trade, a clear appreciation of the principles of action underlying each operation, and such general acquaintance with the laws of chemistry and physical science as will make it easy for him to adapt himself to the new order of things.

In order to be so prepared, it is by no means necessary that you
should have the advantage of an elaborate school education. No man or woman either should ever consider him or herself out of school, and it is through advantages such as are offered by the Midland Institute, that the means are afforded of continuing the educational process near your homes, and without much expense or difficulty of any kind.

Let no one of you suppose that his early training or natural ability is unequal to the task of making a career in life. Goethe, that man of wonderful insight into the working of the human mind, says:—

"Was man sich in der Jugend wünscht,
Hat man im Alter in Fülle."

Or, translated,

"What you desire in youth,
Mature age will give you in abundance."

At first sight this expression seems to involve almost an absurdity, and it is necessary to interpret the "desire" of youth to mean, not simply a vague sentiment or wish to be looked up to in after life, or to drive about in easy carriages, but a determination to leave no stone unturned, and let no opportunity go past that may advance you towards the well-defined object of your ambition. With a firm resolution almost every difficulty in your way will recede before you; disappointments you will have, and they are most desirable, because they are the real teachers in practical life, only you must not allow yourself to be discouraged but rather to be strengthened by them, in your determination to succeed.

A fond mother has sometimes come to me with a doleful story that her son, "an excellent young man," had tried several things in life and had always failed, through some untoward circumstance, but that she felt sure he would succeed if I would only give him a trial in my own particular pursuits. On some occasions I have perhaps yielded to such representations, but found that the "excellent young man," though commencing with a certain vigour, soon tired of the new occupation when he approached its difficulties. He could not realise the fact that the secret of success lies, not in the avoidance of, but in the victory over, difficulties—that each
disappointment teaches an important lesson, and that by taking these lessons to heart without swerving from his purpose he would soon find himself possessed of a power exceeding his most sanguine expectations.

Success in life depends in fact much more upon diligence and steadiness of purpose than upon the more brilliant qualities possessed by an individual; but in order to give force and direction to the sterling qualities within him, it is most important that means should be brought within his reach of enriching his stock of useful information. The Birmingham and Midland Institute, counting its 2688 students of various degrees, of both sexes, has accomplished this important object in a manner never before dreamt of; but not content with this splendid result, the Council has made provision for a further extension of its beneficial action through the erection of the magnificent lecture hall, which has been inaugurated so impressively this morning under the presidency of your Mayor.

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PRICE'S RETORT FURNACE.

TO THE EDITOR OF "THE ENGINEER."

SIR,—Although I noticed in your journal of the 21st ult. a letter from Mr. William Price, finding fault with my observations on Colonel Maitland's paper, read at the last meeting of the Iron and Steel Institute, I did not think it necessary to trouble you with any reply, considering that Mr. Price is evidently not well informed on what I did say, and will before long be in possession of the paper, and of my observations upon the same.

In your issue of last week I observe a further letter from Mr. Price, written in the challenging style, and calling attention to the points of difference between his furnace and the regenerative gas furnace of usual construction, which I admit are very great.

When Mr. Price sees the complete account of the meeting, he will find that I did not criticise his furnace, but stated the diffi-
culties I had found with the combined retort and grate gas producer, as patented by me in 1864, No. 3018, which patent Mr. Price seems to ignore, although it must have been extensively read, seeing that all printed copies of the specification have been sold, and a second edition is being prepared at the Patent Office.

I asked two questions at the meeting, viz., in what respect the retort gas producer employed at Woolwich differed from mine, and what was the consumption of fuel per ton of steel produced? No answer was given at the meeting to these two practical questions; but Mr. Price now states, in reply to the first, six points of difference between his furnace and the regenerative gas furnace with reversible regenerators, as usually constructed by me. These points of difference, however, do not remove the important points of similarity between the two apparatus in question, viz., that of both being gas producers, consisting of a vertical retort placed above a common grate, with admission of atmospheric air, the retort portion being heated by spare sensible heat, in order to pass the fuel through the first stages of distillation. In both cases the hydrocarbons evolved in the retort pass downward and through the fuel made incandescent by the air passing through the grate; and the waste heat of the furnace is also in both cases utilised to heat the air before entering into combustion, although Mr. Price's form of regenerator may differ from the non-reversible form of regenerator I have usually adopted where moderate degrees of heat are required.

The value of Mr. Price's construction should be tested by my second question having reference to the total amount of fuel consumed in both cases per ton of steel produced. If Mr. Price can answer this question satisfactorily, I should be the first to admit that he had made a valuable improvement; but if, on the contrary, as I suspect, the consumption in his furnace considerably exceeds that in the regenerative gas furnace of usual construction, in that case I can only regard it as an imperfect imitation of an existing arrangement of recognised value. But, in any case, I might have expected a graceful acknowledgment of my labours, both as regards the furnace and the steel process employed at the Arsenal, notwithstanding the immunity claimed by public departments from liability under letters patent.

I am pleased to observe that Mr. Price promises us an account
of the circumstances surrounding the first application of the regenerative gas furnace at the Woolwich Gun Factory, from which it will be made clear why that furnace was constructed without reference to the practical information that might easily have been obtained, if not from myself, at the works of my licensees. Regarding my own connection with the transaction, I beg to repeat that I never saw the furnace in operation, and that when I was asked to inspect it after it had been put out, I could only have reported as I did, that its reconstruction was necessary to attain the end in view.

C. William Siemens.

12, Queen Anne's Gate, S.W., November 8th, 1881.

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THE CONSERVATION OF SOLAR ENERGY.

BY DR. SIEMENS, F.R.S.*

A paper was recently read by me before the Royal Society, under the above title, which may be termed a first attempt to open for the sun a creditor and debtor account, inasmuch as he has hitherto been regarded only as the great almoner, pouring forth incessantly his boundless wealth of heat, without receiving any of it back. Such a proposal touches the root of solar physics, and cannot therefore be expected to pass without challenge—to meet which I gladly embrace the opportunity, now offered to me through the courtesy of the Editor of this Review, of enlarging somewhat upon the first concise statement of my views regarding this question.

Man has from the very earliest ages looked up with a feeling of awe and wonderment to our great luminary, to whom we owe not only the light of day, but the genial warmth by which we live, by which our hills are clad with verdure, our rivers flow, and without

* Reprinted by permission from the "Nineteenth Century" of April, 1882.
which our life-sustaining food, both vegetable and animal, could not be produced.

When for our comfort and our use we resort to a fire either of wood or coal, we know now by the light of modern science that we are utilising only solar rays that have been stored up by the aid of the process of vegetation in our forests or in the forests of former geological ages, when our coal-fields were the scenes of rank tropical growth. The potency of the solar ray in this respect was recognised—even before science had discovered its true significance—by clear-sighted men such as the late George Stephenson, who, when asked what in his opinion was the ultimate cause of the motion of his locomotive engine, said that he thought it went by "the bottled-up rays of the sun."

With the exception of our coal-fields and a few elementary combustible substances such as sulphur and what are called the precious metals, which we find sparsely scattered about, our earth consists essentially of combined matter. Thus our rivers, lakes and oceans are filled with oxidised hydrogen, the result of a most powerful combustion; and the crust of our earth is found to consist either of quartz (a combination of the metal silicon with oxygen) or limestone (oxidised calcium combined with oxidised carbon), or of other metals, such as magnesium, aluminium, or iron, oxidised and combined in a similar manner. Excepting, therefore, the few substances before enumerated, we may look upon our earth, near its surface at any rate, as a huge ball of cinder, which, if left to itself, would soon become intensely cold, and devoid of life or animation of any kind.

It is true that a goodly store of heat still exists in the interior of our earth, which according to some geologists is in a state of fusion, and must certainly be in a highly heated condition; but this internal heat would be of no avail, owing to the slow rate of conduction, by which alone, excepting volcanic action, it could be brought to us living upon its surface.

An estimate of the amount of heat poured down annually upon the surface of our earth may be formed from the fact that it exceeds a million times the heat producible by all the coal raised, which may be taken at 280,000,000 tons a year.

If then we depend upon solar radiation for our very existence from day to day, it cannot be said that we are only remotely in-
SIR WILLIAM SIEMENS, F.R.S. 295

interested in solar physics, and the question whether and how solar energy, comprising the rays of heat, of light, and the actinic rays, is likely to be maintained, is one in which we have at least as great a reversionary interest as we have in landed estate or other property.

If the amount of heat, or, more correctly speaking, of energy, supplied annually to our earth is great as compared with terrestrial quantities, that scattered abroad in all directions by the sun strikes us as something almost beyond conception.

The amount of heat radiated from the sun has been approximately computed by the aid of the pyrheliometer of Pouillet, and by the actinometers of Herschel, at 18,000,000 heat units from every square foot of its surface per hour; or, expressed popularly, if coals were consumed on the surface of the sun in the most perfect manner, our total annual production of 280,000,000 tons, being the estimated produce of all the coal-mines of the earth, would suffice to keep up solar radiation for only one forty-millionth part of a second; or, if the earth was a mass of coal, and could be supplied by contract to the solar furnace-men, this supply would last them just thirty-six hours.

If the sun were surrounded by a solid sphere of a radius equal to the mean distance of the sun from the earth (95,000,000 of miles), the whole of this prodigious amount of heat would be intercepted; but considering that the earth's apparent diameter as seen from the sun is only seventeen seconds, the earth can intercept only the 2250-millionth part. Assuming that the other planetary bodies swell the amount of intercepted heat to ten times this amount, there remains the important fact that \( \frac{1}{700,000,000} \) of the solar energy is radiated into space, and apparently lost to the solar system, and only \( \frac{1}{2,250,000,000} \) utilised or intercepted.

Notwithstanding this enormous loss of heat, solar temperature has not diminished sensibly for centuries, if we neglect the periodic changes, apparently connected with the appearance of sun-spots, that have been observed by Lockyer and others, and the question forces itself upon us how this great loss can be sustained without producing an observable diminution of solar temperature even within a human lifetime.

Amongst the ingenious hypotheses intended to account for a continuance of solar heat is that of shrinkage or gradual reduction of the sun's volume suggested by Helmholtz. It may, however,
be argued against this theory that the heat so produced would be liberated throughout its mass, and would have to be brought to the surface by conduction, aided perhaps by convection; but we know of no material of sufficient conductivity to transmit anything approaching the amount of heat lost by radiation.

Chemical action between the constituent parts of the sun has also been suggested; but here again we are met by the difficulty that the products of such combination would ere this have accumulated on the surface, and would have formed a barrier against further action.

These difficulties led Sir William Thomson to the suggestion that the cause of maintenance of solar temperature might be found in the circumstance of meteorites, not falling upon the sun from great distances in space, as had been suggested by Mayer and Waterston, but circulating with an acquired velocity within the planetary distances of the sun, and he shows that each pound of matter so imported would represent a large number of heat units without disturbing the planetary equilibrium. But in considering more fully the enormous amount of planetary matter that would be required for the maintenance of the solar temperature, Sir William Thomson soon abandoned this hypothesis for that of simple transfer of heat from the interior of a fluid sun to the surface by means of convection currents, which latter hypothesis is at the present time supported by Professor Stokes and other leading physicists.

This theory has certainly the advantage of accounting for the greatest possible store of heat within the solar mass, because it supposes the latter to consist in the main of a fluid heated to such a temperature that if it were relieved at any point of the confining pressure, it would flash into gas of a vastly inferior, but still of an elevated, temperature. It is supposed that such fluid material, or material in the "critical" condition, as Professor Thomas Andrews of Belfast has named it, is continually transferred to the surface by means of convection currents, that is to say, by currents forming naturally when a fluid substance is cooled at its upper surface, and sinks down after cooling to make room for ascending material at the comparatively higher temperature. It is owing to such convection currents that the temperature of a room is, generally speaking, higher towards the
ceiling than towards the floor, and that upon plunging a thermometer into a tank of heated water the surface temperature is found slightly superior to that near the bottom.

These convection currents owe their existence to a preponderance of the cooled descending over the ascending current; but this difference being slight, and the ascending and descending currents intermixing freely, they are, generally speaking, of a sluggish character; hence in all heating apparatus it is found essential to resort either to artificial propulsion, or to separating walls between the ascending and the descending currents, in order to give effect to the convective transfer of heat.

In the case of a fluid sun another difficulty presents itself through the circumstance that the vast liquid interior is enveloped in a gaseous atmosphere, which, although perhaps some thousands of miles in depth, represents a relatively very small store of heat. Convection currents may be supposed active in both the gaseous atmosphere and in the fluid ocean below, but the surface of this fluid must necessarily constitute a barrier between the two convective systems, nor could the convective action of the gaseous atmosphere, that is to say, the simple up and down currents caused by surface refrigeration, be such as to disturb the liquid surface below to any great extent, because each descending current would have had plenty of time to get intermixed with its neighbouring ascending current, and would, therefore, have reached its least intensity on arriving on the liquid surface.

As regards the liquid, its most favourable condition for heating purposes would be at the critical point, or that at which the slightest diminution of superincumbent pressure would make it flash off into gas; but considering that, by means of conduction and convection, the liquid matter must have assumed in the course of ages a practically uniform temperature to a very considerable depth, it follows that the liquid below the surface, with fluid pressure in addition to that of the superimposed gaseous atmosphere, must be ordinary fluid, the critical condition being essentially confined only to the surface.

Conditions analogous to those here contemplated are met with in a high-pressure steam boiler, with its heated water and dense vapour atmosphere. Suppose the fire below such a boiler be
withdrawn, and its roof be exposed to active radiation into space, what should we observe through a strong pane of glass inserted in the side of the boiler near the liquid surface, lit up by an incandescent electric lamp within? The loss of heat by radiation from the boiler would give rise to convection currents, and partial condensation of the vapour atmosphere; then, if the motion of the water was made visible by means of colouring matter, we should observe convection currents in the fluid mass separate and distinct from those in the gaseous mass; but these convection currents would cause no visible disturbance of the liquid surface, which would present itself to the eye with the smoothness of a mirror. It is only in the event of the steam pressure being suddenly relieved at any point on the surface that a portion of the water would flash into steam, causing a violent upheaval of the liquid.

The dark spots on the sun appear to indicate commotion of this description, but these are evidently not the result of mere convection currents; if they were, they would occur indiscriminately over the entire surface of the sun, whereas telescopic observation has revealed the fact that they do occur almost exclusively in two belts, between the equator and the polar surfaces on either side. Their occurrence could be satisfactorily explained if we could suppose the existence of strong lateral currents flowing from the polar surfaces towards the equator, which lateral currents in the solar atmosphere would cause cyclones or vortex action with a lower and denser atmosphere consisting probably of metallic vapours; this vortex action extending downward, would relieve the fluid ocean locally from pressure, and give rise to explosive outbursts of enormous magnitude, projecting the lower atmosphere high above the photosphere, with a velocity measured, according to Lockyer, by a thousand miles a second. It will be seen from what follows how, according to my views, such vortex action in those intermediate regions of the sun would necessarily be produced.

But supposing that, notwithstanding the difficulties just pointed out, convection currents sufficed to effect a transfer of internal heat to the surface with sufficient rapidity to account for the enormous surface-loss by radiation, we should only have the poor satisfaction of knowing that the available store would last longer.
than might have been expected, whereas a complete solution of the problem would be furnished by a theory, according to which the radiant energy which is now supposed to be dissipated into space and irrecoverably lost to our solar system, could be arrested and brought back in another form to the sun himself, there to continue the work of solar radiation.

Some six years ago the thought occurred to me that such a solution of the solar problem might not lie beyond the bounds of possibility, and although I cannot claim intimate acquaintance with the intricacies of solar physics, I have watched its progress, and have engaged also in some physical experiments bearing upon the question, all of which have served to strengthen my confidence and to ripen in me the determination to submit my views, not without some misgiving, to the touchstone of scientific criticism.

For the purposes of my theory, stellar space is supposed to be filled with highly rarefied gaseous bodies, including hydrogen, oxygen, nitrogen, carbon, and their compounds, besides solid materials in the form of dust. Each planetary body would in that case attract to itself an atmosphere depending for density upon its relative attractive importance, and it would not seem unreasonable to suppose that the heavier and less diffusible gases would form the staple of these local atmospheres; that, in fact, they would consist mostly of nitrogen, oxygen, and carbonic acid, whilst hydrogen and its compounds would predominate in space.

In support of this view it may be urged, that in following out the molecular theory of gases as laid down by Clausius, Clerk Maxwell, and Thomson, it would be difficult to assign a limit to a gaseous atmosphere in space; and, further, that some writers—among whom I will here mention only Grove, Humboldt, Zoellner and Mattieu Williams—have boldly asserted the existence of a space filled with matter. But Newton himself, as Dr. Sterry Hunt tells us in an interesting paper which has only just reached me, has expressed views in favour of such an assumption.

The history of Newton's paper is remarkable and very suggestive. It was read before the Royal Society on the 9th and 16th of December, 1675, and remained unpublished until 1757, when it was printed by Birch, the then secretary, in the third volume of his History of the Royal Society, but received no attention; in 1846 it was published in the "Philosophical Magazine" at the sugges-
tion of Harcourt, but was again disregarded; and now, once more, only a few months since, a philosopher on the other side of the Atlantic brings back to the birthplace of Newton his forgotten and almost despised work of 200 years ago.

Quoting from Dr. Sterry Hunt's paper:

"Newton in his Hypothesis, imagines 'an ethereal medium much of the same constitution with air, but far rarer, subtler, and more elastic.' 'But it is not to be supposed that this medium is one uniform matter, but composed partly of the main phlegmatic body of ether, partly of other various ethereal spirits, much after the manner that air is compounded of the phlegmatic body of air intermixed with various vapours and exhalations.' Newton further suggests in his Hypothesis that this complex spirit or ether, which, by its elasticity, is extended throughout all space, is in continual movement and interchange. 'For Nature is a perpetual circulatory worker, generating fluids out of solids, and solids out of fluids; fixed things out of volatile, and volatile out of fixed; subtile out of gross, and gross out of subtile; some things to ascend and make the upper terrestrial juices, rivers, and the atmosphere, and by consequence others to descend for a requital to the former. And as the earth, so perhaps may the sun imbibe this spirit copiously, to conserve his shining, and keep the planets from receding farther from him; and they that will may also suppose that this spirit affords or carries with it thither the solary fuel and material principle of life, and that the vast ethereal spaces between us and the stars are for a sufficient repository for this food of the sun and planets.' 'Thus, perhaps, may all things be originated from ether."

If at the time of Newton chemistry had been understood as it now is, and if moreover he had been armed with that most wonderful of all modern scientific instruments, the spectroscope, the direct outcome of his own prismatic analysis, there appears to be no doubt that the author of the laws of gravitation would have so developed his thoughts upon solar fuel, that they would have taken the form rather of a scientific discovery than of a mere speculation.

Our proof that interstellar space is filled with attenuated matter does not rest however solely upon the uncertain ground of speculation. We receive occasionally upon our earth celestial visitors
termed meteorites; these are known to travel in loose masses round the sun in orbits intersecting at certain points that of our earth. When in their transit they pass through the denser portion of our atmosphere they become incandescent, and are popularly known as falling stars. In some cases they are really deserving of that name, because they strike down upon our earth, from the surface of which they have been picked up and subjected to searching examination whilst still warm after their exertion. Dr. Flight has only very recently communicated to the Royal Society an analysis of the occluded gases of one of these meteorites as follows:—

\[
\begin{array}{ll}
\text{CO}_2 \text{ (Carbonic acid)} & 0.12 \\
\text{CO} \text{ (Carbonic oxide)} & 31.88 \\
\text{H} \text{ (Hydrogen)} & 45.79 \\
\text{CH}_4 \text{ (Marsh gas)} & 4.55 \\
\text{N} \text{ (Nitrogen)} & 17.66 \\
\hline
\text{Total} & 100.00
\end{array}
\]

It appears surprising that there was no aqueous vapour, considering there was much hydrogen and oxygen in combination with carbon; but perhaps the vapour escaped observation, or was expelled to a greater extent than the other gases by external heat when the meteorite passed through our atmosphere. Opinions concur that the gases found occluded in meteorites cannot be supposed to have entered into their composition during the very short period of traversing our denser atmosphere; but if any doubt should exist on this head, it ought to be set at rest by the fact that the gas principally occluded is hydrogen, which is not contained in our atmosphere in any appreciable quantity.

Further proof of the fact that stellar space is filled with gaseous matter is furnished by spectrum analysis, and it appears from recent investigation, by Dr. Huggins and others, that the nucleus of a comet contains very much the same gases found occluded in meteorites, including "carbon, hydrogen, nitrogen, and probably oxygen," whilst, according to the views set forth by Dewar and Liveing, it also contains nitrogenous compounds such as cyanogen.

Adversely to the assumption that interplanetary space is filled
with gases, it is urged that the presence of ordinary matter would cause sensible retardation of planetary motion, such as must have made itself felt before this; but, assuming that the matter filling space is an almost perfect fluid not limited by border surfaces, it can be shown on purely mechanical grounds that the retardation by friction through such an attenuated medium would be very slight indeed, even at planetary velocities.

But it may be contended that, if the views here advocated regarding the distribution of gases were true, the sun should draw to himself the bulk of the least diffusible, and therefore the heaviest gases, such as carbonic acid, carbonic oxide, oxygen and nitrogen, whereas spectrum analysis has proved, on the contrary, a great prevalence of hydrogen.

In explanation of this seeming anomaly, it can be shown, in the first place, that the temperature of the sun is so high, that such compound gases as carbonic acid and carbonic oxide could not exist within him, their point of dissociation being very much below the solar temperature. It has been contended, indeed, by Mr. Lockyer, that none of the metalloids have any existence at these temperatures, although as regards oxygen Dr. Draper asserts its existence in the solar photosphere. There must be regions, however, outside that thermal limit, where their existence would not be jeopardised by heat; and here great accumulation of the comparatively heavy gases that constitute our atmosphere would probably take place, were it not for a certain counterbalancing action.

I here approach a point of primary importance in my argument, upon the proof of which my further conclusions must depend.

The sun completes one revolution on its axis in twenty-five days, and its diameter being taken at 882,000 miles, it follows that the tangential velocity amounts to 1.25 miles per second, or to what the tangential velocity of our earth would be if it occupied five hours instead of twenty-four in accomplishing one revolution. This high rotative velocity of the sun must cause an equatorial rise of the solar atmosphere, to which Mairan, in 1731, attributed the appearance of zodiacal light. La Place rejected this explanation on the ground that zodiacal light extended to a distance from the sun exceeding our own, whereas the equatorial rise of the solar atmosphere due to its rotation could not exceed nine-twentieths
of the distance of Mercury. But it must be remembered that
La Place based his calculation upon the generally accepted
hypothesis of an empty stellar space (occupied only by an
imaginary æther), and it can be shown that the result of solar
rotation would be widely different, if supposed to take place
within a medium of unbounded extension. In this case pressures
would be balanced all round, and the sun would act mechanically
upon the floating matter surrounding him in the manner of a
fan, drawing it towards himself upon the polar surfaces, and
projecting it outwards in a continuous disk-like stream from the
equatorial surfaces.

By this fan action, hydrogen, hydrocarbons, and oxygen are
supposed to be drawn in enormous quantities toward the polar
surfaces of the sun; during their gradual approach they pass
from their condition of extreme attenuation and intense cold to
that of compression, accompanied with increase of temperature,
until, on approaching the photosphere, they burst into flame,
giving rise to a great development of heat, and a temperature
commensurate with their point of dissociation at the solar density.
The result of their combustion will be aqueous vapour and carbonic
acid, and these products of combustion, in yielding to the influence
of centrifugal force, will flow towards the solar equator, and be
thence projected into space.

In view of the importance of this centrifugal action for the
purpose of my theory, the following simple mathematical state-
ment of the problem may not be thought out of place. Let us
consider the condition of two equal gaseous masses, at equal
distances from the solar centre, the one in the direction of the
equator, the other in that of either of the poles. These two
masses would be equally attracted towards the sun, and balance
one another as regards the force of gravitation, but the former
would be subject to another force, that of centrifugal action,
which, however small in amount as compared with the enormous
attraction of the sun, would destroy the balance, and determine a
motion towards the sun as regards the mass opposite the polar
surface, and into space as regards the equatorial mass. The same
action would take effect upon the masses filling their places, and
the result must be a continuous current depending for its velocity
upon the rate of solar rotation. The equatorial current so pro-
duced, owing to its mighty proportions, would flow outward into space, to a practically unlimited distance.

The next question for consideration is: What would become of these products of combustion when thus returned into space? Apparently they would gradually change the condition of stellar material, rendering it more and more neutral; but I venture to suggest the possibility, nay, the probability, that solar radiation will, under these conditions, step in to bring back the combined materials to a state of separation by dissociation carried into effect at the expense of that solar energy which is now supposed to be irrevocably lost or dissipated into space as the phrase goes.

According to the law of dissociation as developed by Bunsen and Sainte-Claire Deville, the point of decomposition of different compounds depends upon the temperature on the one hand, and upon the pressure on the other. According to Sainte-Claire Deville, the dissociation tension of aqueous vapour at atmospheric pressure and at 2800° C. is 0.5, that is to say one half of the vapour would exist as such, the remaining half being found as a mechanical mixture of hydrogen and oxygen; but with the pressure, the temperature of dissociation rises and falls, as the temperature of saturated steam rises and falls with its pressure. It is therefore conceivable that the solar photosphere may be raised by combustion to a temperature exceeding 2800° C., whereas dissociation may be effected in space at a lower temperature. This temperature of 2800° would be quite sufficient to account for the character and amount of solar radiation, if it is only borne in mind that the luminous atmosphere may be a thousand miles in depth, and that the flame of hydrogen and hydrocarbons, in the uppermost layers of this zone, is transparent to the radiant energy produced in the layers below, thus making the total radiation rather the sum of matter in combustion than the effect of a very intensely heated surface.

Sainte-Claire Deville's investigations had reference only to heats measured by means of pyrometers, but do not extend to the effects of radiant heat. Dr. Tyndall has shown by his important researches that vapour of water and other gaseous compounds intercept radiant heat in a most remarkable degree, and there is other evidence to show that radiant energy from a source of high intensity possesses a dissociating power far sur-
passing the measurable temperature to which the compound substance under its influence is raised. Thus carbonic acid and water are dissociated in the leaf-cells of plants under the influence of the direct solar ray at ordinary summer temperature, and experiments in which I have been engaged for nearly three years* go to prove that this dissociating action is obtained also under the radiant influence of the electric arc, although it is scarcely perceptible if the energy is such as can be produced by an inferior source of heat.

The point of dissociation of aqueous vapour and carbonic acid admits, however, of being determined by direct experiment. It engaged my attention some years ago, but I have hesitated to publish the qualitative results I then obtained, in the hope of attaining to quantitative proofs.

These experiments consisted in the employment of glass tubes furnished with platinum electrodes, and filled with aqueous vapour or with carbonic acid in the usual manner, the latter being furnished with caustic soda to regulate the vapour pressure by heating. Upon immersing one end of the tube charged with aqueous vapour in a refrigerating mixture of ice and chloride of calcium, its temperature at that end was reduced to \(-32^\circ C\), corresponding to a vapour pressure, according to Regnault, of \(\frac{1}{300}\)th of an atmosphere. When so cooled no slow electric discharge took place on connecting the two electrodes with a small induction coil. I then exposed the end of the tube projecting out of the freezing mixture, backed by white paper, to solar radiation (on a clear summer's day) for several hours, when upon again connecting up to the inductorium, a discharge, apparently that of a hydrogen vacuum, was obtained. This experiment being repeated furnished unmistakeable evidence, I thought, that aqueous vapour had been dissociated by exposure to solar radiation. The carbonic acid tubes gave, however, less unmistakeable effects. Not satisfied with these qualitative results, I made arrangements to collect the permanent gases so produced by means of a Sprengel pump, but was prevented by lack of time from pursuing the inquiry, which I propose, however, to resume shortly, being of opinion that, in-

* See Proceedings, Royal Society, Vol. XXX., March 1, 1880; also a paper read before Section A of the British Association, September 1, 1881, and ordered to be printed in the Report.
dependently of my present speculation, the experiments may prove useful in extending our knowledge regarding the laws of dissociation.

It should be here observed that, according to Professor Stokes, the ultra violet rays are in large measure absorbed in passing through clear glass, and it follows from this discovery that only a small portion of the chemical rays found their way through the tubes to accomplish the work of dissociation. This circumstance being adverse to the experiment only serves to increase the value of the effect observed, whilst it appears to furnish additional proof of the fact, first enunciated by Professor Draper, and corroborated by my own experiments on plants, that the dissociating power of light is not confined to the ultra violet rays, but depends in the process of vegetation chiefly upon the yellow and red rays.

Assuming, for my present purpose, that dissociation of aqueous vapour was really effected in the experiment just described, and assuming, further, that stellar space is filled with aqueous and other vapour of a density not exceeding the \( \frac{1}{300} \)th part of our atmosphere, it seems reasonable to suppose that its dissociation would be effected by solar radiation, and that solar energy would thus be utilised. The conjoint presence of aqueous vapour, carbonic acid and nitrogen would only serve to facilitate their decomposition, in consequence of the simultaneous formation of hydrocarbons and nitrogenous compounds by combination of the nascent hydrogen and the nitrogen with carbon in a manner analogous to what occurs in vegetation. It is not necessary to suppose that all the energy radiated from the sun into space should be intercepted, inasmuch as even a partial return of heat in the manner described would serve to supplement solar radiation, the balance being made up by absolute loss. To this loss of energy would have to be added that consumed in sustaining the circulating current, which however need not relatively be more than what is known to be lost on our earth through the tidal action, and may be supposed to be compensated as regards the time of solar rotation by gradual shrinkage.

By means of the fan-like action resulting from the rotation of the sun, the vapours dissociated in space to-day would be drawn towards the polar surfaces of the sun to-morrow, be heated by increase in density, and would burst into flame at a point where
both their density and temperature had reached the necessary
elevation to induce combustion, each complete cycle taking,
however, years to be accomplished. The resulting aqueous
vapour, carbonic acid, and carbonic oxide would be drawn
towards the equatorial regions, and be then again projected into
space by centrifugal force.

Space would, according to these views, be filled with gaseous
compounds in process of decomposition by solar radiant energy,
and the existence of these gases would furnish an explanation of
the solar absorption spectrum, in which the lines of some of the
substances may be entirely neutralised and lost to observation.
As regards the heavy metallic vapours revealed in the sun by the
spectroscope, it is assumed that these form a lower and denser
solar atmosphere, not participating in the fan-like action which is
supposed to affect the light outer atmosphere only, in which
hydrogen is the principal factor.

Such a dense metallic atmosphere could not participate in the
fan action affecting the lighter photosphere, because this is only
feasible on the supposition that the density of the inflowing cur-
rent is, at equal distances from the gravitating centre, equal or
nearly equal to the outflowing current. It is true that the pro-
ducts of combustion of hydrogen and hydrocarbons are denser
than their constituents, but this difference may be balanced by
their superior temperature on leaving the sun, whereas the metallic
vapours would be unbalanced, and would therefore obey the laws
of gravitation, recalling them to the sun. On the surface of con-
tact between the two solar atmospheres, intermixture induced by
friction must take place, however, giving rise to those vortices and
explosive effects within the zones of the sun, between the equator
and the polar surfaces, to which reference has already been made
in this article; these may appropriately be called the “stormy
regions” of the sun, which were first observed and commented
upon by Sir John Herschel. Some of the denser vapours would
probably get intermixed, be carried away mechanically by the
lighter gases, and give rise to that cosmic dust observed to fall
upon our earth in not inappreciable quantities, and generally
assumed hitherto to be the débris of broken meteorolites. Ex-
cessive intermixture between the heat-producing atmosphere and
the metallic vapours below appears to be prevented by the
existence of an intermediate neutral atmosphere, called the penumbra.

As the whole solar system moves through space at a pace estimated at 150,000,000 of miles annually (being about one-fourth of the velocity of the earth in its orbit), it appears possible that the condition of the gaseous fuel supplying the sun may vary according to its state of previous decomposition, in which other heavenly bodies may have taken part, and whereby an interesting reflex action between our sun and other heavenly bodies would be brought about. May it not be owing to such differences in the quality of the fuel supplied that the observed variations of the solar heat may arise? and may it not be in consequence of such changes in the thermal condition of the photosphere that the extraordinary convulsions revealed to us as sun-spots occur?

The views here advocated could not be thought acceptable unless they furnished at any rate a consistent explanation of the still somewhat mysterious phenomena of the zodiacal light and of comets. Regarding the former, we should be able to revert to Mairan's views, the objection by La Place being met by a continuous outward flow from the solar equator. Luminosity would be attributable to particles of dust emitting light reflected from the sun, or to phosphorescence. But there is another cause for luminosity of these particles, which may deserve serious consideration. Each particle would be electrified by gaseous friction in its acceleration, and its electric tension would be vastly increased in its forcible removal, in the same way as the fine dust of the desert has been observed by Dr. Werner Siemens to be in a state of high electrification on the apex of the Cheops pyramid. Could not the zodiacal light also be attributed to slow electric discharge backward from the dust towards the sun? and would not the same cause account for a great difference of potential between the sun and earth, which latter may be supposed to be washed by the solar radial current? May not the presence of the radial solar current also furnish us with an explanation of the fact that hydrogen, while abounding apparently in space, is practically absent in our atmosphere, where aqueous vapour and carbonic acid, which would come to us directly from the sun, take its place? An action analogous to this, though on a much smaller scale, may be set up
also by terrestrial rotation, giving rise to an electrical discharge from the outgoing equatorial stream to the polar regions, where the atmosphere to be pierced by the return flood is of least resistance. Thus the phenomenon of the aurora borealis or northern lights would find an easy explanation.

The effect of this continuous outpour of solar materials could not be without very important influences as regards the geological conditions of our earth. Geologists have long acknowledged the difficulty of accounting for the amount of carbonic acid that must have been in our atmosphere, at one time or another, in order to form with lime those enormous beds of dolomite and limestone, of which the crust of our earth is in great measure composed. It has been calculated that if this carbonic acid had been at one and the same time in our atmosphere, it would have caused an elastic pressure fifty times that of our present atmosphere; and if we add the carbonic acid that must have been absorbed in vegetation in order to form our coal beds, we should probably have to double that pressure. Animal life, of which we find abundant traces in these "measures," could not have existed under such conditions, and we are almost forced to the conclusion that the carbonic acid must have been derived from an external source.

It appears to me that the theory here advocated furnishes a feasible solution of this geological difficulty. Our earth being situated in the outflowing current of the solar products of combustion, or, as it were, in the solar chimney, would be fed from day to day with its quota of carbonic acid, of which our local atmosphere would assimilate as much as would be necessary to maintain in it a carbonic acid vapour density balancing that of the solar current; we should thus receive our daily supply of this important constituent (with the regularity of fresh rolls for breakfast), which, according to an investigation by M. Reiset, communicated to the French Academy of Sciences by M. Dumas on the 6th of March last, amounts to the constant factor of one ten-thousandth part of our atmosphere. The aqueous vapour in the air would be similarly maintained as to its density, and its influx to, or reflux from, our atmosphere would be determined by the surface temperature of our earth.

It is also important to show how the phenomena of comets could be harmonised with the views here advocated, and I venture to
hope that these occasional visitors will serve to furnish us with positive evidence in my favour. Astronomical physicists tell us that the nucleus of a comet consists of an aggregation of stones similar to meteorites. Adopting this view, and assuming that the stones have absorbed in stellar space gases to the amount of six times their volume, taken at atmospheric pressure, what, it may be asked, will be the effect of such a divided mass advancing towards the sun at a velocity reaching in perihelion the prodigious rate of 366 miles per second (as observed in the comet of 1845), being twenty-three times our orbital rate of motion? It appears evident that the entry of such a mass into a comparatively dense atmosphere must be accompanied by a rise of temperature by frictional resistance, aided by attractive condensation. At a certain point the increase of temperature must cause ignition, and the heat thus produced must drive out the occluded gases, which in an atmosphere 3,000 times less dense than that of our earth would produce \( 6 \times 3,000 = 18,000 \) times the volume of the stones themselves. These gases would issue forth in all directions, but would remain unobserved excepting in that of motion, in which they would meet the interplanetary atmosphere with the compound velocity, and form a zone of intense combustion, such as Dr. Huggins has lately observed to surround the one side of the nucleus, evidently the side of forward motion. The nucleus would thus emit original light, whereas the tail may be supposed to consist of stellar dust rendered luminous by reflex action produced by the light of the sun and comet combined, as foreshadowed already by Tyndall, Tait, and others, starting each from different assumptions.

Although I cannot pretend to an intimate acquaintance with the more intricate phenomena of solar physics, I have long had a conviction, derived principally from familiarity with some of the terrestrial effects of heat, that the prodigious dissipation of solar heat is unnecessary to satisfy accepted principles regarding the conservation of energy, but that solar heat may be arrested and returned over and over again to the sun, in a manner somewhat analogous to the action of the heat recuperator in the regenerative engine and gas furnace. The fundamental conditions are:

1. That aqueous vapour and carbon compounds are present in stellar or interplanetary space.
2. That these gaseous compounds are capable of being dissociated by radiant solar energy while in a state of extreme attenuation.

3. That the vapours so dissociated are drawn towards the sun in consequence of solar rotation, are flashed into flame in the photosphere, and rendered back into space in the condition of products of combustion.

Three weeks have now elapsed since I ventured to submit these propositions to the Royal Society for scientific criticism, and it will probably interest my readers to know what has been the nature of that criticism and the weight of additional evidence for or against my theory.

Criticism has been pronounced by mathematicians and physicists, but affecting singularly enough the chemical and not the mathematical portion of my argument; whereas chemists have expressed doubts regarding my mathematics while accepting the chemistry involved in my reasoning.

Doubts have been expressed as to the sufficiency of the proof that dissociation of attenuated aqueous vapour and carbonic acid is really effected by radiant solar energy, and, if so effected, whether the amount of heat so supplied to the sun could be at all adequate in amount to keep up the known rate of radiation. It was admitted in my paper that my own experiments on the dissociation of vapours within vacuous tubes amounted to inferential rather than absolute proof; but the amount of inferential evidence in favour of my views has been very much strengthened since by chemical evidence received from various sources; and I will here only refer to one of these.

Professor Piazzi Smyth, the Astronomer Royal for Scotland, has, in connection with Professor Herschel of Newcastle, recently presented an elaborate paper or series of papers to the Royal Society of Edinburgh "On the Gaseous Spectra in Vacuum Tubes," of which he has kindly forwarded me a copy. It appears from these memoirs that when vacuum tubes, which contain attenuated vapours, have been laid aside for a length of time, they turn practically into hydrogen tubes. In another very recent paper presented to the Royal Society of Edinburgh, Professor Piazzi Smyth furnishes important additional proof of the presence of oxygen in the outer solar atmosphere, and gives an explanation why this important element has escaped observation by the spectroscope. Additional proof of the existence of oxygen
in the outer solar atmosphere has been given by Professor Stoney, the Astronomer Royal for Ireland, and by Mr. R. Meldola in an interesting paper communicated by him to the "Philosophical Magazine" in June, 1878.

As regards the sufficiency of an inflowing stream of dissociated vapours to maintain solar energy, the following simple calculation may be of service. Let it be assumed that the stream flowing in upon the polar surfaces of the sun flashes into flame when it has attained the density of our atmosphere, that its velocity at that time is 100 feet per second (the velocity of a strong terrestrial wind) and that in its composition only one-twentieth part is hydrogen and marsh gas in equal proportions, the other nineteen-twentieths being made up of oxygen, nitrogen, and neutral compounds. It is well known that each pound of hydrogen develops in burning about 60,000 heat units, and each pound of marsh gas about 24,000; the average of the two gases mixed in equal proportion would yield, roughly speaking, 42,000 units; but, considering that only one-twentieth part of the inflowing current is assumed to consist of such combustible matter, the amount of heat developed per pound of inflowing current would be only 2,100 heat units. One hundred cubic feet, weighing eight pounds, would enter into combustion every second upon each square foot of the polar surface, and would yield $8 \times 60 \times 60 \times 2100 = 60,480,000$ heat units per hour. Assuming that one-third of the entire solar surface may be regarded as polar heat-receiving surface, this would give 20,000,000 heat units per square foot of solar surface; whereas according to Herschel's and Pouillet's measurements only 18,000,000 heat units per square foot of solar surface are radiated away. There would thus be no difficulty in accounting for the maintenance of solar energy from the supposed source of supply. On the other hand I wish to guard myself against the assumption that appears to have been made by some critics, that what I have advocated would amount to the counterpart of "perpetual motion," and therefore to an absurdity. The sun cannot of course get back any heat radiated by himself which has been turned to a purpose; thus the solar heat spent upon our earth in effecting vegetation must be absolutely lost to him.

My paper presented to the Royal Society was accompanied by a diagram of an ideal corona, representing an accumulation of
igneous matter upon the solar surfaces, surrounded by disturbed regions pierced by occasional vortices and outbursts of metallic vapours, and culminating in two outward streams projecting from the equatorial surfaces into space through many thousands of miles. The only supporting evidence in favour of this diagram were certain indications that may be found in the instructive volume on the Sun by Mr. R. A. Proctor. It was therefore a matter of great satisfaction to me to be informed, as I have been by an excellent authority and eye-witness, that my imaginary diagram bore a very close resemblance to the corona observed in America on the occasion of the total eclipse of the sun on the 11th of January, 1880.

Enough has been said, I think, to prove that the theory I have ventured to put forward is the result, at any rate, of considerable reflection; and I may add that, since its first announcement, I have not seen reason to reject any of the links of my chain of argument: these I have here endeavoured to strengthen only by additional facts and explanations.

If these arguments can be proved to the entire satisfaction of those best able to form a judgment, they would serve to justify the poet Addison when he says:—

The unwearied sun from day to day
Does the Creator's power display,
And publishes to every land
The work of an Almighty Hand.

THE CHANNEL TUNNEL AND CARBONIC ACID GAS.

TO THE EDITOR OF "THE TIMES."

SIR,—The question as to whether a railway tunnel under the British Channel could be made secure against foreign invasion is one which should be judged, not by sentiment, but by the weight of scientific evidence placed before such a mixed committee as has been appointed by the Government for that purpose. I, therefore, had no hesitation, when called upon, to put my particular views concerning this matter before them, and I am glad to see in The Times of to-day a letter by my esteemed friend Dr. Tyndall furthering the controversy by challenging my conclusions, although
I should have wished that in writing on the subject he had been in possession of the whole of my argument.

Dr. Tyndall is not only one of the most prominent men of science, but has gained fame also in the Alps and elsewhere for his power of physical endurance, of which his letter under acknowledgment furnishes another striking proof in that he was able to hold his breath for nearly 90 seconds, whereas 60 seconds is the utmost coral fishers are said to be able to endure without inhalation.

We have heard of late of gentlemen swimming across the Channel, and of others crossing it in a balloon, to which feats others, acting on Dr. Tyndall's suggestion, may add that of going across from shore to shore, protected by a Fleuss-dress, through a tunnel filled with carbonic acid. But I imagine that after these adventurous spirits have accomplished their respective feats they will be more inclined to indulge in the good things offered at the Lord Warden Hotel than in schemes of taking this country by assault. Dr. Tyndall's allusions to the means that might be at the disposal of the enemy of ridding the tunnel of carbonic acid as fast as it could be poured in, require, of course, serious consideration, and had not escaped my attention in maturing my scheme. Assuming a certain rate of flow of carbonic acid into the tunnel at the point of its greatest depression, and where it would lodge, owing to its superior specific gravity, I ascertained by a simple calculation that if even 1000 horse-power were employed at either end of the tunnel in causing a current of air through the same, the other being left open to facilitate the operation, the frictional resistance encountered in a channel of such length would be such that the accumulation of carbonic acid in the depressed portion of it could be readily maintained for 30 days, by means of such continuous inflow as I contemplated. The chambers in which the carbonic acid would be generated being inaccessible to the enemy, such a continued inflow would, I maintain, form an effectual barrier to a hostile host, and to increase the pumping capacity to more than 1000 horse-power would require such elaborate installation as would only be the work of time.

I am, Sir, your obedient servant,

C. W. Siemens.

12, Queen Anne's Gate, Westminster, May 6, 1882.
TELEGRAPHIC COMMUNICATION WITH THE EAST.

To the Editor of "The Times."

Sir,—The article in The Times of yesterday from a correspondent, headed "Telegraphic Intercourse with the East," calls attention very properly to the importance of a submarine line from this country to the Cape, via Ascension and St. Helena, and thence to India via the Mauritius. The cable would be situated in deep water throughout nearly its whole length, where, according to our present knowledge of telegraphic engineering, it would be much more securely placed than in shallow water, and could in case of need be picked up with almost the same facility. Independently of its great value as a line connecting important British possessions, it would constitute another alternative means of communication with India. At the present time our communication with India, Australia, and the Cape depends, notwithstanding the nominal existence of a line through Turkey, as pointed out by Colonel Bateman-Champain, in The Times of to-day, on the Indo-European telegraph. This line, referring now to the portion of the system connecting London and Teheran, with the origin and construction of which I have been intimately associated, has not been looked upon with much favour by many in this country, who at the end of its construction predicted its ultimate failure, and threw out broad hints to the effect that the telegraph posts might serve in certain regions to mark the tombs of the staff employed upon the work, while others took the objection that the line if constructed would be liable to frequent interruptions from political causes. I and those acting with me felt no misgivings on these points, nor do I share the apprehensions reiterated by your correspondent, because, before seeking to obtain concessions from Germany, Russia, and Persia, for the construction of the line, we took the precaution of having its neutrality and independence from government interference guaranteed by an international convention between the two principal Powers concerned, which guarantee has been absolutely respected throughout the very trying times of the Franco-German and Russo-Turkish wars, as
well as during the critical period of the subsequent peace negotiations at Constantinople, when the English despatches passed without hindrance over the Indo-European line vid Odessa. At the present time the Indo-European telegraph is—not, indeed, for the first time—practically the only means of communication between England and her eastern possessions, nor does it prove itself insufficient or unreliable under these trying circumstances, land line though it be.

I am, sir, your obedient servant,

C. W. SIEMENS.

12, Queen Anne's Gate S.W., Aug. 3, 1882.

ADDRESS

Of C. WILLIAM SIEMENS,* D.C.L. (Oxon.), LL.D. (Glasgow and Dublin), Ph. D., F.R.S., F.C.S., Member of the Institute of Civil Engineers, President of the British Association for the Advancement of Science,

Delivered at Southampton on Wednesday, August 23, 1882.

In venturing to address the British Association from this chair, I feel that I have taken upon myself a task involving very serious responsibility. The Association has for half a century fulfilled the important mission of drawing together, once every year, scientists from all parts of the country for the purpose of discussing questions of mutual interest, of endowing research, and of cultivating those personal relations which aid so powerfully in harmonising views, and in stimulating concerted action for the advancement of science.

A sad event casts a shadow over our gathering. While still mourning the irreparable loss Science had sustained in the person of Charles Darwin, whose bold conceptions, patient labour, and

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genial mind made him almost a type of unsurpassed excellence; telegraphic news reached Cambridge, just a month ago, to the effect that our General Secretary, Professor F. M. Balfour, had lost his life during an attempted ascent of the Aiguille Blanche de Péteret. Although only thirty years of age, few men have won distinction so rapidly and so deservedly. After attending the lectures of Dr. Michael Foster, he completed his studies of Biology under Dr. Anton Dohrn at the Zoological Station of Naples in 1875. In 1878 he was elected a Fellow, and in November last a Member of Council of the Royal Society, when he was also awarded one of the Royal medals for his embryological researches. Within a short interval of time Glasgow University conferred on him their honorary degree of LL.D., he was elected President of the Cambridge Philosophical Society, and after having declined very tempting offers from the Universities of Oxford and Edinburgh, he accepted a professorship of Animal Morphology created for him by his own University. Few men could have borne without hurt such a stream of honourable distinctions, but in young Balfour genius and independence of thought were happily blended with industry and personal modesty; these won for him the friendship, esteem, and admiration of all who knew him.

It affords me great satisfaction to qualify the sad impression produced by this event, by the happy one of the safe return to these shores of that most persistent and disinterested Arctic explorer, Mr. B. Leigh Smith, together with his much enduring crew and valiant rescuers.

Since the days of the first meeting of the Association at York in 1831, great changes have taken place in the means at our disposal for exchanging views, either personally or through the medium of type. The creation of the railway system has enabled congenial minds to attend frequent meetings of those special societies which have sprung into existence since the foundation of the British Association, amongst which I need only name here the Physical, Geographical, Meteorological, and Anthropological, cultivating abstract science, and the Institution of Mechanical Engineers, of Naval Architects, the Iron and Steel Institute, the Society of Telegraph Engineers and Electricians, the Gas Institute, the Sanitary Institute, and the Society of Chemical Industry,
representing applied science. These meet at frequent intervals in London, whilst others, having similar objects in view, hold their meetings at the University towns, and at other centres of intelligence and industry throughout the country, giving evidence of great mental activity, and producing some of those very results which the founders of the British Association wished to see realised. If we consider further the extraordinary development of scientific journalism which has taken place, it cannot surprise us when we meet with expressions of opinion to the effect that the British Association has fulfilled its mission, and should now yield its place to those special societies it has served to call into existence. On the other hand, it may be urged that the brilliant success of last year's Anniversary Meeting, enhanced by the comprehensive address delivered on that occasion by my distinguished predecessor in office, Sir John Lubbock, has proved, at least, that the British Association is not dead in the affections of its members and it behoves us at this, the first ordinary gathering in the second half century, to consider what are the strong points to rely upon for the continuance of a career of success and usefulness.

If the facilities brought home to our doors of acquiring scientific information have increased, the necessities for scientific inquiry have increased in a greater ratio. The time was when science was cultivated only by the few, who looked upon its application to the arts and manufactures as almost beneath their consideration; this they were content to leave in the hands of others, who, with only commercial aims in view, did not aspire to further the objects of science for its own sake, but thought only of benefiting by its teachings. Progress could not be rapid under this condition of things, because the man of pure science rarely pursued his inquiry beyond the mere enunciation of a physical or chemical principle, whilst the simple practitioner was at a loss how to harmonise the new knowledge with the stock of information which formed his mental capital in trade.

The advancement of the last fifty years has, I venture to submit, rendered theory and practice so interdependent, that an intimate union between them is a matter of absolute necessity for our future progress. Take, for instance, the art of dyeing; and we find that the discovery of new colouring matters derived from waste products, such as coal-tar, completely changes its practice, and
renders an intimate knowledge of the science of chemistry a matter of absolute necessity to the practitioner. In telegraphy and in the new arts of applying electricity to lighting, to the transmission of power, and to metallurgical operations, problems arise at every turn, requiring for their solution not only an intimate acquaintance with, but a positive advance upon, electrical science, as established by purely theoretical research in the laboratory. In general engineering the mere practical art of constructing a machine so designed and proportioned as to produce mechanically the desired effect, would suffice no longer. Our increased knowledge of the nature of the mutual relations between the different forms of energy makes us see clearly what are the theoretical limits of effect; these, although beyond our absolute reach, may be looked upon as the asymptotes to be approached indefinitely by the hyperbolic course of practical progress. Cases arise, moreover, where the introduction of new materials of construction, or the call for new effects, renders former rules wholly insufficient. In all these cases practical knowledge has to go hand in hand with advanced science in order to accomplish the desired end.

Far be it from me to think lightly of the ardent students of nature, who, in their devotion to research, do not allow their minds to travel into the regions of utilitarianism and of self-interest. These, the high priests of science, command our utmost admiration; but it is not to them that we can look for our current progress in practical science, much less can we look for it to the "rule of thumb" practitioner who is guided by what comes nearer to instinct than to reason. It is to the man of science, who also gives attention to practical questions, and to the practitioner, who devotes part of his time to the prosecution of strictly scientific investigations, that we owe the rapid progress of the present day, both merging more and more into one class, that of pioneers in the domain of nature. It is such men that Archimedes must have desired when he refused to teach his disciples the art of constructing his powerful ballistic engines, exhorting them to give their attention to the principles involved in their construction, and that Telford, the founder of the Institution of Civil Engineers, must have had in his mind's eye, when he (at the suggestion of Tredgold) defined civil engineering as "the art of directing the great sources of power in nature."
These considerations may serve to show that although we see
the men of both abstract and applied science group themselves in
minor bodies for the better prosecution of special objects, the
points of contact between the different branches of knowledge are
ever multiplying, all tending to form part of a mighty tree—the
tree of modern science—under whose ample shadow its cultivators
will find it both profitable and pleasant to meet, at least once a
year; and considering that this tree is not the growth of one
country only, but spreads both its roots and branches far and wide,
it appears desirable that at these yearly gatherings other nations
should be more fully represented than has hitherto been the case.
The subjects discussed at our meetings are without exception of
general interest, but many of them bear an international character,
such as the systematic collection of magnetic, astronomical,
meteorological, and geodetical observations, the formation of a
universal code for signalling at sea, and for distinguishing lighthouses,
and especially the settlement of scientific nomenclatures
and units of measurement, regarding all of which an international
accord is a matter of the utmost practical importance.

As regards the measures of length and weight it is to be regretted
that this country still stands aloof from the movement initiated in
France towards the close of last century; but, considering that in
scientific work metrical measure is now almost universally adopted,
and that its use has been already legalised in this country, I
venture to hope that its universal adoption for commercial purposes
will soon follow as a matter of course. The practical advantages
of such a measure to the trade of this country would, I am con-
vincing, be very great, for English goods, such as machinery or
metal rolled to current sections, are now almost excluded from
the Continental market, owing to the unit measure employed in
their production. The principal impediment to the adoption of
the metre consists in the strange anomaly that although it is
legal to use that measure in commerce, and although a copy of
the standard metre is kept in the Standards' Department of the
Board of Trade, it is impossible to procure legalised rods repre-
senting it, and to use a non-legalised copy of a standard in
commerce is deemed fraudulent. Would it not be desirable that
the British Association should endeavour to bring about the use
in this country of the metre and kilogramme, and, as a pre-
liminary step, ask the Government to be represented on the International Metrical Commission, whose admirable establishment at Sèvres possesses, independently of its practical work, considerable scientific interest, as a well-found laboratory for developing methods of precise measurement?

Next in importance to accurate measures of length, weight, and time, stand, for the purposes of modern science, those of electricity.

The remarkably clear lines separating conductors from non-conductors of electricity, and magnetic from non-magnetic substances, enable us to measure electrical quantities and effects with almost mathematical precision; and, although the ultimate nature of this, the youngest scientifically investigated form of energy, is yet wrapt in mystery, its laws are the most clearly established, and its measuring instruments (galvanometers, electrometers, and magnetometers) are amongst the most accurate in physical science. Nor could any branch of science or industry be named in which electrical phenomena do not occur, to exercise their direct and important influence.

If, then, electricity stands foremost amongst the exact sciences, it follows that its unit measures should be determined with the utmost accuracy. Yet, twenty years ago, very little advance had been made towards the adoption of a rational system. Ohm had, it is true, given us the fixed relations existing between electromotive force, resistance and quantity of current; Joule had established the dynamical equivalent of heat and electricity, and Gauss and Weber had proposed their elaborate system of absolute magnetic measurement. But these invaluable researches appeared only as isolated efforts, when, in 1862, the Electric Unit Committee was appointed by the British Association, at the instance of Sir William Thomson, and it is to the long-continued activity of this committee that the world is indebted for a consistent and practical system of measurement, which, after being modified in details, received universal sanction last year by the International Electrical Congress assembled at Paris.

At this congress, which was attended officially by the leading physicists of all civilised countries, the attempt was successfully made to bring about a union between the statical system of
measurement that had been followed in Germany and some other countries, and the magnetic or dynamical system developed by the British Association, also between the geometrical measure of resistance, the (Werner) Siemens unit, that had been generally adopted abroad, and the British Association unit intended as a multiple of Weber's absolute unit, though not entirely fulfilling that condition. The congress, while adopting the absolute system of the British Association, referred the final determination of the unit measure of resistance to an international committee, to be appointed by the representatives of the several governments; they decided to retain the mercury standard for reproduction and comparison, by which means the advantages of both systems are happily combined, and much valuable labour is utilised; only, instead of expressing electrical quantities directly in absolute measure, the congress has embodied a consistent system, based on the ohm, the centimetre, the gramme, and the second, in which the units are of a value convenient for practical measurements. In this, which we must hereafter know as the "practical system," as distinguished from the "absolute system," the units are named after leading physicists, the Ohm, Ampère, Volt, Coulomb, and Farad.

I would venture to suggest that two further units might, with advantage, be added to the system decided on by the International Congress at Paris. The first of these is the unit of magnetic quantity or pole. It is of much importance, and few will regard otherwise than with satisfaction the suggestion of Clausius that the unit should be called a "Weber," thus retaining a name most closely connected with electrical measurements, and only omitted by the congress in order to avoid the risk of confusion in the magnitude of the unit current with which his name had been formerly associated.

The other unit I would suggest adding to the list is that of power. The power conveyed by a current of an Ampère through the difference of potential of a Volt is the unit consistent with the practical system. It might be appropriately called a Watt, in honour of that master mind in mechanical science, James Watt. He it was who first had a clear physical conception of power, and gave a rational method of measuring it. A Watt, then, expresses the rate of an Ampère multiplied by a Volt, whilst a horse-power is 746 Watts, and a Cheval de Vapeur 735.
The system of electro-magnetic units would then be:

1. Weber, the unit of magnetic quantity = \(10^8\) C.G.S. Units.
2. Ohm, resistance = \(10^9\) "
3. Volt, electromotive force = \(10^8\) "
4. Ampère, current = \(10^{-1}\) "
5. Coulomb, quantity = \(10^{-1}\) "
6. Watt, power = \(10^7\) "
7. Farad, capacity = \(10^{-9}\) "

Before the list can be looked upon as complete two other units may have to be added, the one expressing that of magnetic field, and the other of heat in terms of the electro-magnetic system. Sir William Thomson suggested the former at the Paris Congress, and pointed out that it would be proper to attach to it the name of Gauss, who first theoretically and practically reduced observations of terrestrial magnetism to absolute measure. A Gauss will, then, be defined as the intensity of field produced by a Weber at a distance of one centimetre; and the Weber will be the absolute C.G.S. unit strength of magnetic pole. Thus the mutual force between two ideal point-poles, each of one Weber strength held at unit distance asunder, will be one dyne; that is to say, the force which, acting for a second of time on a gramme of matter, generates a velocity of one centimetre per second.

The unit of heat has hitherto been taken variously as the heat required to raise a pound of water at the freezing-point through 1° Fahrenheit or Centigrade, or, again, the heat necessary to raise a kilogramme of water 1° Centigrade. The inconvenience of a unit so entirely arbitrary is sufficiently apparent to justify the introduction of one based on the electro-magnetic system, viz., the heat generated in one second by the current of an Ampère flowing through the resistance of an Ohm. In absolute measure its value is \(10^7\) C.G.S. units, and assuming Joule's equivalent as 42,000,000, it is the heat necessary to raise 0.238 grammes of water 1° Centigrade, or, approximately, the \(\frac{1000}{1000}\) th part of the arbitrary unit of a pound of water raised 1° Fahrenheit and the \(\frac{1000}{1000}\) th part of the kilogramme of water raised 1° Centigrade. Such a heat unit, if found acceptable, might with great propriety, I think, be called the Joule, after the man who has done so much to develop the dynamical theory of heat.
Professor Clausius urges the advantages of the statical system of measurement for simplicity, and shows that the numerical values of the two systems can readily be compared by the introduction of a factor, which he proposes to call the critical velocity; this, Weber has already shown to be nearly the same as the velocity of light. It is not immediately evident how by the introduction of a simple multiple, signifying a velocity, the statical can be changed into dynamical values, and I am indebted to my friend Sir William Thomson for an illustration which struck me as remarkably happy and convincing. Imagine a ball of conducting matter so constituted that it can at pleasure be caused to shrink. Now let it first be electrified and left insulated with any quantity of electricity on it. After that, let it be connected with the earth by an excessively fine wire or a not perfectly dry silk fibre; and let it shrink just so rapidly as to keep its potential constant, till the whole charge is carried off. The velocity with which its surface approaches its centre is the electrostatic measure of the conducting power of the fibre. Thus we see how "conducting power" is, in electrostatic theory, properly measured in terms of a velocity. Weber had shown how, in electromagnetic theory, the resistance, or the reciprocal of the conducting power of a conductor, is properly measured by a velocity. The critical velocity, which measures the conducting power in electrostatic reckoning and the resistance in electromagnetic, of one and the same conductor, measures the number of electrostatic units in the electromagnetic unit of electric quantity.

Without waiting for the assembly of the International Committee charged with the final determination of the Ohm, one of its most distinguished members, Lord Rayleigh, has, with his collaboratrice, Mrs. Sidgwick, continued his important investigation in this direction at the Cavendish Laboratory, and has lately placed before the Royal Society a result which will probably not be surpassed in accuracy. His redetermination brings him into close accord with Dr. Werner Siemens, their two values of the mercury unit being 0.95418 and 0.9536 of the B.A. unit respectively, or 1 mercury unit = 0.9413 x 10^9 C.G.S. units.

Shortly after the publication of Lord Rayleigh’s recent results, Messrs. Glazebrook, Dodds, and Sargent, of Cambridge, communicated to the Royal Society two determinations of the Ohm
by different methods; and it is satisfactory to find that their final values differ only in the fourth decimal, the figures being, according to

Lord Rayleigh . . . 1 Ohm = \(0.98651\) \(\frac{\text{Earth Quadrant}}{\text{Second}}\)

Messrs. Glazebrook, &c. = \(0.986271\)

Professor E. Wiedemann, of Leipzig, has lately called attention to the importance of having the Ohm determined in the most accurate manner possible, and enumerates four distinct methods, all of which should unquestionably be tried with a view of obtaining concordant results, because upon its accuracy will depend the whole future system of measurement of energy of whatever form.

The word Energy was first used by Young in a scientific sense, and represents a conception of recent date, being the outcome of the labours of Carnot, Mayer, Joule, Grove, Clausius, Clerk-Maxwell, Thomson, Stokes, Helmholtz, Macquorn Rankine, and other labourers, who have accomplished for the science regarding the forces in Nature what we owe to Lavoisier, Dalton, Berzelius, Liebig, and others, as regards Chemistry. In this short word Energy we find all the efforts in nature, including electricity, heat, light, chemical action, and dynamics, equally represented, forming, to use Dr. Tyndall's apt expression, so many "modes of motion." It will readily be conceived that when we have established a fixed numerical relation between these different modes of motion, we know beforehand what is the utmost result we can possibly attain in converting one form of energy into another, and to what extent our apparatus for effecting the conversion falls short of realising it. The difference between ultimate theoretical effect and that actually obtained is commonly called loss, but, considering that energy is indestructible, represents really secondary effect which we obtain without desiring it. Thus friction in the working parts of a machine represents a loss of mechanical effect, but is a gain of heat, and in like manner the loss sustained in transferring electrical energy from one point to another is accounted for by heat generated in the conductor. It sometimes suits our purpose to augment the transformation of electrical into
heat energy at certain points of the circuit when the heat rays become visible, and we have the incandescence electric light. In effecting a complete severance of the conductor for a short distance, after the current has been established, a very great local resistance is occasioned, giving rise to the electric arc, the highest development of heat ever attained. Vibration is another form of lost energy in mechanism, but who would call it a loss if it proceeded from the violin of a Joachim or a Norman-Neruda?

Electricity is the form of energy best suited for transmitting an effect from one place to another; the electric current passes through certain substances—the metals—with a velocity limited only by the retarding influence caused by electric charge of the surrounding dielectric, but approaching probably under favourable conditions that of radiant heat and light, or 300,000 kilometres per second; it refuses, however, to pass through oxidised substances, glass, gums, or through gases except when in a highly rarefied condition. It is easy therefore to confine the electric current within bounds, and to direct it through narrow channels of extraordinary length. The conducting wire of an Atlantic cable is such a narrow channel; it consists of a copper wire, or strand of wires, 5 mm. in diameter, by nearly 5,000 kilometres in length, confined electrically by a coating of gutta-percha about 4 mm. in thickness. The electricity from a small galvanic battery passing into this channel prefers the long journey to America in the good conductor, and back through the earth, to the shorter journey across the 4 mm. in thickness of insulating material. By an improved arrangement the alternating currents employed to work long submarine cables do not actually complete the circuit, but are merged in a condenser at the receiving station after having produced their extremely slight but certain effect upon the receiving instrument, the beautiful syphon recorder of Sir William Thomson. So perfect is the channel and so precise the action of both the transmitting and receiving instruments employed, that two systems of electric signals may be passed simultaneously through the same cable in opposite directions, producing independent records at either end. By the application of this duplex mode of working to the Direct United States cable under the superintendence of Dr. Muirhead, its transmitting power was increased from twenty-five to sixty words a minute, being equiva-
lent to about twelve currents or primary impulses per second. In transmitting these impulse-currents simultaneously from both ends of the line, it must not be imagined, however, that they pass each other in the manner of liquid waves belonging to separate systems; such a supposition would involve momentum in the electric flow, and although the effect produced is analogous to such an action, it rests upon totally different grounds—namely, that of a local circuit at each terminus being called into action automatically whenever two similar currents are passed into the line simultaneously from both ends. In extending this principle of action quadruplex telegraphy has been rendered possible, although not yet for long submarine lines.

The minute currents here employed are far surpassed as regards delicacy and frequency by those revealed to us by that marvel of the present day, the telephone. The electric currents caused by the vibrations of a diaphragm acted upon by the human voice naturally vary in frequency and intensity according to the number and degree of those vibrations, and each motor current in exciting the electro-magnet forming part of the receiving instrument deflects the iron diaphragm occupying the position of an armature to a greater or smaller extent according to its strength. Savart found that the fundamental la springs from 440 complete vibrations in a second, but what must be the frequency and modulations of the motor current and of magnetic variations necessary to convey to the ear through the medium of a vibrating armature, such a complex of human voices and of musical instruments as constitutes an opera performance? And yet such performances could be distinctly heard and even enjoyed, as an artistic treat, by applying to the ears a pair of the double telephonic receivers at the Paris Electrical Exhibition, when connected with a pair of transmitting instruments in front of the footlights of the Grand Opera. In connection with the telephone, and with its equally remarkable adjunct the microphone, the names of Reiss, Graham Bell, Edison, and Hughes will ever be remembered.

Considering the extreme delicacy of the currents working a telephone, it is obvious that those caused by induction from neighbouring telegraphic line wires would seriously interfere with the former, and mar the speech or other sounds produced through their action. To avoid such interference, the telephone wires if
suspended in the air require to be placed at some distance from telegraphic line wires, and to be supported by separate posts. Another way of neutralising interference consists in twisting two separately insulated telephone wires together, so as to form a strand, and in using the two conductors as a metallic circuit to the exclusion of the earth; the working current will, in that case, receive equal and opposite inductive influences, and will therefore remain unaffected by them. On the other hand two insulated wires instead of one are required for working one set of instruments; and a serious increase in the cost of installation is thus caused. To avoid this Mr. Jacob has lately suggested a plan of combining pairs of such metallic circuits again into separate working pairs, and these again with other working pairs, whereby the total number of telephones capable of being worked without interference is made to equal the total number of single wires employed. The working of telephones and telegraphs in metallic circuit has the further advantage that mutual volta induction between the outgoing and returning currents favours the transit, and neutralises on the other hand the retarding influence caused by charge in underground or submarine conductors. These conditions are particularly favourable to underground line wires, which possess other important advantages over the still prevailing overground system, in that they are unaffected by atmospheric electricity, or by snowstorms and heavy gales, which at not very rare intervals of time put us back to pre-telegraphic days, when the letter-carrier was our swiftest messenger.

The underground system of telegraphs, first introduced into Germany by Werner Siemens in the years 1847-48, had to yield for a time to the overground system owing to technical difficulties, but it has been again resorted to within the last four years, and multiple land cables of solid construction now connect all the important towns of that country. The first cost of such a system is no doubt considerable (being about £38 per kilometre of conductor as against £8 10s. the cost of land lines); but as the underground wires are exempt from frequent repairs and renewals, and as they insure continuity of service, they are decidedly the cheaper and better in the end. The experience afforded by the early introduction of the underground system in Germany was not, however, without its beneficial results, as it brought to light
the phenomena of lateral induction, and of faults in the insulating coating, matters which had to be understood before submarine telegraphy could be attempted with any reasonable prospect of success.

Regarding the transmission of power to a distance the electric current has now entered the lists in competition with compressed air, the hydraulic accumulator, and the quick running rope as used at Schaffhausen to utilise the power of the Rhine fall. The transformation of electrical into mechanical energy can be accomplished with no further loss than is due to such incidental causes as friction and the heating of wires; these in a properly designed dynamo-electric machine do not exceed 10 per cent., as shown by Dr. John Hopkinson, and, judging from recent experiments of my own, a still nearer approach to ultimate perfection is attainable. Adhering, however, to Dr. Hopkinson's determination for safety's sake, and assuming the same percentage in reconverting the current into mechanical effect, a total loss of 19 per cent. results. To this loss must be added that through electrical resistance in the connecting line wires, which depends upon their length and conductivity, and that due to heating by friction of the working parts of the machine. Taking these as being equal to the internal losses incurred in the double process of conversion, there remains a useful effect of $100 - 38 = 62$ per cent., attainable at a distance, which agrees with experimental results, although in actual practice it would not be safe at present to expect more than 50 per cent. of ultimate useful effect, to allow for all incidental losses.

In using compressed air or water for the transmission of power, the loss cannot be taken at less than 50 per cent., and, as it depends upon fluid resistance, it increases with distance more rapidly than in the case of electricity. Taking the loss of effect in all cases as 50 per cent., electric transmission presents the advantage that an insulated wire does the work of a pipe capable of withstanding high internal pressure, which latter must be more costly to put down and to maintain. A second metallic conductor is required, however, to complete the electrical circuit, as the conducting power of the earth alone is found unreliable for passing quantity currents, owing to the effects of polarization; but as this second conductor need not be insulated, water or gas pipes,
railway metals or fencing wire, may be called into requisition for this purpose. The small space occupied by the electro-motor, its high working speed, and the absence of waste products, render it specially available for the general distribution of power to cranes and light machinery of every description. A loss of effect of 50 per cent. does not stand in the way of such applications, for it must be remembered that a powerful central engine of best construction produces motive power with a consumption of two pounds of coal per horse-power per hour, whereas small engines distributed over a district would consume not less than five; we thus see that there is an advantage in favour of electric transmission as regards fuel, independently of the saving of labour and other collateral benefits, which more than compensate for interest on the cost of installation.

To agriculture, electric transmission of power seems well adapted for effecting the various operations of the farm and fields from one centre. Having worked such a system myself in combination with electric lighting and horticulture for upwards of two years, I can speak with confidence of its economy, and of the facility with which the work is accomplished in charge of untrained persons.

As regards the effect of the electric light upon vegetation there is little to add to what was stated in my paper read before Section A last year, and ordered to be printed with the Report, except that in experimenting upon wheat, barley, oats, and other cereals sown in the open air, there was a marked difference between the growth of the plants influenced and those uninfluenced by the electric light. This was not very apparent till towards the end of February, when, with the first appearance of mild weather, the plants under the influence of an electric lamp of 4000 candle power placed about 5 metres above the surface, developed with extreme rapidity, so that by the end of May they stood about 4 feet high, with the ears in full bloom, when those not under its influence were under 2 feet in height, and showed no sign of the ear.

In the electric railway first constructed by Dr. Werner Siemens, at Berlin, in 1879, electric energy was transmitted to the moving carriage or train of carriages, through the two rails upon which it moved, these being sufficiently insulated from each other by being
placed upon well creosoted cross sleepers. At the Paris Electrical Exhibition the current was conveyed through two separate conductors making sliding or rolling contact with the carriage, whereas in the electric railway now in course of construction in the north of Ireland (which when completed will have a length of 12 miles) a separate conductor will be provided by the side of the railway, and the return circuit completed through the rails themselves, which in that case need not be insulated; secondary batteries will be used to store the surplus energy created in running downhill, to be restored in ascending steep inclines, and for passing roadways where the separate insulated conductor is not practicable. The electric railway possesses great advantages over horse or steam-power for towns, in tunnels, and in all cases where natural sources of energy, such as waterfalls, are available; but it would not be reasonable to suppose that it will in its present condition compete with steam propulsion upon ordinary railways. The transmission of power by means of electric conductors possesses the further advantage over other means of transmission that, provided the resistance of the rails be not very great, the power communicated to the locomotive reaches its maximum when the motion is at its minimum—that is, in commencing to work, or when encountering an exceptional resistance—whereas the utmost economy is produced in the normal condition of working when the velocity of the power-absorbing nearly equals that of the current-producing machine.

The deposition of metals from their solutions is perhaps the oldest of all useful applications of the electric current, but it is only in very recent times that the dynamo current has been practically applied to the refining of copper and other metals, as now practised at Birmingham and elsewhere, and upon an exceptionally large scale at Ocker, in Germany, where the motive power is derived from a water-wheel. The dynamo machine there employed was exhibited at the Paris Electrical Exhibition by Dr. Werner Siemens, its peculiar feature being that the conductors upon the rotating armature consisted of solid bars of copper 30 mm. square, in section, which were found only just sufficient to transmit the large quantity of electricity of low tension necessary for this operation. One such machine consuming 4-horse power deposits about 300 kilogrammes of copper per 24 hours.
Electric energy may also be employed for heating purposes, but in this case it would obviously be impossible for it to compete in point of economy with the direct combustion of fuel for the attainment of ordinary degrees of heat. Bunsen and St. Claire Deville have taught us, however, that combustion becomes extremely sluggish when a temperature of 1800° C. has been reached, and for effects at temperatures exceeding that limit the electric furnace will probably find advantageous applications. Its specific advantage consists in being apparently unlimited in the degree of heat attainable, thus opening out a new field of investigation to the chemist and metallurgist. Tungsten has been melted in such a furnace, and 8 pounds of platinum have been reduced from the cold to the liquid condition in 20 minutes.

The largest and most extensive application of electric energy at the present time is to lighting, but, considering how much has of late been said and written for and against this new illuminant, I shall here confine myself to a few general remarks. Joule has shown that if an electric current is passed through a conductor the whole of the energy lost by the current is converted into heat; or, if the resistance be localised, into radiant energy, comprising heat, light, and actinic rays. Neither the low heat rays nor the ultra-violet of highest refrangibility affect the retina, and may be regarded as lost energy, the effective rays being those between the red and violet of the spectrum, which in their combination produce the effect of white light.

Regarding the proportion of luminous to non-luminous rays proceeding from an electric arc or incandescent wire, we have a most valuable investigation by Dr. Tyndall, recorded in his work on "Radiant Heat." Dr. Tyndall shows that the luminous rays from a platinum wire heated to its highest point of incandescence, which may be taken at 1,700° C., formed $\frac{3}{4}$th part of the total radiant energy emitted, and $\frac{4}{10}$th part in the case of an arc light worked by a battery of 50 Grove's elements. In order to apply these valuable data to the case of electric lighting by means of dynamo currents, it is necessary in the first place to determine what is the power of 50 Grove's elements of the size used by Dr. Tyndall, expressed in the practical scale of units as now established. From a few experiments lately undertaken for myself, it would appear that 50 such cells have an electro-motive force of
98·5 Volts, and an internal resistance of 18·5 Ohms, giving a
current of 7·3 Ampères when the cells are short-circuited. The
resistance of a regulator such as Dr. Tyndall used in his experi-
ments may be taken at 10 Ohms, the current produced in the arc
would be \( \frac{98·5}{13·5 + 10 + 1} = 4 \) Ampères (allowing one Ohm for the
leads), and the power consumed \( 10 \times 4^2 = 160 \) Watts; the light
power of such an arc would be about 150 candles, and comparing
this with an arc of 3,308 candles produced by 1,162 Watts, we
find that \( \left( \frac{1162}{160} \right), \) i.e., 7·3 times the electric energy produce
\( \left( \frac{3308}{150} \right), \) i.e., 22 times the amount of light measured horizontally.

If, therefore, in Dr. Tyndall's arc \( \frac{1}{16} \)th of the radiant energy
emitted was visible as light, it follows that in a powerful arc of
3,300 candles, \( \frac{1}{10} \times \frac{22·0}{7·3}, \) or fully \( \frac{1}{3}, \) are luminous rays. In the
case of the incandescence light (say a Swan light of 20 candle-
power) we find in practice that 9 times as much power has to be
expended as in the case of the arc light; hence \( \frac{1}{3} \times \frac{1}{3} = \frac{3}{17} \) part of
the power is given out as luminous rays, as against \( \frac{1}{3} \)th in
Dr. Tyndall's incandescent platinum—a result sufficiently ap-
proximate considering the wide difference of conditions under
which the two are compared.

These results are not only of obvious practical value, but they
seem to establish a fixed relation between current, temperature,
and light produced, which may serve as a means to determine
temperatures exceeding the melting point of platinum with greater
accuracy than has hitherto been possible by actinimetric methods
in which the thickness of the luminous atmosphere must necessarily
exercise a disturbing influence. It is probably owing to this
circumstance that the temperature of the electric arc as well as
that of the solar photosphere has frequently been greatly over-
estimated.

The principal argument in favour of the electric light is
furnished by its immunity from products of combustion which not
only heat the lighted apartments, but substitute carbonic acid and
deleterious sulphur compounds for the oxygen upon which respira-
tion depends; the electric light is white instead of yellow, and
thus enables us to see pictures, furniture, and flowers as by day-light; it supports growing plants instead of poisoning them, and by its means we can carry on photography and many other industries at night as well as during the day. The objection frequently urged against the electric light, that it depends upon the continuous motion of steam or gas engines, which are liable to accidental stoppage, is met by the introduction into practical use of the secondary battery; this, although not embodying a new conception, has lately been greatly improved in power and constancy by Planté, Faure, Volekmar, Sellon, and others, and promises to accomplish for electricity what the gasholder has done for the supply of gas and the accumulator for hydraulic transmission of power.

It can no longer be a matter of reasonable doubt, therefore, that electric light will take its place as a public illuminant, and that, even though its cost should be found greater than that of gas, it will be preferred for the lighting of drawing-rooms and dining-rooms, theatres and concert-rooms, museums, churches, warehouses, show-rooms, printing establishments and factories, and also the cabins and engine-rooms of passenger steamers. In the cheaper and more powerful form of the arc light, it has proved itself superior to any other illuminant for spreading artificial daylight over the large areas of harbours, railway stations, and the sites of public works. When placed within a holophote the electric lamp has already become a powerful auxiliary in effecting military operations both by sea and land.

The electric light may be worked by natural sources of power such as waterfalls, the tidal wave, or the wind, and it is conceivable that these may be utilised at considerable distances by means of metallic conductors. Some five years ago I called attention to the vastness of those sources of energy, and the facility offered by electrical conduction in rendering them available for lighting and power-supply, while Sir William Thomson made this important matter the subject of his admirable address to Section A last year at York, and dealt with it in an exhaustive manner.

The advantages of the electric light and of the distribution of power by electricity have lately been recognised by the British Government, which has just passed a bill through Parliament to
facilitate the establishment of electrical conductors in towns, subject to certain regulating clauses to protect the interests of the public and of local authorities. Assuming the cost of electric light to be practically the same as gas, the preference for one or other will in each application be decided upon grounds of relative convenience, but I venture to think that gas-lighting will hold its own as the poor man’s friend.

Gas is an institution of the utmost value to the artisan; it requires hardly any attention, is supplied upon regulated terms, and gives with what should be a cheerful light a genial warmth, which often saves the lighting of a fire. The time is moreover not far distant, I venture to think, when both rich and poor will largely resort to gas as the most convenient, the cleanest, and the cheapest of heating agents, and when raw coal will be seen only at the colliery or the gasworks. In all cases where the town to be supplied is within say 30 miles of the colliery, the gasworks may with advantage be planted at the mouth, or still better at the bottom of the pit, whereby all haulage of fuel would be avoided, and the gas, in its ascent from the bottom of the colliery, would acquire an onward pressure sufficient probably to impel it to its destination. The possibility of transporting combustible gas through pipes for such a distance has been proved at Pittsburg, where natural gas from the oil district is used in large quantities for heating purposes.

The quasi monopoly so long enjoyed by gas companies has had the inevitable effect of checking progress. The gas being supplied by meter, it has been seemingly to the advantage of the companies to give merely the prescribed illuminating power, and to discourage the invention of economical burners, in order that the consumption might reach a maximum. The application of gas for heating purposes has not been encouraged, and is still made difficult in consequence of the objectionable practice of reducing the pressure in the mains during daytime to the lowest possible point consistent with prevention of atmospheric indraught. The introduction of the electric light has convinced gas managers and directors that such a policy is no longer tenable, but must give way to one of technical progress; new processes for cheapening the production and increasing the purity and illuminating power of gas are being fully discussed before the Gas Institute; and
improved burners, rivalling the electric light in brilliancy, greet our eyes as we pass along our principal thoroughfares.

Regarding the importance of the gas supply as it exists at present, we find from a Government return that the capital invested in gasworks in England, other than those of local authorities, amounts to 30,000,000l.; in these 4,281,048 tons of coal are converted annually, producing 43,000 million cubic feet of gas, and about 2,800,000 tons of coke; whereas the total amount of coal annually converted in the United Kingdom may be estimated at 9,000,000 tons, and the by-products therefrom at 500,000 tons of tar, 1,000,000 tons of ammonia liquor, and 4,000,000 tons of coke, according to the returns kindly furnished me by the managers of many of the gasworks and corporations. To these may be added say 120,000 tons of sulphur, which up to the present time is a waste product.

Previous to the year 1856—that is to say, before Mr. W. H. Perkin had invented his practical process, based chiefly upon the theoretical investigations of Hofman, regarding the coal-tar bases and the chemical constitution of indigo—the value of coal-tar in London was scarcely a halfpenny a gallon, and in country places gas-makers were glad to give it away. Up to that time the coal-tar industry had consisted chiefly in separating the tar by distillation into naphtha, creosote, oils, and pitch. A few distillers, however, made small quantities of benzene, which had been first shown—by Mansfield in 1849—to exist in coal-tar naphtha mixed with toluene, cumene, &c. The discovery, in 1856, of the mauve or aniline purple gave a great impetus to the coal-tar trade, inasmuch as it necessitated the separation of large quantities of benzene, or a mixture of benzene and toluene, from the naphtha. The trade was further increased by the discovery of the magenta or rosaniline dye, which required the same products for its preparation. In the meantime, carbolic acid was gradually introduced into commerce, chiefly as a disinfectant, but also for the production of colouring matter.

The next most important development arose from the discovery by Graebe and Liebermann that alizarine, the colouring principle of the madder root, was allied to anthracene, a hydrocarbon existing in coal-tar. The production of this colouring-matter from anthracene followed, and is now one of the most important opera-
tions connected with tar-distilling. The success of the alizarine made in this manner has been so great that it has almost entirely superseded the use of madder, which is now cultivated to only a comparatively small extent. The most important colouring matters recently introduced are the azo-scarlets. They have called into use the coal-tar hydrocarbons, xylene and cumene. Napthaline is also used in their preparation. These splendid dyes have replaced cochineal in many of its applications, and have thus seriously interfered with its use. The discovery of artificial indigo by Professor Baeyer is of great interest. For the preparation of this colouring matter tolune is required. At present artificial indigo does not compete seriously with the natural product; but should it eventually be prepared in quantity from tolune, a further stimulus will be given to the coal-tar trade.

The colour industry utilises even now practically all the benzene, a large proportion of the solvent naphtha, all the anthracene, and a portion of the napthaline resulting from the distillation of coal-tar; and the value of the colouring matter thus produced is estimated by Mr. Perkin at 3,350,000l.

The demand for ammonia may be taken as unlimited, on account of its high agricultural value as a manure; and, considering the failing supply of guano and the growing necessity for stimulating the fertility of our soil, an increased production of ammonia may be regarded as a matter of national importance, for the supply of which we have to look almost exclusively to our gasworks. The present production of 1,000,000 tons of liquor yields 95,000 tons of sulphate of ammonia; which, taken at 20l. 10s. a ton, represents an annual value of 1,947,500l.

The total annual value of the gasworks' by-products may be estimated as follows:

<table>
<thead>
<tr>
<th>Product</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colouring matter</td>
<td>£3,350,000</td>
</tr>
<tr>
<td>Sulphate of ammonia</td>
<td>1,947,500</td>
</tr>
<tr>
<td>Pitch (325,000 tons)</td>
<td>365,000</td>
</tr>
<tr>
<td>Creosote (25,000,000 gallons)</td>
<td>208,000</td>
</tr>
<tr>
<td>Crude carbolic acid (1,000,000 gallons)</td>
<td>100,000</td>
</tr>
<tr>
<td>Gas coke, 4,000,000 tons (after allowing 2,000,000 tons consumption in working the retorts) at 12s.</td>
<td>2,400,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>£8,370,500</strong></td>
</tr>
</tbody>
</table>
Taking the coal used, 9,000,000 tons, at 12s., equal 5,400,000l., it follows that the by-products alone exceed in value the coal used by very nearly 3,000,000l.

In using raw coal for heating purposes these valuable products are not only absolutely lost to us, but in their stead we are favoured with those semi-gaseous by-products in the atmosphere too well known to the denizens of London and other large towns as smoke. Professor Roberts has calculated that the soot in the pall hanging over London on a winter's day amounts to fifty tons, and that the carbon present as hydro-carbons and in the half-burnt form of carbonic oxide, a poisonous compound, resulting from the imperfect combustion of coal, may be taken as at least five times that amount. Mr. Aitken has shown, moreover, in an interesting paper communicated to the Royal Society of Edinburgh, last year, that the fine dust resulting from the imperfect combustion of coal is mainly instrumental in the formation of fog; each particle of solid matter attracting to itself aqueous vapour; these globules of fog are rendered particularly tenacious and disagreeable by the presence of tar vapour, another result of imperfect combustion of raw fuel, which might be turned to much better account at the dye-works. The hurtful influence of smoke upon public health, the great personal discomfort to which it gives rise, and the vast expense it indirectly causes through the destruction of our monuments, pictures, furniture, and apparel, are now being recognised, as is evinced by the success of recent Smoke Abatement Exhibitions. The most effectual remedy would result from a general recognition of the fact that wherever smoke is produced, fuel is being consumed wastefully, and that all our calorific effects, from the largest down to the domestic fire, can be realised as completely and more economically, without allowing any of the fuel employed to reach the atmosphere unburnt. This most desirable result may be effected by the use of gas for all heating purposes, with or without the addition of coke or anthracite.

The cheapest form of gas is that obtained through the entire distillation of fuel in such gas-producers as are now largely used in working the furnaces of glass, iron, and steel works; but gas of this description would not be available for the supply of towns owing to its bulk, about two-thirds of its volume being nitrogen.
The use of water-gas, resulting from the decomposition of steam in passing through a hot chamber filled with coke, has been suggested, but this gas also is objectionable, because it contains, besides hydrogen, the poisonous and inodorous gas carbonic oxide, the introduction of which into dwelling-houses could not be effected without considerable danger. A more satisfactory mode of supplying heating separately from illuminating gas would consist in connecting the retort at different periods of the distillation with two separate systems of mains for the delivery of the respective gases, as has been proposed by me elsewhere. Experiments made some years ago by Mr. Ellisen of the Paris gasworks have shown that the gases rich in carbon, such as olefiant and acetylene, are developed chiefly during an interval of time, beginning half an hour after the commencement and terminating at half the whole period of distillation, whilst, during the remainder of the time, marsh gas and hydrogen are chiefly developed, which, while possessing little illuminating power, are most advantageous for heating purposes. By resorting to improved means of heating the retorts with gaseous fuel, such as have been in use at the Paris gasworks for a considerable number of years, the length of time for effecting each distillation may be shortened from six hours, the usual period in former years, to four, or even three hours, as now practised at Glasgow and elsewhere. By this means a given number of retorts can be made to produce, in addition to the former quantity of illuminating gas of superior quality, a similar quantity of heating gas, resulting in a diminished cost of production and an increased supply of the valuable by-products previously referred to. The quantity of both ammonia and heating gas may be further increased by the simple expedient of passing a streamlet of steam through the heated retorts towards the end of each operation, whereby the ammonia and hydrocarbons still occluded in the heated coke will be evolved, and the volume of heating gas produced be augmented by the products of decomposition of the steam itself. It has been shown that gas may be used advantageously for domestic purposes with judicious management even under present conditions, and it is easy to conceive that its consumption for heating would soon increase, perhaps tenfold, if supplied separately at, say, 1s. a thousand cubic feet. At this price gas would be not only the cleanest and most
convenient, but also the cheapest form of fuel, and the enormous increase of consumption, the superior quality of the illuminating gas obtained by selection, and the proportionate increase of by-products, would amply compensate the gas company or corporation for the comparatively low price of the heating gas.

The greater efficiency of gas as a fuel results chiefly from the circumstance that a pound of gas yields in combustion 22,000 heat units, or exactly double the heat produced in the combustion of a pound of ordinary coal. This extra heating power is due partly to the freedom of the gas from earthy constituents, but chiefly to the heat imparted to it in effecting its distillation. Recent experiments with gas-burners have shown that in this direction also there is much room for improvement.

The amount of light given out by a gas flame depends upon the temperature to which the particles of solid carbon in the flame are raised, and Dr. Tyndall has shown that, of the radiant energy set up in such a flame, only the $\frac{1}{35}$th part is luminous; the hot products of combustion carry off at least four times as much energy as is radiated, so that not more than one hundredth part of the heat evolved in combustion is converted into light. This proportion could be improved, however, by increasing the temperature of combustion, which may be effected either by intensified air currents or by regenerative action. Supposing that the heat of the products of combustion could be communicated to metallic surfaces, and be transferred by conduction or otherwise to the atmospheric air supporting combustion in the flame, we should be able to increase the temperature accumulatively to any point within the limit of dissociation; this limit may be fixed at about 2,300° C., and cannot be very much below that of the electric arc. At such a temperature the proportion of luminous rays to the total heat produced in combustion would certainly be more than doubled, and the brilliancy of the light would at the same time be greatly increased. Thus improved, gas-lighting may continue its rivalry with electric lighting both as regards economy and brilliancy, and such rivalry must necessarily result in great public advantage.

In the domestic grate radiant energy of inferior intensity is required, and I for one do not agree with those who would like to see the open fireplace of this country superseded by the continental
stove. The advantages usually claimed for the open fireplace are, that it is cheerful, 'pokable,' and conducive to ventilation, but to these may be added another of even greater importance, viz., that the radiant heat which it emits passes through the transparent air without warming it, and imparts heat only to the solid walls, floor, and furniture of the room, which are thus constituted the heating surfaces of the comparatively cool air of the apartments in contact with them. In the case of stoves the heated air of the room causes deposit of moisture upon the walls in heating them, and gives rise to mildew and germs injurious to health. It is, I think, owing to this circumstance that upon entering an apartment one can immediately perceive whether or not it is heated by an open fireplace; nor is the unpleasant sensation due to stove-heating, completely removed by mechanical ventilation; there is, moreover, no good reason why an open fireplace should not be made as economical and smokeless as a stove or hot-water apparatus.

In the production of mechanical effect from heat, gaseous fuel also presents most striking advantages, as will appear from the following consideration. When we have to deal with the question of converting mechanical into electrical effect, or vice versa, by means of the dynamo-electrical machine, we have only to consider what are the equivalent values of the two forms of energy, and what precautions are necessary to avoid losses by the electrical resistance of conductors and by friction. The transformation of mechanical effect into heat involves no losses, except those resulting from imperfect installation, and these may be so completely avoided that Dr. Joule was able by this method to determine the equivalent values of the two forms of energy. But in attempting the inverse operation, of effecting the conversion of heat into mechanical energy, we find ourselves confronted by the second law of thermo-dynamics, which says, that whenever a given amount of heat is converted into mechanical effect, another but variable amount descends from a higher to a lower potential, and is thus rendered unavailable.

In the condensing steam engine this waste heat comprises that communicated to the condensing water, whilst the useful heat, or that converted into mechanical effect, depends upon the difference
of temperature between the boiler and condenser. The boiler pressure is limited, however, by considerations of safety and convenience of construction, and the range of working temperature rarely exceeds 120° C. except in the engines constructed by Mr. Perkins, in which a range of 160° C., or an expansive action commencing at 14 atmospheres, has been adopted with considerable success, as appears from an able report on this engine by Sir Frederick Bramwell. To obtain more advantageous primary conditions we have to turn to the caloric or gas engine, because in them the coefficient of efficiency expressed by $\frac{T - T'}{T}$ may be greatly increased. This value would reach a maximum if the initial absolute temperature $T$ could be raised to that of combustion, and $T'$ reduced to atmospheric temperature, and these maximum limits can be much more nearly approached in the gas engine, worked by a combustible mixture of air and hydro-carbons, than in the steam engine.

Assuming, then, in an explosive gas engine a temperature of 1,500° C. at a pressure of 4 atmospheres, we should, in accordance with the second law of thermo-dynamics, find a temperature after expansion to atmospheric pressure of 600° C., and therefore a working range of $1500° - 600° = 900°$, and a theoretical efficiency of $\frac{900}{1500 + 274}$ = about one-half, contrasting very favourably with that of a good expansive condensing steam engine, in which the range is $150 - 30 = 120°$ C., and the efficiency $\frac{120}{150 + 274} = \frac{2}{7}$. A good expansive steam engine is therefore capable of yielding as mechanical work $\frac{3}{4}$th parts of the heat communicated to the boiler, which does not include the heat lost by imperfect combustion and that carried away in the chimney. Adding to these the losses by friction and radiation in the engine, we find that the best steam engine yet constructed does not yield in mechanical effect more than $\frac{1}{4}$th part of the heat energy residing in the fuel consumed. In the gas engine we have also to make reductions from the theoretical efficiency, on account of the rather serious loss of heat by absorption into the working cylinder, which has to be cooled artificially in order to keep its temperature down to a point at which lubrication is possible; this, together with frictional loss,
cannot be taken at less than one-half, and reduces the factor of efficiency of the engine to \( \frac{1}{4} \)th.

It follows from these considerations that the gas or caloric engine combines the conditions most favourable to the attainment of maximum results, and it may reasonably be supposed that the difficulties still in the way of their application on a large scale will gradually be removed. Before many years have elapsed we shall find in our factories and on board our ships engines with a fuel consumption not exceeding 1 pound of coal per effective horse power per hour, in which the gas producer takes the place of the somewhat complex and dangerous steam boiler. The advent of such an engine and of the dynamo-machine must mark a new era of material progress at least equal to that produced by the introduction of steam power in the early part of our century. Let us consider what would be the probable effect of such an engine upon that most important interest of this country—the merchant navy.

According to returns kindly furnished me by the Board of Trade and "Lloyd’s Register of Shipping," the total value of the merchant shipping of the United Kingdom may be estimated at 126,000,000l., of which 90,000,000l. represent steamers having a net tonnage of 3,003,988 tons; and 36,000,000l. sailing vessels, of 3,688,008 tons. The safety of this vast amount of shipping, carrying about five-sevenths of our total imports and exports, or 500,000,000l. of goods in the year, and of the more precious lives connected with it, is a question of paramount importance. It involves considerations of the most varied kind: comprising the construction of the vessel itself, and the material employed in building it; its furniture of engines, pumps, sails, tackle, compass, sextant, and sounding apparatus, the preparation of reliable charts for the guidance of the navigator, and the construction of harbours of refuge, lighthouses, beacons, bells, and buoys, for channel navigation. Yet notwithstanding the combined efforts of science, inventive skill, and practical experience—the accumulation of centuries—we are startled with statements to the effect that during last year as many as 1,007 British-owned ships were lost, of which fully two-thirds were wrecked upon our shores, representing a total value of nearly 10,000,000l. Of these ships 870
were sailing vessels and 137 steamers. The number of sailing vessels included in these returns being 19,325, and of steamers 5,505, it appears that the steamer is the safer vessel, in the proportion of 4.43 to 3.46; but the steamer makes on an average three voyages for one of the sailing ship taken over the year, which reduces the relative risk of the steamer as compared with the sailing ship per voyage in the proportion of 13.29 to 3.46. Commercially speaking, this large factor of safety in favour of steam-shipping is to a great extent counterbalanced by the value of the steamship, which bears to that of the sailing vessel per net carrying ton the proportion of 3:1, thus reducing the ratio in favour of steam shipping as 13.29 to 10.38, or in round numbers as 4:3. In testing this result by the charges of premium for insurance, the variable circumstances of distance, nature of cargo, season and voyage have to be taken into account; but judging from information received from shipowners and underwriters of undoubted authority, I find that the relative insurance paid for the two classes of vessel represents an advantage of 30 per cent. in favour of steam-shipping, agreeing very closely with the above deductions derived from statistical information.

In considering the question how the advantages thus established in favour of steam-shipping could be further improved, attention should be called in the first place to the material employed in their construction. A new material was introduced for this purpose by the Admiralty in 1876, when they constructed at Pembroke dockyard the two steam corvettes, the Iris and Mercury, of mild steel. The peculiar qualities of this material are such, as to have enabled shipbuilders to save 20 per cent. in the weight of the ship's hull, and to increase to that extent its carrying capacity. It combines with a strength, 30 per cent. superior to that of iron, such extreme toughness that in the case of collision the side of the vessel has been found to yield or bulge several feet without showing any signs of rupture, a quality affecting the question of sea risk very favourably. When to the use of this material there are added the advantages derived from a double bottom and from the division of the ship's hold by means of bulkheads of solid construction, it is difficult to conceive how such a vessel could perish by collision either with another vessel or with a sunken rock. The spaces between the two bottoms are not lost, because
they form convenient chambers for water ballast, but powerful pumps should in all cases be added to meet emergencies.

The following statement of the number and tonnage of vessels building and preparing to be built in the United Kingdom on the 30th of June last, which has been kindly furnished me by Lloyd's, is of interest as showing that wooden ships are fast becoming obsolete, and that even iron is beginning to yield its place, both as regards steamers and sailing ships, to the new material mild steel; it also shows that by far the greater number of vessels now building are ships of large dimensions propelled by engine power:

<table>
<thead>
<tr>
<th></th>
<th>Mild Steel</th>
<th>Iron</th>
<th>Wood</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>89</td>
<td>159,751</td>
<td>555</td>
<td>929,921</td>
</tr>
<tr>
<td>Sailing</td>
<td>11</td>
<td>16,800</td>
<td>70</td>
<td>120,259</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>176,551</td>
<td>625</td>
<td>1,050,180</td>
</tr>
</tbody>
</table>

If, to the improvements already achieved, could be added an engine of half the weight of the present steam engine and boilers, and working with only half the present expenditure of fuel, a further addition of 30 per cent. could be made to the cargo of an Atlantic propeller vessel—no longer to be called a steamer—and the balance of advantages in favour of such vessels would be sufficient to restrict the use of sailing craft chiefly to the regattas of this and neighbouring ports.

The admirable work on the "British Navy," lately published by Sir Thomas Brassey, the Civil Chief Lord of the Admiralty, shows that the naval department of this country is fully alive to all improvements having regard to the safety as well as to the fighting qualities of Her Majesty's ships of war, and recent experience goes far to prove that although high speed and manœuvring qualities are of the utmost value, the armour plate, which appeared to be fast sinking in public favour, is not without its value in actual warfare.

The progressive views perceptible in the construction of the navy are further evidenced in a remarkable degree in the hydrographic department. Captain Sir Frederick Evans, the hydrographer, gave us at York last year a very interesting account of
the progress made in that department, which, while dealing chiefly with the preparation of charts showing the depth of water, the direction and force of currents, and the rise of tides near our shores, contains also valuable statistical information regarding the more general questions of the physical conditions of the sea, its temperature at various depths, its flora and fauna, as also the rainfall and the nature and force of prevailing winds. In connection with this subject the American Naval Department has taken an important part, under the guidance of Captain Maury and the Agassiz, father and son, whilst in this country the persistent labours of Dr. William B. Carpenter deserve the highest commendation.

Our knowledge of tidal action has received a most powerful impulse through the invention of a self-recording gauge and tide-predictor, which will form the subject of one of the discourses to be delivered at our present meeting by its principal originator, Sir William Thomson; when I hope he will furnish us with an explanation of some extraordinary irregularities in tidal records, observed some years ago by Sir John Coode at Portland, and due apparently to atmospheric influence.

The application of iron and steel in naval construction rendered the use of the compass for some time illusory, but in 1839 Sir George Airy showed how the errors of the compass, due to the influence experienced from the iron of the ship, may be perfectly corrected by magnets and soft iron placed in the neighbourhood of the binnacle, but the great size of the needles in the ordinary compasses rendered the correction of the quadrantal errors practically unattainable. In 1876 Sir William Thomson invented a compass with much smaller needles than those previously used, which allows Sir George Airy's principles to be applied completely. With this compass correctors can be arranged so that the needle shall point accurately in all directions, and these correctors can be adjusted at sea from time to time, so as to eliminate any error which may arise through change in the ship's magnetism or in the magnetism induced by the earth through change of the ship's position. By giving the compass card a long period of free oscillation great steadiness is obtained when the ship is rolling.

Sir William Thomson has also enriched the art of navigation by
the invention of two sounding machines; the one being devised for ascertaining great depths very accurately, in less than one-quarter the time formerly necessary, and the other for taking depths up to 130 fathoms without stopping the ship in its onward course. In both these instruments steel pianoforte wire is used instead of the hempen or silken lines formerly employed; in the latter machine the record of depth is obtained not by the quantity of wire run over its counter and brake wheel, but through the indications produced upon a simple pressure gauge consisting of an inverted glass tube, whose internal surface is covered beforehand with a preparation of chromate of silver, rendered colourless by the sea-water up to the height to which it penetrates. The value of this instrument for guiding the navigator within what he calls “soundings” can hardly be exaggerated; with the sounding machine and a good chart he can generally make out his position correctly by a succession of three or four casts in a given direction at given intervals, and thus in foggy weather is made independent of astronomical observations and of the sight of lighthouses or the shore. By the proper use of this apparatus, accidents such as happened to the mail steamer Mosel, not a fortnight ago, would not be possible. As regards the value of the deep-sea instrument I can speak from personal experience; on one occasion it enabled those in charge of the Cable s.s. Faraday to find the end of an Atlantic Cable, which had parted in a gale of wind, with no other indication of the locality than a single sounding, giving a depth of 950 fathoms. To recover the cable a number of soundings in the supposed neighbourhood of the broken end were taken, the 950 fathom contour line was then traced upon a chart, and the vessel thereupon trailed its grapnel two miles to the eastward of this line, when it soon engaged the cable 20 miles away from the point where dead reckoning had placed the ruptured end.

Whether or not it will ever be practicable to determine oceanic depths without a sounding line, by means of an instrument based upon gravimetric differences, remains to be seen. Hitherto the indications obtained by such an instrument have been encouraging, but its delicacy has been such as to unfit it for ordinary use on board a ship when rolling.

The time allowed me for addressing you on this occasion is
wholly insufficient to do justice to the great engineering works of the present day, and I must therefore limit myself to making a short allusion to a few only of the more remarkable enterprises.

The great success, both technically and commercially, of the Suez Canal, has stimulated M. de Lesseps to undertake a similar work of even more gigantic proportions, namely, the piercing of the Isthmus of Panama by a ship canal, 40 miles long, 50 yards wide on the surface, and 20 yards at the bottom, upon a dead level from sea to sea. The estimated cost of this work is £20,000,000, and, more than this sum having been subscribed, it appears unlikely that political or climatic difficulties will stop M. de Lesseps in its speedy accomplishment. Through it, China, Japan, and the whole of the Pacific coasts will be brought to half their present distance, as measured by the length of voyage, and an impulse to navigation and to progress will be given which it will be difficult to over-estimate.

Side by side with this gigantic work, Captain Eads, the successful improver of the Mississippi navigation, intends to erect his ship railway, to take the largest vessels, fully laden and equipped, from sea to sea, over a gigantic railway across the Isthmus of Tehuantepec, a distance of 95 miles. Mr. Barnaby, the chief constructor of the navy, and Mr. John Fowler have expressed a favourable opinion regarding this enterprise, and it is to be hoped that both the canal and the ship railway will be accomplished, as it may be safely anticipated that the traffic will be amply sufficient to support both these undertakings.

Whether or not M. de Lesseps will be successful also in carrying into effect the third great enterprise with which his name has been prominently connected, the flooding of the Tunis-Algerian Chotts, thereby re-establishing the Lake Tritonis of the ancients, with its verdure-clad shores, is a question which could only be decided upon the evidence of accurate surveys, but the beneficial influence of a large sheet of water within the African desert could hardly be matter of doubt.

It is with a feeling not unmixed with regret that I have to record the completion of a new Eddystone Lighthouse, in substitution for the chef-d'œuvre of engineering, erected by John Smeaton more than 100 years ago. The condemnation of that
structure was not, however, the consequence of any fault of construction, but was caused by inroads of the sea upon the rock supporting it. The new lighthouse, designed and executed by Mr., now Sir, James Douglass, engineer of Trinity House, has been erected in the incredibly short time of less than two years, and bids fair to be worthy of its famed predecessor. Its height above high water is 130 feet, as compared with 72 feet (the height of Smeaton's structure), which gives its powerful light a considerably increased range. The system originally suggested by Sir William Thomson some years ago, of distinguishing one light from another by flashes following at varied intervals, has been adopted by the Elder Brethren in this as in other recent lights in the modified form introduced by Dr. John Hopkinson, in which the principle is applied to revolving lights, so as to obtain a greater amount of light in the flash.

The geological difficulties which for some time threatened the accomplishment of the St. Gotthard Tunnel have been happily overcome, and this second and most important sub-Alpine thoroughfare now connects the Italian railway system with that of Switzerland and the south of Germany, whereby Genoa will be constituted the shipping port for those parts.

Whether we shall be able to connect the English with the French railway system by means of a tunnel below the English Channel is a question that appears dependent, at this moment, rather upon military and political than technical and financial considerations. The occurrence of a stratum of impervious grey chalk, at a convenient depth below the bed of the Channel, minimises the engineering difficulties in the way, and must influence the financial question involved. The protest lately raised against its accomplishment can hardly be looked upon as a public verdict, but seems to be the result of a natural desire to pause, pending the institution of careful inquiries. Such inquiries have lately been made by a Royal scientific Commission, and will be referred for further consideration to a mixed Parliamentary Committee, upon whose Report it must depend whether the natural spirit of commercial enterprise has to yield in this instance to political and military considerations. Whether the Channel Tunnel is constructed or not, the plan proposed some years ago by Mr. John Fowler of connecting England and France by means of a ferry.
boat capable of taking railway trains would be a desideratum justified by the ever-increasing intercommunication between this and Continental countries.

The public inconvenience arising through the obstruction to traffic by a sheet of water is well illustrated by the circumstance that both the estuaries of the Severn and of the Mersey are being undermined in order to connect the railway systems on the two sides, and that the Frith of Forth is about to be spanned by a bridge exceeding in grandeur anything as yet attempted by the engineer. The roadway of this bridge will stand 150 feet above high-water mark, and its two principal spans will measure a third of a statute mile each. Messrs. Fowler and Baker, the engineers to whom this great work has been entrusted, could hardly accomplish their task without having recourse to steel for their material of construction, nor need the steel used be of the extra mild quality particularly applicable for naval structures to withstand collision, for, when such extreme toughness is not required, steel of very homogeneous quality can be produced, bearing a tensile strain fully double that of iron.

The tensile strength of steel, as is well known, is the result of an admixture of carbon with the iron, varying between $\frac{1}{10}$ th and 2 per cent., and the nature of this combination of carbon with iron is a matter of great interest both from a theoretical and practical point of view. It could not be a chemical compound which would necessitate a definite proportion, nor could a mere dissolution of the one in the other exercise such remarkable influence upon the strength and hardness of the resulting metal. A recent investigation by Mr. Abel has thrown considerable light upon this question. A definite carbide of iron is formed, it appears, soluble at high temperatures in iron, but separating upon cooling the steel gradually, and influencing only to a moderate degree the physical properties of the metal as a whole. In cooling rapidly there is no time for the carbide to separate from the iron, and the metal is thus rendered both hard and brittle. Cooling the metal gradually under the influence of great compressive force, appears to have a similar effect to rapid cooling in preventing the separation of the carbide from the metal, with this difference, that the effect is more equal throughout the mass, and that more uniform temper is likely to result.
When the British Association met at Southampton on a former occasion, Schönbein announced to the world his discovery of gun-cotton. This discovery has led the way to many valuable researches on explosives generally, in which Mr. Abel has taken a leading part. Recent investigations by him, in connection with Captain Noble, upon the explosive action of gun-cotton and gunpowder confined in a strong chamber (which have not yet been published), deserve particular attention. They show that while by the method of investigation pursued about twenty years ago by Karolye (of exploding gunpowder in very small charges in shells confined within a large shell partially exhausted of air), the composition of the gaseous products was found to be complicated and liable to variation, the chemical metamorphosis which gun-cotton sustains, when exploded under conditions such as obtain in its practical application, is simple and very uniform. Among other interesting points noticed in this direction was the fact that, as in the case of gunpowder, the proportion of carbonic acid increases, while that of carbonic oxide diminishes with the density of the charge. The explosion of gun-cotton, whether in the form of wool or loosely spun thread, or in the packed compressed form devised by Abel, furnished practically the same results if fired under pressure, that is, under strong confinement—the conditions being favourable to the full development of its explosive force; but some marked differences in the composition of the products of metamorphosis were observed when gun-cotton was fired by detonation.

With regard to the tension exerted by the products of explosion, some interesting points were observed, which introduce very considerable difficulties into the investigation of the action of fired gun-cotton. Thus whereas no marked differences are observed in the tension developed by small charges and by very much larger charges of gunpowder having the same density (i.e. occupying the same volume relatively to the entire space in which they are exploded), the reverse is the case with respect to gun-cotton. Under similar conditions in regard to density of charge, 100 grammes of gun-cotton gave a measured tension of about 20 tons on the square inch, 1500 grammes gave a tension of about 29 tons (in several very concordant observations), while a charge of 2-5 kilos gave a pressure of about 45 tons, this being the maximum measured
tension obtained with a charge of gunpowder of five times the density of the above.

The extreme violence of the explosion of gun-cotton as compared with gunpowder when fired in a closed space was a feature attended with formidable difficulties. In whatever way the charge was arranged in the firing cylinder, if it had free access to the inclosed crusher gauge, the pressures recorded by the latter were always much greater than when means were taken to prevent the wave of matter suddenly set in motion from acting directly upon the gauge. The abnormal or wave-pressures recorded at the same time that the general tension in the cylinder was measured amounted in the experiment to 42·3 tons, when the general tension was recorded at 20 tons; and in another, when the pressure was measured at 29 tons, the wave-pressure recorded was 44 tons. Measurements of the temperature of explosion of gun-cotton showed it to be about double that of the explosion of gunpowder. One of the effects observed to be produced by this sudden enormous development of heat was the covering of the inner surfaces of the steel explosion-vessel with a network of cracks, small portions of the surface being sometimes actually fractured. The explosion of charges of gun-cotton up to 2·5 kilos in perfectly closed chambers, with development of pressures approaching to 50 tons on the square inch, constitutes alone a perfectly novel feat in investigations of this class.

Messrs. Noble and Abel are also continuing their researches upon fired gunpowder, being at present occupied with an inquiry into the influence exerted upon the chemical metamorphosis and ballistic effects of fired gunpowder by variation in its composition, their attention being directed especially to the discovery of the cause of the morc or less considerable erosion of the interior surface of guns produced by the exploding charge—an effect which, notwithstanding the application of devices in the building up of the charge specially directed to the preservation of the gun's bore, have become so serious that, with the enormous charges now used in our heavy guns, the erosive action on the surface of the bore produced by a single round is distinctly perceptible. As there appeared to be prima facie reasons why the erosive action of powder upon the surface of the bore, at the high temperatures developed, should be at any rate in part due to its one component
sulphur, Noble and Abel have made comparative experiments with powders of usual composition and with others in which the proportion of sulphur was considerably increased, the extent of erosive action of the products escaping from the explosion vessel under high tension being carefully determined. With small charges a particular powder containing no sulphur was found to exert very little erosive action as compared with ordinary cannon powder; but another powder, containing the maximum proportion of sulphur tried (15 per cent.), was found equal to it under these conditions, and exerted very decidedly less erosive action than it, when larger charges were reached. Other important contributions to our knowledge of the action of fired gunpowder in guns, as well as decided improvements in the gunpowder, manufactured for the very heavy ordnance of the present day, may be expected to result from a continuance of these investigations. Professor Carl Himly, of Kiel, having been engaged upon investigations of a similar nature, has lately proposed a gunpowder in which hydrocarbons (precipitated from solution in naphtha) take the place of the charcoal and sulphur of ordinary powder; this powder has amongst others the peculiar property of completely resisting the action of water, so that the old caution, "Keep your powder dry," may hereafter be unnecessary.

The extraordinary difference of condition, before and after its ignition, of such matter as constitutes an explosive agent, leads us up to a consideration of the aggregate state of matter under other circumstances. As early as 1776 Alexander Volta observed that the volume of glass was changed under the influence of electrification, by what he termed electrical pressure. Dr. Kerr, Govi, and others have followed up the same inquiry, which is at present continued chiefly by Dr. George Quincke, of Heidelberg, who finds that temperature, as well as chemical constitution of the dielectric under examination, exercises a determining influence upon the amount and character of the change of volume effected by electrification; that the change of volume may under certain circumstances be effected instantaneously as in flint glass, or only slowly as in crown glass, and that the elastic limit of both is diminished by electrification, whereas in the case of mica and of gutta percha an increase of elasticity takes place.
Still greater strides are being made at the present time towards a clearer perception of the condition of matter when particles are left some liberty to obey individually the forces brought to bear upon them. By the discharge of high tension electricity through tubes containing highly rarefied gases (Geissler’s tubes), phenomena of discharge were produced which were at once most striking and suggestive. The Sprengel pump afforded a means of pushing the exhaustion to limits which had formerly been scarcely reached by the imagination. At each step, the condition of attenuated matter revealed varying properties, when acted upon by electrical discharge and magnetic force. The radiometer of Crookes imported a new feature into these inquiries, which at the present time occupy the attention of leading physicists in all countries.

The means usually employed to produce electrical discharge in vacuum tubes were Ruhmkorff’s coil; but Mr. Gassiot first succeeded in obtaining the phenomena by means of a galvanic battery of 3,000 Leclanché cells. Mr. De La Rue, in conjunction with his friend Dr. Hugo Müller, has gone far beyond his predecessors in the production of batteries of high potential. At his lecture “On the Phenomena of Electric Discharge,” delivered at the Royal Institution in January, 1881, he employed a battery of his own invention consisting of 14,400 cells (14,832 Volts), which gave a current of 0·054 Ampère, and produced a discharge at a distance of 0·71 inch between the terminals. During last year he increased the number of cells to 15,000 (15,450 Volts), and increased the current to 0·4 Ampère, or eight times that of the battery he used at the Royal Institution.

With the enormous potential and perfectly steady current at his disposal, Mr. De La Rue has been able to contribute many interesting facts to the science of electricity. He has shown, for example, that the beautiful phenomena of the stratified discharge in exhausted tubes are but a modification and a magnification of those of the electric arc at ordinary atmospheric pressure. Photography was used in his experiments to record the appearance of the discharge, so as to give a degree of precision otherwise unattainable in the comparison of the phenomena. He has shown that between two points the length of the spark, provided the insulation of the battery is efficacious, is as the square of the number of cells employed. Mr. De La Rue’s experiments have
proved that at all pressures the discharge in gases is not a current in the ordinary acceptation of the term, but is of the nature of a disruptive discharge. Even in an apparently perfectly steady discharge in a vacuum tube, when the strata as seen in a rapidly revolving mirror are immovable, he has shown that the discharge is a pulsating one; but, of course, the period must be of a very high order.

At the Royal Institution, on the occasion of his lecture, he produced, in a very large vacuum tube, an imitation of the Aurora Borealis; and he has deduced from his experiments that the greatest brilliancy of Aurora displays must be at an altitude of from thirty-seven to thirty-eight miles—a conclusion of the highest interest, and in opposition to the extravagant estimate of 281 miles, at which it had been previously put.

The President of the Royal Society has made the phenomena of electrical discharge his study for several years, and resorted in his important experiments to a special source of electric power. In a note addressed to me, Dr. Spottiswoode describes the nature of his investigations much more clearly than I could venture to give them. He says: "It had long been my opinion that the dis-symmetry, shown in electrical discharges through rarefied gases, must be an essential element of every disruptive discharge, and that the phenomena of stratification might be regarded as magnified images of features always present, but concealed under ordinary circumstances. It was with a view to the study of this question that the researches by Moulton and myself were undertaken. The method chiefly used consisted in introducing into the circuit intermittence of a particular kind, whereby one luminous discharge was rendered sensitive to the approach of a conductor outside the tube. The application of this method enabled us to produce artificially a variety of phenomena, including that of stratification. We were thus led to a series of conclusions relating to the mechanism of the discharge, among which the following may be mentioned:—

1. That a stria, with its attendant dark space, forms a physical unit of a striated discharge; that a striated column is an aggregate of such units formed by means of a step-by-step process; and that the negative glow is merely a localised stria, modified by local circumstances.
"2. That the origin of the luminous column is to be sought for at its negative end; that the luminosity is an expression of a demand for negative electricity; and that the dark spaces are those regions where the negative terminal, whether metallic or gaseous, is capable of exerting sufficient influence to prevent such demand.

"3. That the time occupied by electricity of either name in traversing a tube is greater than that occupied in traversing an equal length of wire, but less than that occupied by molecular streams (Crookes' radiations) in traversing the tubes. Also that, especially in high vacua, the discharge from the negative terminal exhibits a durational character not found at the positive.

"4. That the brilliancy of the light with so little heat may be due in part to brevity in the duration of the discharge; and that for action so rapid as that of individual discharges, the mobility of the medium may count as nothing; and that for these infinitesimal periods of time gas may itself be as rigid and as brittle as glass.

"5. That striae are not merely loci in which electrical is converted into luminous energy, but are actual aggregations of matter.

"This last conclusion was based mainly upon experiments made with an induction coil excited in a new way—viz. directly by an alternating machine, without the intervention of a commutator or condenser. This mode of excitement promises to be one of great importance in spectroscopic work, as well as in the study of the discharge in a magnetic field, partly on account of the simplification which it permits in the construction of induction coils, but mainly on account of the very great increase of strength in the secondary currents to which it gives rise."

These investigations assume additional importance when we view them in connection with solar—I may even say stellar—physics, for evidence is augmenting in favour of the view that interstellar space is not empty, but is filled with highly attenuated matter of a nature such as may be put into our vacuum tubes. Nor can the matter occupying stellar space be said any longer to be beyond our reach for chemical and physical test. The spectroscope has already thrown a flood of light upon the chemical constitution and physical condition of the sun, the stars, the comets,
and the far distant nebulae, which latter have yielded spectroscopic photographs under the skilful management of Dr. Huggins, and Dr. Draper of New York. Armed with greatly improved apparatus the physical astronomer has been able to reap a rich harvest of scientific information during the short periods of the last two solar eclipses; that of 1879, visible in America, and that of May last, observed in Egypt by Lockyer, Schuster, and by Continental observers of high standing. The result of this last eclipse expedition has been summed up as follows: “Different temperature levels have been discovered in the solar atmosphere; the constitution of the corona has now the possibility of being determined, and it is proved to shine with its own light. A suspicion has been aroused once more as to the existence of a lunar atmosphere, and the position of an important line has been discovered. Hydrocarbons do not exist close to the sun, but may in space between us and it.”

To me personally these reported results possess peculiar interest, for in March last I ventured to bring before the Royal Society a speculation regarding the conservation of solar energy, which was based upon the three following postulates, viz.:

1. That aqueous vapour and carbon compounds are present in stellar or interplanetary space.

2. That these gaseous compounds are capable of being dissociated by radiant solar energy while in a state of extreme attenuation.

3. That the effect of solar rotation is to draw in dissociated vapours upon the polar surfaces, and to eject them after combustion back into space equatorially.

It is therefore a matter of peculiar gratification to me that the results of observation here recorded give considerable support to that speculation. The luminous equatorial extensions of the sun which the American observations revealed in such a striking manner (with which I was not acquainted when writing my paper) were absent in Egypt; but the outflowing equatorial streams (I suppose to exist) could only be rendered visible by reflected sunlight, or by electric discharge when mixed with dust produced by exceptional solar disturbances; and the occasional appearance of such luminous extensions would serve only to disprove the hypothesis entertained by some, that they are divided planetary matter,
in which case their appearance should be permanent. Professor Langley, of Pittsburg, has shown by means of his bolometer, that the solar actinic rays are absorbed chiefly in the solar instead of in the terrestrial atmosphere, and Captain Abney has found, by his new photometric method, that absorption, due to hydrocarbons, takes place somewhere between the solar and terrestrial atmosphere; in order to test this interesting result still further, he has lately taken his apparatus to the top of the Riffel with a view of diminishing the amount of terrestrial atmospheric air between it and the sun, and intends to bring a paper on this subject before Section A. Stellar space filled with such matter as hydro-carbon and aqueous vapour would establish a material continuity between the sun and his planets, and between the innumerable solar systems of which the universe is composed. If chemical action and reaction can further be admitted, we may be able to trace certain conditions of thermal dependence and maintenance, in which we may recognise principles of high perfection, applicable also to comparatively humble purposes of human life.

We shall thus find that in the great workshop of nature there are no lines of demarcation to be drawn between the most exalted speculation and commonplace practice, and that all knowledge must lead up to one great result, that of an intelligent recognition of the Creator through His works. So then, we members of the British Association and fellow-workers in every branch of science may exhort one another in the words of the American bard who has so lately departed from amongst us:

"Let us then be up and doing,
With a heart for any fate;
Still achieving, still pursuing,
Learn to labour and to wait."
ON WASTE.

Substance of an Address delivered at the Annual Meeting of the Coventry Science Classes on October 20th, 1882,

By C. William Siemens,* D.C.L., LL.D., F.R.S.

When I was requested a few weeks ago by your honorary secretary to come amongst you and distribute these prizes, I was in the north of Scotland taking a holiday after a hard spell of work at Southampton, and I felt that I should not undertake duties of this kind until another year. But it was really such a pleasure to come down to this old town, and the easy terms which were imposed, induced me not to postpone my visit, but to come to-night. I thought I should have told you something about science and science education, but I saw that last year my friend and predecessor in office, Mr. Norman Lockyer—(applause)—had delivered a very able oration on technical education. Moreover, I have been asked to go to Birmingham, as President of the Midland Institute, to deliver an address of a similar kind. Therefore I shall have enough of that subject, and I think I had better look out for some other matter as the subject of my discourse to-night.

I might have taken the hint thrown out by the Mayor, and given you an address on the wonders of electricity, but I think electricity has now become a matter of study, and I could not, in the short space of time allowed me, add any useful matter to the knowledge you already possess on the subject. I think we should have done with the wonders of electricity. I do not like to hear about them. I prefer to hear of actual results; of the amount of power necessary to produce certain effects; I like to hear students speak intelligently of the units of heat necessary to produce certain units of electricity and so forth. Therefore I have thought that on the whole it would be better to talk, not about something to be desired, but of something we do not desire, and yet something that interests all of us; in a word "Waste." I am going to tell you something about waste.

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There are different kinds of waste. There is waste of time, waste of food, waste of personal energy, waste of mechanical energy, and waste of material. These are five kinds of waste, which, if they could not be avoided but reduced to inconsiderable proportions, would constitute an enormous source of wealth.

As regards waste of time. I think we must all plead guilty to wasting a great deal of time—even the best of us. It seems strange that men who are very economical in some respects—who don’t like to pay away their money which they might earn again, are very liberal with their time. They think nothing of wasting a day, or many hours every day, in doing nothing, and some men, I am afraid, and even ladies, spend a very considerable portion of their time in their bed-rooms. Our ancestors were much more active than we are, and I have heard it said that it used to be an adage, “six hours bed for a man, seven for a woman, and eight for a fool.” I suppose those who take nine hours are exempted from this comparison, and think they are doing quite right. Then, in addition to the time wasted in one’s bed-chamber, there is a great deal of time frittered away in idle talk and in pastime, which is not profitable either to the body or the mind. In fact we must all confess to wasting say two hours in the day, and if the Legislature could exact a tax of a penny an hour on that, it would pay off the National Debt in a very little time. Therefore wasting time is a thing we ought to learn to avoid—and may avoid.

A very wise suggestion was made by a great moral philosopher and poet, who led a most industrious life, and yet had time for everything. He was fond of a rubber at whist, fond of a long talk with his friends, fond of society, the theatre and arts, and yet he accomplished an enormous amount of work. He wrote volumes and volumes of books, involving an immense amount of thought. He was a minister in his country and directed the Government; he directed the academy of arts and the theatre; and the secret, he said, consisted entirely in packing into every day the different occupations as you would pack a box. Give a set time for everything, and you will find time for many things which you now think you cannot possibly attend to, and which, indeed, you cannot without such methods.

Then we have another kind of waste that we might avoid. We
waste a great deal of food, not only by drinking too much—that is very hurtful—but a great many of us eat too much. We don't think exactly that this is hurtful, but I think it is, and perhaps as hurtful as too much drinking. This waste can be easily avoided by a little method, but the kind of waste of food I would allude to is that in our kitchens. There science begins to step in. I see here a great number of ladies who have come to this room evidently taking an interest in science teaching. If they were to begin with the science of chemistry as applied to the kitchen there is a good deal of scope for it to be displayed there. A friend of mine who took a philosophical view of things presented his niece on her marriage, not with ornaments, but with a cookery book, and wrote inside this inscription, "Kissing don't last, but cookery do." This I thought was a very suggestive present, because, however much we may admire the other sex—and we shall always and must admire them, yet if the dinner is well served, if the bills at the end of the week or month are not excessive, it adds very materially to our happiness.

This can be brought about in a great measure by a little science in the culinary department. For instance there is almost as much nourishment in the bone as in the meat attached to it, and yet in many households—I may say in the great run of households—the bones are thrown away, whereas they would form material for excellent soup such as is found in Scotland and in Ireland, and also in France in the form of *pot-au-feu*. In the French household there is always a pot boiling by the side of the stove, and whatever is to spare is put into that pot, and strange to say the result is not at all unpalatable, as I can testify, having partaken of it. There is I say in this country, in the preparation of food, great waste, which by a little science, a little method and prudence, could be greatly ameliorated.

We then come to another form of waste—that of personal energy. We find men who are quite ready to do something—go to the hunt, to the play, undertake all sorts of mental and bodily exercise, but they don't take any interest in those things which can be turned to profitable account. Instead of reading trashy novels, it would be far more profitable to read books of history and elementary books of science. You would recur to the reading which you left interested in those subjects, again and again, and it would
give you pleasure for years to come, whereas the wasteful enjoyment of an hour is lost the moment the excitement is over.

There is great room for improvement in this respect, in directing our energies to some purpose. Where you find successful men you may almost invariably trace their success under otherwise equal circumstances, to the fact that they have more earnest bias than others who, with equal ability, equal desire to get on, fritter their time and energy away. This waste of personal energy is one which has to be watched, and I hope that through institutions of this kind we shall instil by degrees a taste for profitable mental exercises and profitable bodily exercises, instead of the wasteful methods in which these energies have been expended hitherto.

The next form of waste is that of mechanical energy, and there we come more directly toward the application of science itself. One workman will spend a great deal more labour in accomplishing a given amount of set work than another. If he has method he will not move his limbs more than is necessary, he will not lift a weight oftener than is necessary for the accomplishment of his purpose, whereas a novice will dance about without reflection, and incur a great deal of labour to produce little result.

But there is more serious waste of mechanical energy. Take for instance the great motive power of the day—the steam-engine. The steam-engine of twenty years ago expended about 10 lbs. of coal for every horse-power of effect yielded from it. By applying scientific methods and mechanical skill in this direction we have been able to greatly reduce the amount of fuel consumed per horse-power—namely from 10 lbs. to 2 lbs. The engine is exactly the same in its essential parts, there are boiler, steam cylinder, and if it is a low-pressure engine, the condenser. Yet by more judicious arrangement of these parts, without any other expenditure than that of thought and a little more mechanical skill, we accomplish the marvellous result of obtaining our effects with an expenditure of one-fifth of what was spent before.

In like manner in our smelting works, to produce a ton of iron used to take seven or eight tons of coal, and to produce a ton of steel used to take about fourteen tons of coal, whereas, by dint of invention, of method in applying these inventions, and of mechanical skill we have reduced this expenditure of fuel fully in the
ratio of five to one. To produce a ton of steel at the present time from the ore takes no more than about three tons of coal—to put it into the form of rail or tyre.

These are instances showing how much waste can be prevented by proper direction of the working of machinery, and of thought, to the development of the processes by which these effects are to be produced. At the bottom of these improvements must always be science; in fact any improvement that is not the outcome of first scientific principles cannot be trusted. If it is an improvement that is merely the result of rule of thumb, or of a kind of rough observation of the working of machines and their effects, it generally leads to a very partial and very doubtful result, applicable only to the particular instance. Whereas it is always applicable when founded on those first principles in science that should be, and no doubt are, taught at this school of science. It is by the thorough comprehension of those first principles and their application that the great revolutionising inventions of the present time have been brought about.

There is great room for the saving of energy in various forms. We do not depend exclusively upon coal for the power and the heat we require; we have great stores of force the outcome of the solar radiations from day to day upon our earth, in the form of water power, of wind, and of tidal action. All these can, and no doubt will in time, be made useful for our purposes. I was only lately paying a visit to my friend Sir William Armstrong, and there saw that he had placed one of our dynamo machines at a distance of a mile from his house under a waterfall. By this means his house was lighted by electricity. There was a brook which had run to waste from time immemorial, and now by a very simple arrangement it had been made available to light a large house entirely by electricity. How great that waste has been through the ages during which that brook has flowed, which is now utilised. During the daytime, when the light is not required, the same electric energy produced from the waterfall is made available for turning a lathe, in turning planing machines, and for other mechanical purposes.

At my own farm near Tunbridge Wells I have not the advantage of a waterfall, but there also I have been experimenting with another form of energy—that produced by the steam-engine—but
in such a way that none of the effect of steam should be lost. The way this is done is very simple. The steam engine works a dynamo machine. This dynamo machine gives the necessary power to light the house in the evening, and for lighting up certain greenhouses during the night, in order to supply them with an artificial sun. This artificial sun enables me to grow fruit, such as melons, peaches, strawberries, and the like in the depth of winter. If I were fortunate enough to have water power at my disposal I should require no expenditure of any sort except the maintenance of a few simple machines for producing these effects. But my steam is not lost. After it has gone through the engine I condense it in a heater. Through this heater I supply all the greenhouses and other places to be heated in winter with warmth, so that I do not expend much more fuel since I have started the electric light and the dynamo machine than I did before in simply heating these greenhouses. During the daytime the current produced by the dynamo machine is conducted to another part of the farm, where it is made use of to pump water. Water is pumped 200 feet high to supply house, garden, tables, and the whole establishment. Another branch wire is used to cut wood, to cut chaff, and to do other work on the farm. In this way waste can be prevented to such an extent that is perfectly surprising to those who have never given the matter due consideration. It is very simple indeed when put into practice, and involves no expenditure that is not amply repaid by the results.

I have now spoken about waste of energy, and I wish to say, before concluding, a few words about the waste of material, which, perhaps, is the greatest source of waste amongst us. The waste of fuel I have already alluded to, inasmuch as fuel is the essence of energy. Nearly all the energy we use, nearly all the power we use, is obtained from fuel. We can see that a vast amount of the fuel we heap on our fire goes up the chimneys and produces no other effect than that of poisoning our atmosphere. (Applause.) That is a waste which, if estimated, could only be estimated by many millions of tons. And its importance will be seen more and more when we consider what could be done with that same fuel if, instead of burning it in this happy-go-lucky manner by throwing raw coal on to our fires, we were to reduce the whole of it into its constituents—gas and coke. We can burn gas much more
economically than fuel, because we can adjust the amount of air necessary for its combustion with the greatest accuracy. We can burn coke with much more heat than raw coal because it does not fly off of its own accord into smoke. Therefore by simply separating these two constituents of coal we take each of them at a much greater advantage to ourselves.

But another element presents itself which is of the greatest importance, and that is the element of the secondary products which modern science has brought to the fore. Not very many years ago—perhaps 20—coal tar was almost valueless; gas companies sold it for one halfpenny a gallon. In like manner ammonia-water was allowed to run waste and to poison the fish in our brooks. I have lately had occasion to estimate the value of these products that were utterly wasted 20 years ago, and I find to my astonishment that they exceed in value all the coal that is used at those works—the gas works—where they are produced. The total amount of coal used at our gas works is something like nine million tons, which may be valued at four and a half million pounds. The waste products, including the coke, have been valued at seven million pounds sterling in England, showing that their value exceeds by two and a half millions the total value of all the coal consumed in producing the gas. Not only have we, by the use of coal tar, turned to account this enormous amount of waste products, but we have enriched our arts and manufactures by those beautiful colours which now give the art of dyeing a new and enormous development. (Applause.) The ammonia liquor has a national value, because it is the only source from which ammonia can be obtained that can be depended upon for agricultural purposes, and there is an unlimited demand for it in that direction. If we can only make up our minds to use fuel in the refined forms of gas and coke, we should have the command of much larger value than they themselves come to in the secondary products. Therefore the point which science and the arts should be directed to chiefly is the prevention of waste. In doing so we should vastly increase not only our national resources but our individual well being. We have an old proverb which says, "Waste not, want not." We have had it in our mouths for hundreds of years, but we are only now beginning to realise it scientifically. (Loud and prolonged applause.)
ADDRESS

Of C. W. Siemens,* D.C.L., LL.D., F.R.S., Chairman of the Council of the Society of Arts,

Delivered at the Opening Meeting of the 126th Session, November 15, 1882.

Having received the honour of being elected Chairman of the Council of the Society of Arts for the ensuing year, the duty devolves upon me of opening the coming Session with some introductory remarks.

Only a few months have elapsed since I was called upon to deliver a presidential address to the British Association at Southampton, and it may be reasonably supposed that I then exhausted my stock of accumulated thought and observation regarding the present development of science, both abstract and applied; that, in fact, I come before you, to use a popular phrase, pretty well pumped dry. And yet so large is the field of modern science and industry, that, notwithstanding the good opportunity given me at Southampton, I could there do only scanty justice to comparatively few of the branches of modern progress, and had to curtail, or entirely omit, reference to others, upon which I should otherwise have wished to dwell.

There is this essential difference between the British Association and the Society of Arts, that the former can only take an annual survey of the progress of science, and must then confide to individuals, or to committees, specific inquiries, to be reported upon to the different sections at subsequent meetings; whereas the Society of Arts, with its 3,450 permanent members, its ninety-five associated societies, spread throughout the length and breadth of the country, its permanent building, its well-conducted Journal, its almost daily meetings and lectures, extending over six months of the year, possesses exceptionally favourable opportunities of following up questions of industrial progress to the point of their practical accomplishment.

In glancing back upon its history during the 128 years of its existence, we discover that the Society of Arts was the first institution to introduce science into the industrial arts; it was through the Society of Arts and its illustrious Past President, the late Prince Consort, that the first Universal Exhibition was proposed, and brought to a successful issue in 1851; and it is due to the same society, supported on all important occasions by its present President, the Prince of Wales, that so many important changes in our educational and industrial institutions have been inaugurated, too numerous to be referred to specifically on the present occasion.

Amongst the practical questions that now chiefly occupy public attention are those of Electric Lighting, and of the transmission of force by electricity. These together form a subject which has occupied my attention and that of my brothers for a great number of years, and upon which I may consequently be expected to dwell on the present occasion, considering that at Southampton I could deal only with some purely scientific considerations involved in this important subject.

I need hardly remind you that electric lighting, viewed as a physical experiment, has been known to us since the early part of the present century, and that many attempts have, from time to time, been made to promote its application. Two principal difficulties have stood in the way of its practical introduction, viz., the great cost of producing an electric current so long as chemical means had to be resorted to, and the mechanical difficulty of constructing electric lamps capable of sustaining, with steadiness, prolonged effects.

The dynamo-machine, which enables us to convert mechanical into electrical force, purely and simply, has very effectually disposed of the former difficulty, inasmuch as a properly conceived and well constructed machine of this character converts more than ninety per cent. of the mechanical force imparted to it into electricity, ninety per cent. again of which may be re-converted into mechanical force at a moderate distance. The margin of loss therefore, does not exceed twenty per cent., excluding purely mechanical losses, and this is quite capable of being further reduced to some extent by improved modes of construction; but it results from these figures that no great step in advance can be
looked for in this direction. The dynamo-machine presents the great advantage of simplicity over steam or other power-transmitting engines; it has but one working part, namely, a shaft which, revolving in a pair of bearings, carries a coil or coils of wire admitting of perfect balancing. Frictional resistance is thus reduced to an absolute minimum, and no allowance has to be made for loss by condensation, or badly fitting pistons, stuffing-boxes, or valves, or for the jerking action due to oscillating weights. The materials composing the machine, namely, soft iron and copper wire, undergo no deterioration or change by continuous working, and the depreciation of value is therefore a minimum, except where currents of exceptionally high potential are used, which appear to render the copper wire brittle.

The essential points to be attended to in the conception of the dynamo-machine, are the prevention of induced currents in the iron, and the placing of the wire in such position as to make the whole of it effective for the production of outward current. These principles, which have been clearly established by the labours of comparatively few workers in applied science, admit of being carried out in an almost infinite variety of constructive forms, for each of which may be claimed some real or imaginary merits regarding questions of convenience or cost of production.

For many years after the principles involved in the construction of dynamo-machines had been made known, little general interest was manifested in their favour, and few were the forms of construction offered for public use. The essential feature involved in the dynamo-machine, the Siemens armature (1856), the Pacinotti ring (1861), and the self-exciting principle (1867), were published by their authors for the pure scientific interest attached to them, without being made subject matter of letters patent, which circumstance appears to have had the contrary effect of what might have been expected, in that it has retarded the introduction of this class of electrical machine, because no person or firm had a sufficient commercial interest to undertake the large expenditure which must necessarily be incurred in reducing a first conception into a practical shape. Great credit is due to Monsieur Gramme for taking the initiative in the practical introduction of dynamo-machines embodying those principles; but when, five years ago, I ventured to predict for the dynamo-electric current a great
practical future, as a means of transmitting power to a distance, those views were still looked upon as more or less chimerical. A few striking examples of what could be practically effected by the dynamo-electric current, such as the illumination of the Place de l'Opéra, Paris, the occasional exhibition of powerful arc lights, and their adoption for military and lighthouse purposes, but especially the gradual accomplishment of the much desired lamp by incandescence in vacuum, gave rise to a somewhat sudden reversion of public feeling; and you may remember the scare at the Stock Exchange, affecting the value of gas shares, which ensued in 1878, when the accomplishment of the sub-division of the electric light by incandescent wire was first announced, somewhat prematurely, through the Atlantic cable.

From this time forward electric lighting has been attracting more and more public attention, until the brilliant displays at the exhibition of Paris, and at the Crystal Palace last year, served to excite public interest, to an extraordinary degree. New companies for the purpose of introducing electric light and power have been announced almost daily, whose claims to public attention as investments were based in some cases upon only very slight modifications of well-known forms of dynamo-machines, of arc regulators or of incandescent carbon lights, the merits of which rested rather upon anticipations than upon any scientific or practical proof. These arrangements were supposed to be of such superlative merit that gas and other illuminants must soon be matters simply of history, and hence arose great speculative excitement. It should be borne in mind, however, that any great technical advance is necessarily the work of time and serious labour, and that when accomplished, it is generally found that, so far from injuring existing industries, it calls additional ones into existence, to supply new demands, and thus gives rise to an increase in the sum total of our resources. It is, therefore, reasonable to expect that, side by side with the introduction of the new illuminant, gas lighting will go on improving and extending, although the advantages of electric light for many applications, such as the lighting of public halls and warehouses, of our drawing-rooms and dining-rooms and passenger steamers, our docks and harbours, are so evident, that its advent may be looked upon as a matter of certainty.

Our Legislature has not been slow in recognising the importance
of the new illuminant. In 1879, a Select Committee of the House of Commons instituted a careful inquiry into its nature and probable cost, with a view to legislation, and the conclusions at which they arrived were, I consider, the best that could have been laid down. They advised that applications should be encouraged tentatively by the granting of permissive bills, and this policy has given rise to the Electric Lighting Bill, 1882, promoted by Mr. Chamberlain, the President of the Board of Trade, regarding which much controversy has arisen. It could, indeed, hardly be expected that any act of legislation upon this subject could give universal satisfaction, because, while there are many believers in gas who would gladly oppose any measure likely to favour the progress of the rival illuminant, and others who wish to see it monopolised, either by local authorities, or by large financial corporations, there are others again who would throw the doors open so wide as to enable almost all comers to interfere with the public thoroughfares, for the establishment of conducting wires, without public let or hindrance.

The law as now established takes, I consider, a medium course between these diverging opinions, and, if properly interpreted, will protect, I believe, all legitimate interests, without impeding the healthy growth of establishments for the distribution of electric energy for lighting and for the transmission of power. Any firm or lighting company may, by application to the local authorities, obtain leave to place electric conductors below public thoroughfares, subject to such conditions as may be mutually agreed upon, the term of such license being limited to seven years; or an application may be made to the Board of Trade for a provisional order to the same effect, which, when sanctioned by Parliament, secures a right of occupation for twenty-one years. The license offers the advantage of cheapness, and may be regarded as a purely tentative measure, to enable the firm or company to prove the value of their plant. If this is fairly established, the license would in all probability be affirmed, either by an engagement for its prolongation from time to time, or by a provisional order, which would, in that case, be obtained by joint application of the contractor and the local authority. At the time of expiration of the provisional order, a right of pre-emption is accorded to the local authority, against which it has been objected with much
force, by so competent an authority as Sir Frederick Bramwell, that the conditions of purchase laid down are not such as fairly to remunerate the contracting companies for their expenditure and risk, and that the power of purchase would inevitably induce the parochial bodies to become mere trading associations. But while admitting the undesirability of such a consummation, I cannot help thinking that it was necessary to put some term to contracts entered into with speculative bodies at a time when the true value of electric energy, and the best conditions under which it should be applied, are still very imperfectly understood. The supply of electric energy, particularly in its application to transmission of power, is a matter simply of commercial demand and supply, which need not partake of the character of a large monopoly, similar to gas and water supply, and may therefore be safely left in the hands of individuals, or of local associations, subject to a certain control for the protection of public interests. At the termination of the period of the provisional order, the contract may be renewed upon such terms and conditions as may at that time appear just and reasonable to Parliament, under whose authority the Board of Trade will be empowered to effect such renewal.

Complaints appear almost daily in the public papers, to the effect that townships refuse their assent to applications by electric light companies for provisional orders; but it may be surmised that many of these applications are of a more or less speculative character, the object being to secure monopolies for eventual use or sale, under which circumstances the authorities are clearly justified in withholding their assent; and no licenses or provisional orders should indeed be granted, I consider, unless the applicants can give assurance of being able and willing to carry out the work within a reasonable time. But there are technical questions involved which are not yet sufficiently well understood to admit of immediate operations upon a large scale.

Attention has been very properly called to the great divergence in the opinions expressed by scientific men regarding the area that each lighting district should comprise, the capital required to light such an area, and the amount of electric tension that should be allowed in the conductors. In the case of gas supply, the works are necessarily situated in the outskirts of the town, on account of
the nuisance this manufacture occasions to the immediate neighbourhood; and, therefore, gas supply must range over a large area. It would be possible, no doubt, to deal with electricity on a similar basis, to establish electrical mains in the shape of copper rods of great thickness, with branches diverging from them in all directions; but the question to be considered is, whether such an imitative course is desirable on account either of relative expense or of facility of working. My own opinion, based upon considerable practical experience and thought devoted to the subject, is decidedly adverse to such a plan. In my evidence before the Parliamentary Committee, I limited the desirable area of an electric district in densely populated towns to a quarter of a square mile, and estimated the cost of the necessary establishment of engines, dynamo-machines, and conductors, at £100,000, while other witnesses held that areas from one to four square miles could be worked advantageously from one centre, and at a cost not exceeding materially the figure I had given. These discrepancies do not necessarily imply wide differences in the estimated cost of each machine or electric light, inasmuch as such estimates are necessarily based upon various assumptions regarding the number of houses and of public buildings comprised in such a district, and the amount of light to be apportioned to each, but I still maintain my preference for small districts.

By way of illustration, let us take the parish of St. James's, near at hand, a district not more densely populated than other equal areas within the metropolis, although comprising, perhaps, a greater number of public buildings. Its population, according to the preliminary report of the census taken on the 4th April, 1881, was 29,865, it contains 3,018 inhabited houses, and its area is 784,000 square yards, or slightly above a quarter of a square mile.

To light a comfortable house of moderate dimensions in all its parts, to the exclusion of gas, oil, or candles, would require about 100 incandescence lights (or, if I may suggest a more euphonious expression, glow-lights) of from 15 to 18-candle power each, that being, for instance, the number of Swan lights employed by Sir William Thomson in lighting his house at Glasgow University. Eleven-horse power would be required to excite this number of incandescence lights, and at this rate the parish of St. James's would
require $3,018 \times 11 = 33,200$-horse power to work it. It may be fairly objected, however, that there are many houses in the parish much below the standard here referred to, but, on the other hand, there are 600 of them with shops on the ground floor, involving larger requirements. Nor does this estimate provide for the large consumption of electric energy that would take place in lighting the eleven churches, eighteen club-houses, nine concert halls, three theatres, besides numerous hotels, restaurants, and lecture halls. A theatre of moderate dimensions, such as the Savoy Theatre, has been proved by experience to require 1,200 incandescence lights, representing an expenditure of 133-horse power; and about one-half that power would have to be set aside for each of the other public buildings here mentioned, constituting an aggregate of 2,926-horse power; nor does this general estimate comprise street lighting, and to light the six-and-a-half miles of principal streets of the parish with electric light, would require, per mile, thirty-five arc lights of 350-candle power each, or a total of 227 lights. This, taken at the rate of 0·8-horse power per light, represents a further requirement of 182-horse power, making a total of 3,108-horse power, for purposes independent of house lighting, being equivalent to 1-horse power per inhabited house, and bringing the total requirements up to 109 lights $= 12$-horse power per house.

I do not, however, agree with those who expect that gas lighting will be entirely superseded, but have, on the contrary, always maintained that the electric light, while possessing great and peculiar advantages for lighting our principal rooms, halls, warehouses, &c., owing to its brilliancy, and more particularly to its non-interference with the healthful condition of the atmosphere, will leave ample room for the development of the former, which is susceptible of great improvement, and is likely to hold its own for the ordinary lighting up of our streets and dwellings.

Assuming, therefore, that the bulk of domestic lighting remains to the gas companies, and that the electric light is introduced into private houses, only, at the rate of, say twelve incandescence lights per house, the parish of St. James's would have to be provided with electric energy sufficient to work $(9 + 12) 3,018 = 63,378$ lights $= 7,042$-horse power effective; this is equal to about one-fourth the total lighting power required, taking into account that the total number of lights that have to be provided for a house are

\[ \text{require } 3,018 \times 11 = 33,200 \text{-horse power to work it.} \]
not all used at one and the same time. No allowance is made in this estimate for the transmission of power, which, in course of time, will form a very large application of electric energy; but considering that power will be required mostly in the day time, when light is not needed, a material increase in plant will not be necessary for that purpose.

In order to minimise the length and thickness of the electric conductor, it would be important to establish the source of power, as nearly as may be, in the centre of the parish, and the position that suggests itself to my mind is that of Golden Square. If the unoccupied area of this square, representing 2,500 square yards, was excavated to a depth of 25 feet, and then arched over so as to re-establish the present ground level, a suitable covered space would be provided for the boilers, engines, and dynamo-machines, without causing obstruction or public annoyance; the only erection above the surface would be the chimney, which, if made monumental in form, might be placed in the centre of the square, and be combined with shafts for ventilating the subterranean chamber, care being taken of course to avoid smoke by insuring perfect combustion of the fuel used. The cost of such a chamber, of engine power, and of dynamo-machines, capable of converting that power into electric energy, I estimate at £140,000. To this expense would have to be added that of providing and laying the conductors, together with the switches, current regulators, and arrangements for testing the insulation of the wire.

The cost and dimensions of the conductors would depend upon their length, and the electromotive force to be allowed. The latter would no doubt be limited, by the authorities, to the point at which contact of the two conductors with the human frame would not produce injurious effects, or say to 200 volts, except for street lighting, for which purpose a higher tension is admissible. In considering the proper size of conductor to be used in any given installation, two principal factors have to be taken into account; first the charge for interest and depreciation on the original cost of a unit length of the conductor; and, secondly, the cost of the electrical energy lost through the resistance of a unit of length. The sum of these two, which may be regarded as the cost of conveyance of electricity, is clearly least, as Sir William Thomson pointed out some time ago, when the two components are equal.
This, then, is the principle on which the size of a conductor should be determined.

From the experience of large installations, I consider that electricity can, roughly speaking, be produced in London at a cost of about one shilling per 10,000 Ampère-Volts or Watts (746 Watts being equal to 1-horse power) for an hour. Hence, assuming that each set of four incandescence lamps in series (such as Swan’s, but for which may be substituted a smaller number of higher resistance and higher luminosity) requires 200 volts electromotive force, and 60 Watts for their efficient working, the total current required for 64,000 such lights is 19,200 amperes, and the cost of the electric energy lost by this current in passing through \( \frac{1}{100} \)th of an ohm resistance, is £16 per hour.

The resistance of a copper bar one quarter of a mile in length, and one square inch in section, is very nearly \( \frac{1}{100} \)th of an ohm, and the weight is about 2\( \frac{1}{3} \) tons. Assuming, then, the price of insulated copper conductor at £90 per ton, and the rate of interest and depreciation at 7\( \frac{1}{2} \) per cent., the charge per hour of the above conductor, when used eight hours per day, is 1\( \frac{1}{2} \)d. Hence, following the principle I have stated above, the proper size of conductor to use for an installation of the magnitude I have supposed, would be one of 48·29 inches section, or a round rod eight inches diameter.

If the mean distance of the lamps from the station be assumed as 350 yards, the weight of copper used in the complete system of conductors would be nearly 168 tons, and its cost £15,120. To this must be added the cost of iron pipes, for carrying the conductors underground, and of testing boxes, and labour in placing them. Four pipes of 10-inch diameter each, would have to proceed in different directions from the central station, each containing sixteen separate conductors of one inch diameter, and separately insulated, each of them supplying a sub-district of 1,000 lights.

The total cost of establishing these conductors may be taken at £37,000, which brings up the total expenditure for central station and leads to £177,000. I assume the conductors to be placed underground, as I consider it quite inadmissible, both as regards permanency and public safety and convenience, to place them above ground, within the precincts of towns. With this expenditure, the parish of St. James’s could be supplied with the electric
light to the extent of about 25 per cent. of the total illuminating power required. To provide a larger percentage of electric energy would increase the cost of establishment proportionately; and that of conductors, nearly in the square ratio of the increase of the district, unless the loss of energy by resistance is allowed to augment instead.

It may surprise uninitiated persons to be told that to supply a single parish with electric energy necessitates copper conductors of a collective area equal to a rod of eight inches in diameter; and how, it may be asked, will it be possible under such conditions to transmit the energy of waterfalls to distances of twenty or thirty miles, as has been suggested. It must indeed be admitted that the transmission of electric energy of such potential (200 volts) as is admissible in private dwellings would involve conductors of impracticable dimensions, and in order to transmit electrical energy to such distances, it is necessary to resort in the first place to an electric current of high tension. By increasing the tension from 200 to 1,200 volts the conductors may be reduced to one-sixth their area, and if we are content to lose a larger proportion of the energy obtained cheaply from a waterfall, we may effect a still greater reduction. A current of such high potential could not be introduced into houses for lighting purposes, but it could be passed through the coils of a secondary dynamo-machine, to give motion to another primary machine, producing currents of low potential to be distributed for general consumption. Or secondary batteries may be used to effect the conversion of currents of high into those of low potential, whichever means may be found the cheaper in first cost, in maintenance, and most economical of energy. It may be advisable to have several such relays of energy for great distances, the result of which would be a reduction of the size and cost of conductor at the expense of final effect, and the policy of the electrical engineer will, in such cases, have to be governed by the relative cost of the conductor, and of the power at its original source. If secondary batteries should become more permanent in their action than they are at the present time, they may be largely resorted to by consumers, to receive a charge of electrical energy during the daytime, or the small hours of the night, when the central engine would otherwise be unemployed, and the advantage of resorting to these means will depend upon
the relative first cost, and cost of working the secondary battery and the engine respectively. These questions are, however, outside the range of our present consideration.

The large aggregate of dwellings comprising the metropolis of London covers about seventy square miles, thirty of which may be taken to consist of parks, squares, and sparsely inhabited areas, which are not to be considered for our present purpose. The remaining forty square miles could be divided into say 140 districts, slightly exceeding a quarter of a square mile on the average, but containing each fully 3,000 houses, and a population similar to that of St. James's.

Assuming twenty of these districts to rank with the parish of St. James's (after deducting the 600 shops which I did not include in my estimate) as central districts, sixty to be residential districts, and sixty to be comparatively poor neighbourhoods, and estimating the illuminating power required for these three classes in the proportion of $1$ to $\frac{2}{3}$ to $\frac{1}{3}$, we should find that the total capital expenditure for supplying the metropolis with electric energy to the extent of 25 per cent. of the total lighting requirements would be—

\[
20 \times 177,000 = £3,540,000 \\
60 \times \frac{2}{3} \times 177,000 = £7,080,000 \\
60 \times \frac{1}{3} \times 177,000 = £3,540,000 \\
\hline 
\text{£14,160,000}
\]

or say £14,000,000, without including lamps and internal fittings, and making an average capital expenditure of £100,000 per district.

To extend the same system over the towns of Great Britain and Ireland would absorb a capital exceeding certainly £64,000,000, to which must be added £16,000,000 for lamps and internal fittings, making a total capital expenditure of £80,000,000. Some of us may live to see this realised, but to find such an amount of capital, and, what is more important, to find the manufacturing appliances to produce work representing this value of machinery and wire, must necessarily be the result of many years of technical development. If, therefore, we see that electric companies apply for provisional orders to supply electric energy, not only for every
town throughout the country, but also for colonies, and for foreign parts, we are forced to the conclusion that their ambition is somewhat in excess of their power of performance; and that no provisional order should be granted except conditionally on the work being executed within a reasonable time, as without such a provision the powers granted may have the effect of retarding instead of advancing electric lighting, and of providing an undue encouragement to purely speculative operations.

The extension of a district beyond the quarter of a square mile limit, would necessitate an establishment of unwieldy dimensions, and the total cost of electric conductors per unit area would be materially increased; but independently of the consideration of cost, great public inconvenience would arise in consequence of the number and dimensions of the electric conductors, which could no longer be accommodated in narrow channels placed below the kerb stones, but would necessitate the construction of costly subways—veritable *cava electrica*.

The amount of the working charges of an establishment comprising the parish of St. James's would depend on the number of working hours in the day, and on the price of fuel per ton. Assuming the 64,000 lights to incandesce for six hours a day, the price of coal to be 20s. a ton, and the consumption 2 lbs. per effective horse power per hour, the annual charge under this head, taking 8 hours' firing, would amount to about £18,300, to which would have to be added for wages, repairs, and sundries, about £6,000; for interest, with depreciation, at seven and a-half per cent., £13,300; and for general management say, £3,400; making a total annual charge of £41,000, or at the rate of 12s. 9½d. per incandescence lamp per annum. To this has to be added the cost of renewal of lamps, which may be taken at 5s. per lamp of 16 candles, lasting 1,200 hours, or to 9s. per annum, making a total of 21s. 9½d. per lamp for a year.

In comparing these results with the cost of gas lighting, we shall find that it takes 5 cubic feet of gas, in a good argand burner, to produce the same luminous effect, as one incandescence light of 16-candle power. In lighting such a burner every day, for six hours on the average, we obtain an annual gas consumption of 10,950 cubic feet, the value of which, taken at the rate of 2s. 8d. per thousand, represents an annual charge of 29s., showing
that electric light by incandescence, when carried out on a large scale, is decidedly cheaper than gas lighting at present prices, and with the ordinary gas burners.

On the other hand, the cost of establishing gas works and mains of a capacity equal to 64,000 argand burners, would involve an expenditure not exceeding £80,000 as compared with £177,000 in the case of electricity; and it is thus shown that, although it is more costly to establish a given supply of illuminating power by electricity than gas, the former has the advantage as regards current cost of production.

It would not be safe, however, for the advocates of electric lighting to rely upon these figures as representing a permanent state of things. In calculating the cost of electric light, I have only allowed for depreciation and 5 per cent. interest upon capital expenditure, whereas gas companies are in the habit of dividing large dividends, and can afford to supply gas at a cheaper rate, by taking advantage of recent improvements in manufacturing operations, and of the ever-increasing value of their by-products, including tar, coke, and ammoniacal liquor. Burners have, moreover, been recently devised by which the luminous effect for a given expenditure of gas can be nearly doubled by purely mechanical arrangements, and the brilliancy of the light can be greatly improved.

On the other hand, electric lighting also may certainly be cheapened by resorting, to a greater extent than has been assumed, to arc lighting, which, though less agreeable than the incandescence (or glow) light for domestic purposes, can be produced at less than half the cost, and deserves on that account the preference for street lighting, and for large halls, in combination with incandescence lights. Lamps by incandescence may be produced hereafter at a lower cost, and of a more enduring character.

Considering the increasing public demand for improved illumination, it is not unreasonable to expect that the introduction of the electric light to the full extent here contemplated, would go hand-in-hand with an increasing consumption of gas for illuminating and for heating purposes, and the neck-to-neck competition between the representatives of the two systems of illumination which is likely to ensue, cannot fail to improve the quality, and to cheapen the supply of both, a competition which the consuming public can
afford to watch with complacent self-satisfaction. Electricity must
win the day, as the light of luxury; but gas will, at the same
time, find an ever-increasing application for the more humble
purposes of diffusing light.

In my address to the British Association, I dwelt upon the
capabilities and prospects of gas, both as an illuminant and as a
heating agent, and I do not think that I was over sanguine in
predicting for this combustible a future exceeding all present
anticipations.

I showed that if supplied specially for the purpose, it would
become not only the most convenient, but by far the cheapest
form of fuel that can be delivered to our towns. Such a general
supply of heating separately from illuminating gas, by collecting
the two gases into separate holders during the process of distilla-
tion, would have the beneficial effects—

1st. Of giving to lighting gas a higher illuminating power.

2nd. Of relieving our towns of their most objectionable traffic,
that in coal and ashes.

3rd. Of effecting the perfect cure of that bugbear of our winter
existence—the smoke nuisance.

4th. Of largely increasing the production of those valuable by-
products, tar, coke, and ammonia, the annual value of which
already exceeds by nearly £3,000,000 that of the coal consumed
in the gas works.

The late exhibitions have been beneficial in arousing public
interest in favour of smoke abatement, and it is satisfactory to
find that many persons, without being compelled to do so, are now
introducing perfectly smokeless arrangements for their domestic
and kitchen fires.

The Society of Arts, which for more than 100 years has given
its attention to important questions regarding public health, com-
fort, and instruction would, in my opinion, be the proper body to
examine thoroughly into the question of the supply and economical
application of gas and electricity for the purposes of lighting, of
power production and of heating. They would thus pave the way
to such legislative reform as may be necessary to facilitate the
introduction of a rational system.

If I can be instrumental in engaging the interest of the society
in these important questions, especially that of smoke prevention,
I shall vacate this chair next year with the pleasing consciousness that my term of office has not been devoid of a practical result.

Sir Frederick Bramwell, F.R.S., said, it was his privilege, as late Chairman of the Council, to move a hearty vote of thanks to the present Chairman for his address. The society might be congratulated on this occasion, on having for the chairman of its council a gentleman who, of all others, had in recent years applied pure science to the purposes of industry, and had done so with the most marked success. Having regard to what the society was, and to the objects which it pursued, a gentleman in that position was the one who, if the choice were always open, would be selected for the purpose; but such persons were scarce, and very difficult to catch; and he looked upon it as one of the greatest feats of the council, over which he had had the honour to preside last year, that they had caught his successor and had placed him in that chair. Dr. Siemens, when applied to, put forward the feeble excuse that he was about to become President of the British Association, and he did not see therefore how he could be Chairman of the Society of Arts. The council replied that this was no excuse at all; on the contrary, it was the very reason why they wanted him. Then he said, as he had said that evening, that he should be pumped out by having said all he had to say at Southampton, to which he (Sir Frederick) replied that it would take not only Southampton, but a great many towns, to pump Dr. Siemens dry; and that the Society of Arts would be well content with the practical residuum after he had delivered himself of pure science. He was sure that the meeting would feel that the address that evening justified that answer, and justified the council for having insisted on Dr. Siemens becoming their chairman. His address had been confined almost exclusively to one subject—one of many of which he was a thorough master—that of electric lighting. He had touched upon a variety of topics in connection with it, but the address was mainly a practical one, relating to that which so many wanted to know—what was possible to be done, what would be the cost, and what would be the result. Everyone must have been pleased with the information given. Dr. Siemens had himself said that there were other skilled persons who entertained different views—views more favourable as regards area of districts served from one
station, and as regards the cost of electric lighting. They all knew that he was not one to set himself up as infallible, and that no one was more ready to acknowledge, if he were proved to be wrong, that someone else was in the right, and that things were better than he had thought. But even supposing Dr. Siemens were right, and that it was not possible to deal with larger areas than he had suggested, or at least cost, yet he had shown that, by an outlay of capital which appeared about two to one as compared to an equal amount of illumination by means of gas, after allowing 5 per cent, on this double capital, and depreciation on a large portion of it—which on the copper conductors and matters of that kind would be very small indeed—there could be delivered to the consumer the incandescent light, at a price of 22s. as compared with gas at 29s. All who had studied the matter would say that it would not have been an unfair comparison if Dr. Siemens had taken as his standard not gas-light, but the light of luxury which they used in their own houses. Many of them would not have gas-light in their sitting-rooms, and resorted to wax candles or lamps, or something of the kind, the cost of which was considerably in excess of what he had mentioned. He was quite certain, therefore, that there would be a large and increasing demand, on the part of persons living in well-appointed private houses, for a light free from the various objections which appertained to lighting by gas, good as that undoubtedly was, compared with anything which preceded it. However, he would not go further into details which led him away from the true subject before the meeting, which was simply to pass a vote of thanks to Dr. Siemens. He was sure all must feel it was a happy thing for the society that on this, its 128th anniversary, they had a chairman in every way competent to guide the council in the development of the objects of the society, viz., the promotion of arts, manufactures, and commerce in this country.

Lord Alfred Churchill begged leave to second most heartily the vote of thanks which had been so ably moved, and to add his testimony to what Sir Frederick Bramwell had said, as to their very fortunate position in being able to secure the services of Dr. Siemens for the current year. The admirable address he had given them, dealt principally with electric lighting; but he did not think there was anything in it which need cause those inte-
rested in gas companies any trepidation. Gas was so essential for heating and cooking purposes, that there was no fear of its falling into disuse.

The motion having been carried unanimously,

Dr. Siemens thanked the meeting very heartily for the kind manner in which the address had been received, and Sir F. Bramwell and Lord A. Churchill for the way in which they had spoken of it. He had endeavoured to trace out generally the conditions under which electricity and gas could be most advantageously distributed for practical purposes at the present time, and although he quite agreed with Sir F. Bramwell that conditions might arise which would alter to some extent the principles upon which he argued, yet there were principles of a certain class which were exceedingly stubborn, and not easily moved out of the way. You never could get more than 20s. for a pound; and if one saw statements to the effect that for a given expenditure of power more light could be produced than was theoretically represented in luminous energy, one had a right to doubt such statements. He believed the true progress of the new illuminant would be better ensured by frankly bringing to the front the limits and the cost within which certain effects could be produced, and this he had endeavoured to do. The room that evening was lighted from a machine driven by a gas engine, and this would account for any slight variation which might have been noticed in the light. Gas engines, no doubt, would have a great future, but they must be materially improved, especially in regard to uniformity of action, before they could be used for the purpose of electric lighting to the extent one would wish.
ADDRESS

Delivered at the distribution of Prizes and Certificates to the Students of the City and Guilds of London Institute, on Thursday, 14th December, 1882,

BY DR. C. WILLIAM SIEMENS, F.R.S.

Dr. Siemens* said: Ladies and gentlemen,—It may cause surprise to some of you that I rise here to address you instead of your Chairman of the Committee, who sits in the chair at my right. I believe it is his ordinary duty to perform this important office of distributing the prizes, but for some reason, which he did not fully explain to me, he required me to officiate on this occasion. I first remonstrated that if he did not wish to distribute the prizes, there were other gentlemen, more prominently connected with the City and Guilds of London Institute than I was, who ought to be asked in preference to myself. However, our Chairman of Committee is a man who likes to have his own way. We all like it, but somehow or other he gets it, and so you see me here. I may mention that I feel myself at home here, because I have the honour of being a member of the Goldsmiths' Company, and as such represent, perhaps, to some extent your hosts on this occasion. However that may be, I have been placed in this position, and am expected, I find, to make a few remarks regarding the City and Guilds Institute, its work and prospects.

From the accounts of the Council which have been read to you, you have gathered that the Institution is now in a very prosperous condition as regards the number of educational institutes employed to bring up prizemen for our examination, their number being 372. The number of students who have presented themselves is nearly 2000, of them 1222 have been found worthy of prizes or certificates, and 235 have taken prizes in honours. (Applause.) Now, the distinction that is made of prizes in honours over the ordinary kind consists in the circumstance that they afford evidence of efficiency in applied science, in addition to practical knowledge;

and it is a distinction well worthy of the attention of all students. It is not sufficient in after life to be competent to perform the routine work of a craft or calling. Unless you comprehend the scientific principles underlying that calling, you may be left high and dry any day, in consequence of an invention which may entirely change the mode of performing the operation upon which you have been engaged; but whatever you have acquired in scientific fundamental knowledge remains a useful acquisition for life, as a foundation upon which to build and advance in any new direction connected with your avocation that may turn up. Therefore, I think it is highly commendable that the Institute makes a broad distinction in favour of those who, without neglecting practical knowledge, have given careful attention also to scientific principles.

The Institute, in appointing examiners, have called into existence a number of educational establishments throughout the country. Some of them have received monetary aid from the Institute where such aid was needed; but all of them received very powerful aid in an indirect way, by the prizes that are given to the teachers of those institutes for successful candidates at these examinations. You may say that this is a sort of Chinese way of rewarding teachers. When in China a man distinguishes himself, his father receives high honours instead of himself. But whether Chinese or not, it has the excellent effect of stimulating the teacher to do his very best to bring on the young students.

In addition to the important function of the City and Guilds Institute of conducting these examinations, three large schools are now in course of formation under their immediate auspices and control. The one in this immediate neighbourhood, the Finsbury College, I had an opportunity of viewing the other day. The building is in a very advanced condition, and we are told that in a few months it will be fully occupied. I think nothing could be more striking and more complete than the arrangements for teaching Physical Science and Chemistry at that Institution. The lecture room, the laboratories, especially the large chemical laboratory, are the most perfect things that I have seen. I almost regret that I have been born too soon, that I am, instead of being at the beginning, near the end of my career, because if I carry my thoughts back to the laboratory connected with the
school where I received my instruction in physical and chemical science, one would almost think it impossible that anything could have been efficiently taught there. Now, the artizan and the apprentice of the neighbourhood may have the benefit of lectures and of a laboratory such as any scientist may be proud of, and I hope that these young men will come forward to use these great privileges freely. It is one thing to have an inkling of the laws of Nature, such as may be got by listening to popular lectures, and quite another thing to make them as it were a part of yourself, and this intimate and useful knowledge of science is best acquired in handling the apparatus and eliciting results by actual experiment. In this College there will be regular courses of lectures during the daytime, but what I look upon with particular interest are the evening classes, in which instruction will be given to any person of either sex, but which I hope will be used especially by apprentices. Young men who have not received a scientific education, to begin with, will there find the means of studying the science allied to their business, and if they will only take advantage of this opportunity, they may rise to a considerable position in their particular calling, which is, of course, the object every young man should have in view.

Another and important object of the Institute comprises the erection of a central College at South Kensington, where Science of a higher class in its applications will be taught to advanced students. I hope that this Institute will not be a mere École Centrale, such as we find in France, or a mere Polytechnische Schule, such as we find in Germany. These schools are very efficient in a certain way; but, after all, you cannot learn the business of a trade in a school. You must go into the workshop. One thing in which this Institute will be of great importance is the formation of teachers of Technical Science. These have to be exceedingly well instructed in Science generally; they have moreover to study special science as applied to particular crafts, and they have to know sufficient of the craft itself to explain the connection of that science and that craft to the young. If the Central Institute accomplishes this, a great want will be met.

To speak here freely, I must say that I missed something in going over the Finsbury Institute. Physical Science and Chemistry are extremely well represented, but Mechanical Science only indif-
ferently. The apparatus which I saw is not nearly sufficient, and the rooms for Mechanical Drawing, especially, leave much to be desired. I saw no accommodation for teaching the most important items in every education, that is, Art and Literature. I hope these branches of knowledge will not be neglected, because a man who is brought up only to understand his particular craft or business has a very limited understanding of even that particular business. He must be able to rise into other regions occasionally, in order that he may get a bird's-eye view of the matter that interests him daily, and a wider view of life and its purposes generally. I have no doubt this want will be supplied, either by the erection of an additional building, or by re-arrangements within the present one.

How much interest there is evinced throughout the country in favour of this Institute and its doings may be best gathered perhaps from the Report of the Royal Commission that was appointed to examine into Technical Education in all European countries and in America, which report is very favourable to the doings of the Institute; and it may be also gathered from the fact that last week only, the President of the Royal Society, in addressing that representative body of pure science, devoted two pages and a-half to Technical Education, with particular reference to the doings of the City and Guilds Institute. These, I think, are proofs of the interest which the highest and best in the land take in your progress; and with the eyes of all the country upon you, I doubt not that you will be all the more ready to satisfy the just expectations that are entertained.

I have already said that what I look upon with the greatest interest with reference to the City and Guilds Institute is the facility which it offers for the apprentice to acquire scientific knowledge. In this respect the Institute reminds me of the ancient Trade Guilds; and it is curious that the Guilds of London have now introduced a system by which the trades which they severally represent will be raised and ennobled in every way. (Hear, hear.) The Trades Guilds of this country were powerful bodies in the middle ages in London, Bristol, Coventry, and several other cities, but there was no connection between the Guilds of one city and those of another. The great political friction and contention that was going on in those days was perhaps necessary for settling the foundation of that superstructure of
political freedom and advancement, upon which the throne of Queen Victoria is at present safely placed; but it left the Guilds a less important part than that which they took in other countries, and especially in Germany. In Germany, the Guilds, which were established in the 11th century, endured throughout the changes of centuries till the year 1869, when they were finally abolished. I, when a boy at school, was living under the full vigour of the old Guild system at the free city of Lubeck. There, in going through the streets, you saw Carpenters’ Arms, Tailors’ Arms, Goldsmiths’ Arms and Blacksmiths’ Arms. These were lodging houses where every journeyman belonging to that trade or craft had to stop if he came into the town. In commencing his career, he had to be bound as an apprentice for three or four years, and the master, on taking an apprentice, had to enter into an engagement to teach him the art and mystery, which means the science of his trade, and also look to his moral welfare in every way. Before the young man could leave his state of apprenticeship he had to pass a certain examination; he had to produce his Gesellenstück, and if that was found satisfactory, he was pronounced a journeyman. He had then to travel for four years, from place to place, not being allowed to remain for longer than four months under any one master, but he had to go from city to city and thus pick up knowledge in the best way that could have been devised in those days. Then, after he had completed his time of travel, on coming back to his native city, he could not settle as a master to his trade until he had produced his Meisterstück. These master-pieces in the trade were frequently works of art in every sense of the word. They were, in blacksmithy, for instance, the most splendid pieces of armoury; in every trade, and in clocks above all others, great skill was displayed in their production. These were examined by the Guild Masters’ Committee, and upon approval were exposed at the Arms of the Trade for a certain time after which the journeyman was pronounced a master; he was then allowed to marry, provided he had made choice of a young woman of unimpeachable character. These rules would hardly suit the taste of the present day, but still there was a great deal of good in those old Guild practices. The result you can see, for instance, on going into the old Trade Museum of Nuremberg, where you find the skill of the blacksmith, the
weaver, and every other tradesman, represented in most exquisite pieces of work. These Guild Associations were not Trades Unions in the modern sense. They were not combinations to raise prices or regulate wages; all that was left to its natural course. But they were very antagonistic to what has been called "shoddyism." Any master who was found selling wares proved to be of a kind inferior to what they were represented to be, or who took an old article and brushed it up to make it appear new and sold it as such, was liable to be expelled from the Guild.

It would be well if a little of the supervision then in force could, in another form, be still applied. But I do not know whether we are not actually in the way of accomplishing this result. Give a young man a love of his craft or calling, and you have almost gained the victory as regards his future. A man who is really proud of his calling, who understands the principles upon which he is working, who knows that he can produce an article equal to or better than any that can be brought against him, would never stoop to produce an inferior one; he would rather stand aloof. If the method were practised of first cultivating the taste of a young man in the science that underlies his calling, and then giving him sound instruction in the application of that calling, I believe that, with good moral training to start with, he would never join a trades union with no higher aim than tenpence an hour as the ultimate object in life. Such men remind one of the ants, which seem to be moving about, carrying things to and fro, without having apparently any definite purpose in view. Perhaps if Sir John Lubbock was here, he could tell us whether those ants which brought up food or constructing material to the nest, share alike with those which merely run about like busybodies accomplishing nothing; if so, they are real trade unionists in the modern sense.

I hope that, through the dissemination of practical science, a higher spirit will take possession of the artizan; that he will work with the object of attaining higher results, instead of only discussing with his employers questions of rates of wages; where rightly interpreted, the interests of the two are absolutely identical. Another habit which I wish to see brought out through this education is that of seeing. We all have, I hope, eyes, and we imagine we see; and yet very few people, indeed, can
see properly or intelligently. If a man has seen an engine, and you ask, "What was the construction of the engine?" you may get the reply, "Oh, there was a wheel and cylinder and other working parts." "But was it a high pressure or a condensing engine? What was the governor employed? Were all the working parts strong enough to do their work, according to the best of your judgment on the subject?" You might ask such questions, but very few, after seeing the engine, would be able to give you satisfactory replies. Those who have noticed these particulars have taken a sort of visual photograph of the engine; but if they have not seen the machine with their mind's eye, they have not improved their knowledge of it, but have remained, as regards their knowledge of it, exactly where they were. It is by education only that the art of seeing with profit can be developed; and whenever it is cultivated in a person, the education of that person will proceed at a very much more rapid rate.

What we want is to instil in the young man a love of his art or calling, to amount, if possible, to enthusiasm. Enthusiasm is akin to genius, which has been defined "as the power to bestow infinite pains upon details." Now, I don't mean to say that every one of you, by giving this attention to detail could become a Watt, a Stephenson or a Brunel; there is something more than that required to produce such a result; it would indeed be unfortunate if you were all to become men of that high stamp, for in that case there would be nobody remaining to do the ordinary work of life. But I do say that we may all step in that direction, and that there is not one young person in this room who has not got it in his power to gain for himself a respectable and an honourable position in his particular calling.

Those are the remarks which I wish to address to our young friends who have received such fine encouragement in the form of prizes and testimonials, and I hope that encouragement will serve to increase their ardour in order to gain additional prizes during the time of their schooling, and more substantial ones to follow, as a matter of course, in after life. (Applause.)
THE ELECTRICAL TRANSMISSION AND STORAGE OF POWER.

A Lecture delivered on the 15th March, 1883, being one of the series of lectures delivered at the Institution of Civil Engineers, Session 1882–3,

BY C. WILLIAM SIEMENS, F.R.S., M. Inst. C.E.

MR. PRESIDENT, Colleagues, and Gentlemen,—If I interpret rightly the intention of your Council, it was not that these lectures should be what may be called popular lectures, or appeals to mere amateurs interested in the subject; nor do I understand that it was their intention that they should be strictly scientific lectures, such as would deal with ultimate laws, and formulæ, or such other information as might be found in text-books; but I presume the intention was that those members of your body who have given thought and study, and also attained experience in particular branches of engineering, should communicate their knowledge to their colleagues, having regard particularly to the younger members of the profession.

The general subject that has been selected for the present session is Electricity—the most subtle of the forces of nature which it is the business of the Civil Engineer, according to the terms of our Charter, to direct. The two lectures preceding this have been devoted to the action of electricity when it is a swift agent, carrying our thoughts to distances only limited by geographical bounds. The first lecture, by Mr. Preece, dealt with telegraphy; the second, by Sir Frederick Bramwell, was upon that branch of telegraphy (for so I must call it)—telephony, which accomplishes the wonderful feat of communicating speech to reasonable distances. In both cases the receiving instrument is of the most delicate nature that the ingenuity of engineers has been able to contrive for recording the small efforts of energy flowing through the wire. The task that has been assigned to me is to introduce electricity to you, still as a precise and swift agent, but as one that can moreover accomplish quantitative effects, rivalling those produced by
our steam-engines, by our hydraulic accumulators, and by compressed air. It is with reference to electricity in this form that I propose to put certain experiments and explanations before you.

Electricity, as you know, is the youngest form of energy with which we are practically acquainted. Although the only available source of that energy was until lately the galvanic battery, attempts were made from the days of Volta, at the beginning of the present century, to apply that force for the obtaining and transmitting of power. A very little consideration will convince us that all those efforts must necessarily have been futile. A pound of zinc is produced by the combustion of from 15 to 20 pounds of coal, and while a pound of coal in burning gives out 12,000 heat-units, a pound of zinc in burning gives only 2,340. Thus zinc gives in burning only one-fifth of the effect in energy that coal does, and taking the cost of zinc at 50 times that of coal, it follows that the cost of energy, in the case of a galvanic battery, is, roughly speaking, 250 times greater than in a steam-boiler. Thus handicapped, it was not likely that electricity could be made available for producing powerful effects, although the attempts that were made—in ignorance of the laws of nature governing the force of electricity—were numerous.

Before entering upon the most essential part of my subject, I must mention an invention or discovery of Seebeck in 1822—that of the thermo-battery. I have here a thermo-battery in which the heating agent is gas, which we will have lighted, and you will see that from it proceeds a current, exceedingly weak, yet a current which owes its origin entirely to heat; and by it we can effect transmutation, so to speak, of heat energy into electrical energy, without any intermediate mechanism or contrivance. If alternate strips of metal, of different positions in the thermo-electrical scale, such as bismuth and antimony, are joined at the ends into couples, and one point of juncture is heated, while the next is kept cool, a current is set up, flowing from the hot to the cold juncture, and the moving power of the current thus produced is proportionate to the difference of temperature between the hot juncture and the cold, and to the relative positions of the two metals in the thermo-electric scale. If this transformation could be effected without loss, we might hope that the thermo-battery would be the ultimate and most perfect solution of the problem of
developing electric energy out of heat. Sir William Armstrong, in his inaugural address at York in 1881, as President of the Mechanical Section of the British Association, drew particular attention to the thermo-battery, as one of the most hopeful sources of ultimate electrical effect, and physical experimentalists should never lose sight of this interesting problem. Yet the thermo-battery has one drawback, in common with the steam-engine or any thermo-motor—that is, it is dependent, not only on the first law of thermo-dynamics, according to which heat is changed entirely into its equivalent of electricity, but also on the second law, which says that whenever such conversion of heat takes place, a certain amount of heat must descend from a point of high-potential to a point of low-potential. It is thus that our best steam-engines give in mechanical force only about one-seventh of the theoretical equivalent of the heat-energy; and it is owing to this second law of thermo-dynamics that there must be necessarily a loss of heat, by conduction in the metal strips themselves, which conducted heat must be abstracted at the cooled extremities all round, in order to keep up the extremes of temperature upon which the action of the thermo-battery depends. We will now see whether we can produce a visible effect by the current on the electro-dynamometer, an instrument the nature of which I shall have occasion to describe hereafter. The action is not great, but you see that there is a very decided deflection to this side of about 5 degrees. The battery has not been on long, or it would probably amount to 10 degrees. From measurements which I have only lately made at leisure, I find that it would require one thousand eight hundred single pairs of these strips to produce a potential sufficient to work an incandescent electric light, showing how very slight the current really is.

I now approach a subject in our lecture which is of the greatest importance. I have here the original magnet, and the original coil, which Faraday used in the year 1831—fifty-two years ago—to develop the first induction spark. In 1826, or 1827, he had already conceived the idea that when an armature was removed forcibly from a permanent magnet, the expenditure of force should give rise to a current in the wire surrounding the armature; but it took him three or four years to develop the idea. When Faraday saw the spark, and was able to show it to the members of the
Royal Institution, it was a red-letter day in his existence, and he even then thought that it would be a point of departure of some importance, because he said on that occasion: "Although this spark is very small, so that you can hardly perceive it, others will follow who will make this power available for very important purposes." Now that the light is lowered, I will draw your attention to the point of the wire touching this little disk or pan, and you will distinctly observe the spark when I break the connection. This magnet is the very steel magnet which Faraday used, and at that time it was quite a giant amongst magnets.

Faraday next turned his attention to magneto-electricity, and to what was called by him the magnetic field. I have here a horse-shoe electro-magnet, with its two stems surrounded by coils of wire. If a current is passed through the coils, these extensions become magnetic poles, and if I lay a piece of cardboard upon them, and spread over it some iron filings, you will observe that, under the influence of the electric current, they distribute themselves in a very peculiar way. Most of the iron filings you see have massed upon two spots, exactly corresponding to the two poles; and all round these spots, lines which are called the lines of magnetic force are shown by the iron filings. It is, of course, difficult, in an experiment of this sort, to show the action as completely as one can in a laboratory; I have accordingly brought some photographed cards, which are certainly very instructive. In these the result of the attraction of the poles, the outflowing lines, as it were, of force from the magnet running in all directions, are well depicted. In the one that has been reproduced, in Fig. 1, Plate 8, the two half-circles, intensely white, are the magnetic fields of a dynamo-machine such as you see before you, and the diagram enables us to trace the intensity and direction of the magnetic action in every part of the machine.

Now if a wire forming a closed circuit was taken across these lines of force, although passing only through air (indeed it might be passing through a vacuum), it would encounter resistance due to the magnetism, and this resistance manifests itself as a current of electricity passing through the wire. I shall endeavour to make the experiment in such a way as to render this action visible to you. I have here my magnetic field, that is to say, two polar surfaces opposed to one another, and a framework wound six
times round and round with wire; a single wind would do, but by winding six times I repeat the action which would take place upon the one wire sixfold, and this action I expect will be manifested upon a galvanometer-needle with which this frame is connected. I can move the frame about away from the magnetic field and no action is produced on the needle, but when I move the wires into the magnetic field, there is an action in one direction, and when I move it out again there is an action in the contrary direction. The current produced in this wire is exactly proportionate to the amount of force which I exerted, and this again is proportionate to the rapidity of the motion and to the intensity of the magnetic field. If the two poles are set very close together, and if the current exciting the electro-magnet is great, the current produced in the induction wires will be great also. Again, if I move the wires through the magnetic field with great velocity I encounter greater resistance, and I shall obtain a still greater result. In fine the mechanical power expended in passing the wires through the magnetic field, is converted at once into electric power or current.

When the magneto-current had been scientifically proved, it was soon taken advantage of in the construction of the machines of Pixii, of Holmes, and of the Alliance Company, which latter machines were made successful at a very early date in lighting some of the coasts of France, and also of this country. Steel magnets were employed, between the poles of which armatures furnished with coils of insulated wire were made to rotate, when by the inductive action thus produced, alternating currents were set up in the coils, and conveyed to the electric lamp without being changed into a continuous current by means of a commutator.

The next advance upon Faraday's original conception was an armature by which the inductive action can be multiplied considerably. In the Faraday instrument the armature was separated from the magnet by lifting it away from it. In this, which is generally known as the (Werner) Siemens armature, the coil is put upon an H piece of iron, and made to rotate in a magnetic field. There are in the magneto-machine placed on the table steel magnets superposed one above the other, and between the poles of these magnets such an armature is made to rotate with considerable velocity. You will easily perceive that each time the
iron head of the armature is separated from the line of poles of the permanent magnets, i.e., each time it makes a half-revolution, there is a severance due to each of these magnets. Therefore if there are eight bars, we have on the one side of the electro-magnet the joint effect of eight severances, and on the other side a similar amount of effect. So that for each half-revolution we get the result of sixteen such sparks as that shown in Faraday's experiment, and if this can be repeated at a very rapid rate we may get sixteen sparks perhaps ten times in a second. We will now connect the current, not with the dynamometer, because it would not be so suitable, but with one of these instruments which are generally used for exploding mines, and I will, with your permission, explode a mine. Instead of one we might have ten or twelve mine-exploders in a series. You observe a very powerful instantaneous current resulting from the action of the machine.

A further step in the development of magneto-machines was furnished by Mr. Wilde of Manchester, by substituting for the steel magnets electro-magnets excited by the current from a separate magneto-machine furnished with the Siemens armature. By this arrangement Mr. Wilde was able to realise much more powerful effects than could have been obtained previously.

Another form in which the Faraday or induced current manifests itself is in an induction coil, and this also represents an essential action which we should realise before going any further. In an induction coil one spiral of insulated wire is put within another, both upon an iron centre. When a bar of iron is surrounded, as in this instance, with wire, through which a current is passed, the bar becomes a magnet; and if outside the wire of the primary coil, as it is called, fine wire is wound, a current is induced in the secondary coil which is of high potential, or tension, according to the number of turns which the wire makes round and round the bar; therefore if a current of very high potential is wanted, very thin wire has to be taken and coiled round a great number of times, whereas if a current of larger quantity and small potential is required, a thicker wire has to be used, having only a small number of turns. If I were to take a thick wire and make the same number of turns, the outer convolutions would be too far away from the magnet to produce energetic action; I am therefore limited by the space at my disposal round this bar of iron in
the amount of effect either in quantity or in potential which I can command. I will now ask Mr. Nebel to connect this wire, and you will see that we have here between these points such a potential that a spark similar to a lightning discharge takes place across the gap, about an inch long, between them. This represents, electrically speaking, a very high potential — probably 80,000 volts.

The machines which we have so far considered depend for their action upon the severance of an armature from a permanent magnet. In the year 1865 another principle of action saw the light of day. It was first communicated by my brother, Werner Siemens, to the Berlin Academy; it was also communicated by myself to the Royal Society three weeks later, and when my Paper was read Professor Wheatstone brought the same idea forward. The principle consists in this, that when the current produced by the severance of an armature surrounded by conducting wire from the poles of an electro-magnet, is sent through the coils of the very magnet that produces the magnetism, a kind of regenerator action is set up. There must be a magnetic field to commence the action, and in our first experiments, this initial amount of magnetism was produced by means of a small battery connected with a separate coil on the electro-magnets; we soon found, however, that no such initial excitement was necessary, but that terrestrial magnetism sufficed to induce in the bars of the electro-magnets a magnetic action sufficient to cause a slight current in the coils of the rotary armature, which, in passing through the coils of the field magnets, increased their magnetic tendency; the result was an increased inductive action, and an increased induced current; this again, in passing through the coils of the field magnets, further increased the magnetic intensity, giving rise to increased inductive action, and to a current of increased intensity. The accumulative action thus set up is limited, however, by the point of magnetic saturation of which a bar of iron is capable. Up to that point the resistance of the rotary armature rapidly increases, thus causing a direct conversion of mechanical into electrical energy. This is the principle upon which dynamo-machines are now generally conceived, and it gives us a power of increase which Faraday foresaw in his original experiment, when he said that the time would come when the primary effect
which he showed would be multiplied indefinitely. The machine which I placed before the Royal Society in the year 1865 is now before you; it has done a great deal of useful work since, having been employed at the Telegraph Works at Woolwich to magnetise steel bars to make them permanent magnets; we will set it at work. The machine is now being worked by a current, for the dynamo-machine can serve either as a power-giving machine, or as a power-receiving machine. If you pass a current through these coils, you transform electric into mechanical energy; if, on the other hand, you turn the armature forcibly round at the same speed as before, you produce nearly the same current which was originally taken in driving it.

At the time the dynamo principle was first announced, great interest was expressed in its behalf by my friend, the late Professor Clerk Maxwell, who saw in the mutual convertibility, by the same piece of mechanism, of mechanical into electrical effect, and vice versa, a great practical proof of the correlation of physical forces. The phrase, attributed to him in popular essays, viz., that one of the greatest discoveries of the present century was the reversibility of the Gramme machine, must however be received with great reserve, considering that the particular machine with which the name of Gramme is associated was not brought out until five years after the dynamo-electric principle of action had been established.

It is a remarkable feature connected with dynamo-electricity that the second law of thermo-dynamics is not involved. Theoretically speaking, a certain amount of mechanical force can be converted entirely into electrical force; and electrical force theoretically speaking can be so converted into dynamical force. Practically speaking, of course, that is not so. There are necessarily losses, and one of these, which is self-evident, is that the current passing through the coils must produce resistance, and electrical resistance, wherever it appears, converts electric energy into heat energy. Again, the iron bars which are magnetised and demagnetised at every half-revolution set up currents in themselves, for it is natural that instead of the current flowing only through the convolutions of the wire, the iron itself being a metal, some current will be set up in it, and this current so set up produces the effect of heating the iron; it simply circulates round
and round, forming as it were electrical eddies which must be productive of heat.

These losses, however, can be diminished almost indefinitely by increasing the size and conductivity of the wires, and as regards the iron, a form of armature has been devised, which is best illustrated in the machine before us—the Gramme machine—the original conception of which is due to Dr. Pacinotti in 1861. This consists in putting the iron, in the form of wire coiled round and round a non-conducting body, which is surrounded in its turn by the insulated copper wire forming the coils of the rotating armature. The iron wires being surrounded by a non-conducting material, electric eddies cannot circulate in the direction in which they would occur, viz., transversely to that of the wires, whereas the magnetic-poles induced by the field-magnets are free to advance within the iron wires at the rate of the rotative motion imparted to them.

We have here another armature which is not entirely according to Pacinotti's idea, but involves it—an armature such as is now largely used in dynamo-machines. On a wooden bobbin are wound coils of insulated wire in a direction parallel to its longitudinal axis, according to a plan due to Von Heftner Alteneck. Each coil of wire thus wound is brought successively into metallic connection with one of these laminae, through which the current produced within the coil in passing through the magnetic field is conveyed by the commutator and its contact brushes, into the wire constituting the outer circuit, and the coils of the field magnets. A succession of currents is thus set up, all flowing in the same direction and constituting in their aggregate a continuous flow. The chief advantage claimed for this arrangement is that the whole of the wire upon the armature, except where it crosses from side to side at the end, is effective; whereas in the Pacinotti ring the copper returns on the inside of the iron ring, so that only one half of its length receives inductive effect in passing through the magnetic field.

Professor Wheatstone in his Paper mentioned a very significant fact. He said: "If I make a cross-connection between the circuit passing round the armature and the field, I get a momentary very powerful effect." This cross-connection really severs the current into two parallel circuits, one portion passing at once
out to the electric light or to the place where the electric effect is
to be produced, and the other flowing round the bar-magnets and
back again to the machine. If this arrangement is applied to a
machine wound for a continuous circuit, it will not produce any
useful result, but if it is modified—that is to say, if, as I showed
in a Paper before the Royal Society in 1880, the resistance of the
wire on the field-magnets is increased a hundred-fold, then we get
a machine capable of very sustained action, and this form of shunt
dynamo machine, as it is called, has been since largely adopted in
the production of electric light. The greatest uniformity of
current is produced, however, in combining the shunt with the
old method of winding the field-magnets by furnishing them with
two separate coils, the one of low resistance forming part of the
outer circuit, and the other of high resistance consisting of thin
wire forming a shunt circuit.

There is another form of dynamo machine which differs essen-
tially from those I have as yet described, viz., the alternate
current machine. This differs from Holmes’s type, chiefly in the
substitution of electro-magnets for permanent magnets, although
De Meritens in his ingenious modification of Holmes’s machine
continues to give the preference to permanent magnets. The
modification adopted by my firm consists in substituting mere
coils of wire for the armatures, rotating through the magnetic
fields produced by electro-magnets which are excited by means of
a dynamo machine of the original type. The principal advantages
obtained in suppressing the iron armatures, are, that less weight
has to be put into rapid motion, and that less energy is converted
into heat by eddies set up within the iron. This machine repre-
sents in fact a return to Faraday’s original demonstration of the
current set up in a conductor passed through a magnetic field,
and it is interesting to observe by inspection of the Table on
page 401, that these machines give the highest yield of electrical
energy for a given expenditure of mechanical power. This Table
contains a considerable amount of practically useful information.
The machines marked D in the first column are of the self-
exciting type first described; those marked S D (S meaning
shunt) are wound in the manner of a parallel circuit as next
described, and those marked W are the alternating current
machines to which I have just referred. The second column gives
the number of incandescent lights which each machine will sustain. That is perhaps of little importance to our present enquiry; but in another column, to which I would draw particular attention, you have the relative effect per lb. of copper wire in the different machines, and the enormous difference in the values shows sufficiently what scope there is for the development of the dynamo machine. For instance, in one machine, 1 lb. of copper produces only 17 watts, or units of electric energy; and in another—the last which has been produced—the effect is 48.

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Table of Particulars of Dynamo and Alternate Current Machines.

<table>
<thead>
<tr>
<th>Type of Machine</th>
<th>Number of Incandescent Lights and 1 1/4 Ampères</th>
<th>Number of Watts</th>
<th>Total Number of Watts Developed</th>
<th>Percentage of Total Watts Electrical in Outer Circuit</th>
<th>Total Weight of Copper Wire on Machine in lbs.</th>
<th>Number of Watts in Outer Circuit per lb. of Copper Wire in Machine</th>
<th>Approximate Circumferential Speed of Helix in Feet.</th>
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<tbody>
<tr>
<td>S D 5</td>
<td>12</td>
<td>120</td>
<td>248</td>
<td>796</td>
<td>1,164</td>
<td>68:0</td>
<td>43</td>
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<td>S D 7</td>
<td>25 x 2</td>
<td>305</td>
<td>370</td>
<td>3,316</td>
<td>3,994</td>
<td>83:0</td>
<td>113</td>
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<tr>
<td>S D 2</td>
<td>40</td>
<td>326</td>
<td>326</td>
<td>3,980</td>
<td>4,835</td>
<td>82:0</td>
<td>141</td>
</tr>
<tr>
<td>S D 1</td>
<td>60</td>
<td>526</td>
<td>526</td>
<td>3,980</td>
<td>4,832</td>
<td>82:0</td>
<td>262</td>
</tr>
<tr>
<td>S D 1</td>
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<td>11,764</td>
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<td>582</td>
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<td>D S D'D'00</td>
<td>150 x 2</td>
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<td>2,562</td>
<td>19,890</td>
<td>24,532</td>
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<td>857</td>
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<td>2,666</td>
<td>26,532</td>
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<td>81:7</td>
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<td>...</td>
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<td>88:0</td>
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<tr>
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<td>...</td>
<td>177</td>
<td>206</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
[At this point the lecturer was interrupted by a violent report, resulting in the breakage of some glass in the dome of the theatre, which, fortunately, fell outwards, only slight fragments descending into the body of the hall. Windows towards the back of the building were broken, but the Secretary having at once taken steps, and ascertained that the explosion had occurred outside, the lecturer immediately resumed; and it was only after the lecture that it was known that the real cause of the report heard was the explosion of dynamite below the offices of the Local Government Board.]

The effect of variation of the resistance of a dynamo-machine is given in Fig. 2, Plate 9. The dash and dot line represents the electro-motive force in volts, the complete thin line the horse-power which the machine absorbs, and the dotted line the power developed in the outer circuit, the complete thick line gives the current in the outer circuit in Ampères. You will observe that in proportion as the resistance of the machines increases, both the power expended and power developed diminish, the loss being the difference between these lines. The effect is the height up to the dotted lines, and it at once becomes evident that the best result is obtained with not quite 1 Ohm resistance. Fig. 3, Plate 9, shows how a dynamo in series differs from a dynamo in shunt. In an ordinary dynamo, the effect increases rapidly with increase of velocity. If the machine were set to work, say with incandescent lights, it will be seen that it would at a low speed give very poor results; but when a certain speed had been obtained, it would be more constant; by the shunt winding, you find, on the contrary, a diminution of effect with increase of speed; whereas in a third (the composite, before described) mode of winding, we can obtain the greatest constancy of effect.

I shall now show you some of the effects that can be produced in transmitting power. In a yard adjoining this Institution a portable steam engine has been erected giving motion to a D 2 dynamo-machine, capable of developing about 8 HP. of electrical energy, or $746 \times 8 = 5968$ Watts. This power is conveyed through an insulated wire to the coils of a D 7 dynamo-machine, the rotating axis of which is practically in one piece with that of a centrifugal pump, by means of which water can be raised in considerable quantities, and when forced through a nozzle may be
lifted 60 feet high. The mechanical effect thus realised amounts to $3\frac{3}{4}$ HP., deduction being made for frictional losses of every kind, and the experiment is interesting as showing a practical application of electric energy to useful purposes. Considering that the weight of the machine is only $3\frac{3}{4}$ cwt., and of the pump about the same (the total being at any rate within half a ton), and that the power could be easily augmented to 5 or 6 HP., I think we may look forward to the time when our fire engines will be worked on this principle.

The Electric Storage Company have been kind enough to send me some of their batteries, and I shall turn their current upon this machine in order to produce the same results as shown before. In this instance the effect, originally produced by the steam-engine, has given motion to a dynamo-machine, the electricity from which has been transferred to the secondary battery, where it has produced chemical action such as I shall presently describe. The store of chemical effect thus produced within the battery is now made available in forming a current, which, passing through the dynamo-machine connected with the pump, imparts motion to the latter. I will now connect the current with a second dynamo-machine to work a saw bench, giving motion at the same time to another dynamo-machine, wound with comparatively thick wire in order to set up a current of very low electrical potential. The potential of the dynamo-machine outside the building is equal to 100 volts, but it is inconvenient sometimes to use a current of such high tension, and my object in transferring the power derived from a machine of high potential to another dynamo-machine wound with thick wire is to obtain a current of low potential, which in this instance does not exceed 10 volts. Such a current could not harm a child, but is most effective where quantity rather than high potential is required, as for instance, for electrolytic purposes. This is what may be called a tertiary machine, and you will observe that it has more effect than either the primary or secondary in heating an iron wire of considerable thickness (\textfrac{1}{4}th of an inch thick), it being what is called a quantitative current. We will now connect the current with a little toy railway, and you will see the result. I may call this a quaternary transmission of force. The steam-engine transferred its energy to a dynamo-machine; this dynamo-machine gave motion
to a second, that to a third dynamo-machine, and this again has given motion to the carriage upon the rails, which latter perform the function of conducting wires. The same power has thus been four times transmitted, showing the great facility with which we can reconvert it again and again from mechanical into electrical, and from electrical into mechanical, effect; and alter its character from a current of high potential to a current of low potential, or vice versa.

I will now allude to an application of electricity lately made by Dr. John Hopkinson, which appears to me to be full of promise. Mr. Nebel will set it to work. It is an electrical hoist. Imagine this to be at the top of a warehouse, and the chain ten times as long as it could be made in this instance, and you will observe that by putting on the current of this dynamo-machine, the weight (which might be much heavier), will be lifted readily, and may be stopped and lowered at will according to the position of the brushes upon the dynamo-commutator.

Another application which has been made with great effect, is that of raising the wire which is used in sounding by Sir William Thomson's wire sounder. On board the "Faraday," the machine has been employed, and the wire is drawn up in an extraordinarily short space of time. We find that by these means we can make a sounding in 2500 fathoms in an hour, because we can go on with the steamer while the electric machine is pulling in the wire. The only drawback which was found in the early trials was that, the machine having been placed near the compasses, the latter were influenced magnetically: the caution, therefore, to be observed, is to put it in a part of the ship away from the compasses.

When losses by unnecessary wire-resistance, by Foucault currents and by induced currents in the rotating armature, are avoided, as much as 90 per cent., or even more, of the power communicated to the machine is realised in the form of electric energy, and vice versa the reconversion of electric into mechanical energy can be accomplished with similarly small loss. Thus, by means of two machines at a moderate distance apart, nearly 80 per cent. of the power imparted to the one machine can be again yielded as mechanical energy by the second, if we leave out of consideration frictional losses, which latter need not be great, considering that a
The dynamo-machine has only one moving part well balanced, and is acted upon along its entire circumference by propelling force. Jacobi proved, many years ago, that the maximum efficiency of a magneto-electric engine was obtained when \( \frac{e}{E} = \frac{w}{W} = \frac{1}{2} \) which law has been construed, by Verdet (Théorie Mécanique de la Chaleur) and others, to mean that one-half is the maximum theoretical efficiency obtainable in electric transmission of power, and that one-half of the current must be necessarily wasted or turned into heat. I could never be reconciled to a law necessitating such a waste of energy, and have maintained, without disputing the accuracy of Jacobi's law, that it has reference really to the condition of maximum work accomplished with a given machine, whereas its efficiency must be governed by the equation

\[ \frac{e}{E} = \frac{w}{W} = \text{nearly } 1. \]

From this it follows that the maximum yield is obtained when two dynamo-machines (of similar construction) rotate nearly at the same speed, but under these conditions the amount of force transmitted is a minimum. Practically the best condition of working consists in giving to the primary machine such proportions as to produce a current of the same magnitude, but of 50 per cent. greater electromotive force than the secondary; by adopting such an arrangement, as much as 50 per cent. of the power imparted to the primary could be practically received from the secondary machine at a distance of several miles. Professor Silvanus Thompson, in his recent Cantor Lectures, has shown an ingenious graphical method of proving these important fundamental laws.

The possibility of transmitting power electrically is so obvious that suggestions to that effect have been frequently made since the days of Volta, by Ritchie, Jacobi, Henry, Page, Hjorth and others; but it is only in recent years that such transmission has been rendered practically feasible.

Just six years ago, when delivering my presidential address to the Iron and Steel Institute, I ventured to suggest that "time will probably reveal to us effectual means of carrying power to great distances, but I cannot refrain from alluding to one which is, in my opinion, worthy of consideration, namely, the electrical conductor. Suppose water-power to be employed to give motion
to a dynamo-electrical machine, a very powerful electrical current will be the result, which may be carried to a great distance, through a large metallic conductor, and then be made to impart motion to electro-magnetic engines, to ignite the carbon points of electric lamps, or to effect the separation of metals from their combinations. A copper rod 3 inches in diameter would be capable of transmitting 1,000 HP a distance of say 30 miles, an amount sufficient to supply one quarter of a million candle-power, which would suffice to illuminate a moderately-sized town." This suggestion was much criticised at the time, when it was still thought that electricity was incapable of being massed so as to deal with many horse-power of effect, and the size of conductor I proposed was also considered wholly inadequate. It will be interesting to test this early calculation by recent experience. Mr. Marcel Deprez has, it is well known, lately succeeded in transmitting as much as 3 HP to distances up to 40 kilometers (25 miles) through a pair of ordinary telegraph wires of 4 millimetres diameter. The results so obtained were carefully noted by Mr. Tresca, and were communicated a fortnight ago to the French Academy of Sciences. Taking the relative conductivity of the iron wire employed by Deprez, and the 3-inch rod proposed by myself, the amount of power that could be transmitted through the latter would be about 4,000 HP. But Deprez employed a motor-dynamo of 2,000 Volts, and was contented with a yield of 32 per cent. only of the power imparted to the primary machine, whereas I calculated at the time upon an electromotive force of 200 Volts, and upon a return of at least 40 per cent. of the energy imparted. Sir William Thomson at once accepted these suggestions, and with the conceptive ingenuity peculiar to himself, went far beyond me, in showing before the Parliamentary Electric Light Committee of 1879, that through a copper wire of only \( \frac{1}{2} \) inch diameter, 21,000 HP might be conveyed to a distance of 300 miles with a current of an intensity of 80,000 Volts. The time may come when such a current can be dealt with, having a striking distance of about 12 foot in air, but then, probably, a very practical law enunciated by Sir William Thomson would be infringed. This is to the effect that electricity is conveyed at the cheapest rate through a conductor, the cost of which is such that the annual interest upon the money expended equals the annual
expenditure for lost effect in the conductor in producing the power to be conveyed. It does not appear that Mr. Deprez has considered the effect of this economic law upon his recent experiments.

Sir William Armstrong, in the year 1878, was probably first to take practical advantage of these suggestions in lighting his house at Cragside during night-time, and working his lathe and saw-bench during the day, by power transmitted through a wire from a waterfall nearly a mile distant from his mansion. I have also for some years accomplished the several objects of pumping water, cutting wood, hay, and swedes, of lighting my house, and of carrying on experiments in electro-horticulture from a common centre of steam-power. The results have been most satisfactory; the whole of the management has been in the hands of a gardener and of labourers, who were without previous knowledge of electricity, and the only repairs that have been found necessary were one renewal of the commutators and an occasional change of metallic contact brushes.

Amongst the numerous other applications of the electrical transmission of power, that to electrical railways, first exhibited by Dr. Werner Siemens at the Berlin Exhibition of 1879, has attracted more than ordinary public attention. In it the current produced by a dynamo-machine, fixed at a convenient station and driven by a steam-engine or other motor, was conveyed to a dynamo placed upon the moving car, through a central rail supported upon insulating blocks of wood, the two working-rails serving to convey the return current. The line was 900 yards long, of 2-feet-gauge, and the moving car served its purpose of carrying twenty visitors through the Exhibition each trip. The success of this experiment soon led to the laying of the Lichterfelde line, in which both rails were placed upon insulating sleepers, so that the one served for the conveyance of the current from the power station to the moving car, and the other for completing the return circuit. This line has a gauge of 3 feet 3 inches, is 2,500 yards in length, and is worked by two dynamo-machines, developing an aggregate current of 9,000 Watts, equal to 12 HP. It has now been in constant operation since the 16th of May, 1881, and has never failed in accomplishing its daily traffic. A line $\frac{1}{2}$ a kilometer in length, but of 4 feet 8$\frac{1}{2}$ inches gauge, was established at Paris in
connection with the Electric Exhibition of 1881. In this case, two suspended conductors in the form of hollow tubes with a longitudinal slit were adopted, the contact being made by metallic bolts drawn through these slit tubes, and connected with the dynamo-machine on the moving car by copper ropes passing through the roof. On this line 95,000 passengers were conveyed within the short period of seven weeks. The Administration charged 25 centimes (2½d.), for the conveyance from end to end of the railway, and the amount was sufficient to pay all expenses. That, therefore, was a case of an electric railway that did pay.

An electric tramway, 6 miles in length, is nearly completed, connecting Port Rush with Bush Mills, in the North of Ireland, in the installation of which I have been aided by Mr. Traill, as engineer of the Company, and by Mr. Alexander Siemens, and Dr. E. Hopkinson, representing my firm. In this instance the two rails, 3 feet apart, are not insulated from the ground, but being joined electrically by means of copper staples they form the return circuit, the current being conveyed to the car through a T-iron placed upon short standards, and insulated by means of insulite caps, as shown in Plate 10. Where a gap necessarily occurs, such as at a cross road, we simply stop the T-iron, and commence it again at the other side of the gap, connecting the two ends by means of an insulated conductor below ground. In order to span this gap we have two brushes attached to the car, one in front and the other towards the back of the car, and the gap being a little less than the distance between the two brushes, the one brush catches the opposite side before the other one leaves. Thus by a simple arrangement we get over the difficulty of crossing bye-roads. For the present the power is produced by a steam-engine at Portrush, giving motion to a shunt-wound dynamo of 15,000 Watts = 20 HP., but arrangements are in progress to utilize a waterfall of ample power near Bush Mills, by means of three turbines of 40 HP. each, now in course of erection. The working-speed of this line is restricted by the Board of Trade to 10 miles an hour, which is readily obtained. With regard to this line, Dr. Edward Hopkinson, who is there, superintending the electrical arrangements, writes to-day, "There is now no difficulty in starting the loaded car on the worst part of the hill, which a steam-engine frequently fails to do." This requires some expla-
nation. You will observe in the plan and sections of the railway given in Plate 11, that there is a long and rather steep incline —1 in 38—two miles in length. There was some doubt in my mind whether, with the arrangements adopted, this incline could be worked satisfactorily; it now appears that it has been, and that the car is drawn up the incline without difficulty when fully loaded. I may, therefore, say that transmission or propulsion by electricity, even under adverse circumstances, is an accomplished fact. A further six miles of extension to Dervock will connect this railway with the railway system of the north of Ireland; we shall then have a length of twelve miles of line of the same gauge, and using the same carriages as those generally used there. Under these circumstances, it seems to me almost a pity that on the Embankment there should be made that series of unsightly and noisome ventilators to disembarrass the underground railway of steam and products of combustion, when it can be clearly demonstrated that electric propulsion would, for the underground railway, not only be the most agreeable, but also the cheapest mode of traction. I shall, at any rate, be most happy to afford to engineers every opportunity of studying this question.

The advantages of electrical propulsion are that the weight of the engine, so destructive of power and of the plant itself in starting and stopping, will be saved, and that perfect immunity from products of combustion will be ensured. The limited experience at Lichterfelde, at Paris, and with another electric line of 765 yards in length, and 2 feet 2 inches gauge, worked in connection with the Zaukerode Colliery since October, 1882, are extremely favourable to this mode of propulsion. I, however, do not advocate its prospective application in competition with the locomotive engine for main lines of railway.

For tramways within populous districts the insulated conductor involves a serious difficulty. It will be more advantageous under these circumstances to resort to secondary batteries, forming a store of electrical energy carried under the seats of the car itself, and working a dynamo-machine connected with the moving wheels.

The secondary battery, to which I have already alluded in this lecture, is not an entirely new conception. The hydrogen gas battery suggested by Sir William Grove in 1841, realised in the
most perfect manner the conception of storage, only that the power obtained from it was exceedingly slight. In working upon Sir William Grove's idea, twenty-five years ago I constructed a battery of considerable power in substituting porous carbon for platinum, impregnating the same with a precipitate of lead peroxidized by a charging current. At that time little practical importance attached however to the subject, and even when Planté, in 1860, produced his secondary battery, composed of lead plates peroxidized by a charging current, little more than scientific curiosity was excited. It is only since the dynamo-machine has become an accomplished fact, that the importance of this mode of storing energy has become of practical importance, and great credit is due to Faure, to Sellon, and to Volckmar, for putting this valuable addition to practical science into available forms. A question of great interest in connection with the secondary battery has reference to its permanence. A fear has been expressed by many that local action would soon destroy the fabric of which it was composed, and that the active surfaces would become coated with sulphate of lead preventing further action. It has, however, lately been proved in a paper read by Dr. Franklin before the Royal Society, corroborated by simultaneous investigations by Dr. Gladstone and Mr. Tribe, that the action of the secondary battery depends essentially upon the alternative composition and decomposition of sulphate of lead, which is therefore not an enemy of, but the best friend to, its continued action. The action of the battery depends simply upon the decomposition of the coating of sulphate of lead, so that, commencing with sulphate of lead on both surfaces, this is on the one hand changed into metallic lead, and on the other hand into peroxide; by the action of the battery in producing power it is changed back into its original condition; and there is no à priori reason why such a battery should not be available for use for a very long time. Of course you cannot expect to get quite as much of effect out of it as you put in. I am not prepared to say precisely what the loss is, but certainly it is not of such serious import as to prevent the practical use of these secondary batteries. As regards their application to tramways, their usefulness will extend to lines in the interior of towns, and to crossing parts of towns where it would be difficult to establish separate insulated conductors; in such applications the
batteries may be charged occasionally by the dynamo on the car in running down hill, or they may be charged in running upon level ground from the dynamo at the power station. In like manner for boat propulsion, the secondary battery is the only available means; because we could never hope to attach a vessel permanently to a rope connected with the shore. The batteries, although heavy, may be made part of the keel-weight; and although neither with the railway nor with the boat should I expect long distances to be traversed with electricity as a motive power, for short distances, and under conditions where steam power is for various reasons not applicable, I believe we have in electric energy an efficient and practicable means of propulsion.

I had intended to say something on the subject of electrical units, and also of the principles involved in measuring currents; but this is a subject which Sir William Thomson will bring before you in a much more complete and exhaustive manner than I can hope to do. I hold, however, in order to know anything about a physical effect, you must be able to measure it, and it is therefore impossible to deal with electric quantities without at the same time looking round at the means at our hand for measuring and weighing, as it were, one effect against the other. The Electric Congress, which met in Paris in 1881, laid down certain general rules, and made certain determinate units for the use of the electrician—the Ohm, the Volt, the Ampère, the Coulomb, and the Farad. But there seemed to be a general want felt for a unit that would give us more directly the amount of work done by a given current; and last summer, in delivering my presidential address to the British Association, I ventured to propose two additional units—the Joule, representing the unit of heat or of work accomplished by a unit of current in a unit of resistance; and the Watt, the unit of power, or the Ampère flowing through the Volt. This proposal, I am glad to find, has met with very general acceptance. We now measure the power of the dynamo machine in Watts; and the advantage of this measurement of Volt-Ampères, or Watts, is, that it is the best expression of the power of a machine of given dimensions, which will be capable of producing the same Watt power, either of a high potential and small quantity when thin wire is used on its coils, or of low potential and larger quantity when thick wire is used. Seven
hundred and forty-six such Watts are equal to 1 HP.; therefore, if a machine was given to you of say 10,000 Watt power, you would know at once that it would take about 13 HP. to drive it, to which you would have to add 10 per cent. for frictional losses. If we wished to know the effect from that machine, say in working incandescent lights, we may calculate that 3 Watts produce one candle of effect, whereas in the case of a powerful arc light 1 Watt is capable of producing 3-candle power.

I should have alluded to a number of instruments which have been lent me by the kindness of Professors Ayrton and Perry. They are machines for measuring the different electric quantities, the Volt, the Ampère, and the dynamic effect. I have here, also, an instrument kindly sent me by the Edison Company, which measures the electric quantity in Coulombs. It is based upon the principle of work done chemically. A given current produces an amount of chemical work, and by the amount of chemical work so produced in a branch circuit, the current that has flowed through is estimated. I have already alluded to the dynamometer I usually employ which measures the current in Ampères. This dynamometer consists of one fixed coil surrounded by another coil of a single turn at right angles to the former, through both of which the current passes, so that there will be an attraction between the one wire and the coil of wires, which is proportionate to the square of the current passing; and by the aid of a Table which I have here, I can interpret the deflection produced on the index in Ampères. But we have lately improved upon this in a very simple manner, so as to get the reading at once in Ampère-Volts or Watts. The only difference between the two instruments is, that in the latter case the stationary coil consists of many convolutions, and is of very high resistance, and the single convolution of thick wire, suspended freely, is of very low resistance (see Fig. 4, Plate 8). Now, when a current flows through a high resistance, we measure its potential, and when through a low resistance, its quantity, hence the mutual attraction between the two is no longer according to the square of the current, but as the energy of the current, and we get Volt-Ampères of current, or Watts.

In conclusion I would only observe that I should have wished to have drawn attention to the various kinds of dynamo-machines which have been developed by different inventors; but it would
have been impossible to accomplish this in the space of time allowed me, and moreover I think it better to deal with the principles involved in these machines, than with those most important, yet practical and secondary, results obtained by modifications of the elements which are at the bottom of all of them. It is so far fortunate that all the essential principles involved in dynamo-machines are public property, and there is a fair field for inventive faculty to develop those forms which are productive of maximum results with the least amount of inconvenience or expense. This is a matter that can only be decided by experience, and little would be gained by upholding one machine to the detriment of another. I hope, at any rate, I have succeeded in giving you a general outline of this most important question of the dynamo-machine and the electric transmission of power.

Mr. Brunlees, President, said the lecture just delivered had been so interesting and so instructive, that he was satisfied all present would desire to record the sense of their indebtedness to Dr. Siemens, in the usual manner, by passing a cordial vote of thanks.

The vote was carried by acclamation.

[When Sir William Siemens was attacked by his fatal illness, he was engaged in preparing the Address which he would have delivered to the Society of Arts, as Chairman of their Council, at the Opening Meeting of the 130th Session of that Society, on the 21st of November last. The Address was not in a sufficiently advanced form to render it fit for publication, even as a fragment; but a few copies of what was actually in type at the time of Sir William Siemens’s death have been struck off, with the idea that some of his friends might like to possess them, unfinished as they are. It will be understood that these copies are intended for private circulation only.]

Having been a second time honoured by being appointed Chairman of your Council, I shall now open the proceedings of
our Society for the coming Session by addressing you on some of the questions which interest members at the present time. The Society of Arts continues to progress in its sphere of usefulness.

In addressing you at the commencement of last Session, I dwelt upon the conditions under which electric lighting could be introduced into public use, calling attention more particularly to the great difficulty and cost that must attend every attempt to light a large populous district from one power centre, as was contemplated by many at that time, but insisting on its advantages over every other source of illumination, under conditions favourable to its application. The extended use of the electric light which has taken place within the last twelve years appears to bear out these conclusions. No centres of illumination upon a gigantic scale have been carried into effect; but, on the other hand, undoubted progress has been made in the introduction of electric lighting into railway stations, public halls, theatres, docks, warehouses, and factories, and, to some extent at least, into domestic dwellings from relatively small sources of supply. One hundred and six applications for provisional orders have been received by the Board of Trade, being 99 for England, 8 for Scotland, and 1 for Ireland. Of these 25 related to London and the suburbs, and 23 were promoted by local authorities. Sixty-nine orders have been granted as the result of the presentation to Parliament of 11 Bills, but up to the present time not one of these has been carried out.

When we look back upon the sanguine expectations entertained a twelvemonth ago regarding the rapid and universal introduction of electric lighting in substitution for other sources of illumination, and consider the numerous companies that were called into existence with the object of effecting large applications according to special patented improvements of superlative merit, a feeling of disappointment is natural, when we find how little those expectations have been realised.

Notwithstanding these apparently negative results, I am of opinion that much real progress has been effected in the interval of time that has elapsed since I addressed you this time last year. If sanguine expectations regarding particular forms of dynamo-machines or electric lamps have been disappointed, we have gained
much practical knowledge in the process, and may now look forward to that steady progress which, without appealing to the imagination, is much more likely to yield permanently useful results. The illumination of the Fisheries Exhibition has furnished, perhaps, the most decided proofs of the case with which large buildings and spaces can be lighted electrically, effects of beauty being at the same time produced peculiar to that source of illumination; and it is not, perhaps, too much to say that the great success of these summer evenings' enchantments, which we have all enjoyed, and shall not easily forget, could hardly have been realised but through its agency.

The International Electrical Exhibition of Vienna, which has just closed its successful career, has served to illustrate very completely the capabilities and the present state of advancement of the various useful applications of electricity. The Rotunda, the noble conception of our late member and former secretary, Mr. Scott Russell, is a building pre-eminently well adapted for the purposes of an Exhibition. The illumination of the lofty central hall, lighted as it was by 112 arc lights, arranged in two tiers, produced an effect analogous to broad daylight, the elevation of the lights being sufficient to avoid a glare, and to cause partial atmospheric absorption of the violet rays, which are commonly complained of with reference to the electric arc light. Beneath this mighty cone, and the galleries outside the supporting columns, telegraphic electric apparatus of every kind and description were displayed in graceful groups, and under pavilions representing different nations; while the spacious rectangular galleries enclosing the cone afforded convenient sites for the dynamo-machines, and the gas and steam-engines in motion. The central fountain, throwing an ample jet of water eighty feet high by means of power transmitted electrically, and descending over cascades brilliantly illuminated by electric lights seen through the falling water, constituted an interesting exhibit in itself, and added greatly to the general effect at night.

On the outside of the building a theatre lighted by electricity, a gallery of elegantly furnished apartments under the effect of incandescent lamps artistically arranged, an electric rope-tramway, an electric boat upon the Donau Canal, an electric railway to convey the intending visitor from the Prater Stern to the Rotunda,
added to the general interest of this most complete and successful exhibition.

But apart from the interest afforded to the general observer in bringing before him a great variety of practical applications of electric energy, apparently under complete control, the Vienna Exhibition is chiefly remarkable, in my opinion, for its display of measuring instruments, and for the great attention given both by exhibitors and the examining judges to accurate information, rather than to mere visual effects. The directing council, in justly appreciating this tendency, have substituted for the usual international jury a scientific commission, charged with a careful investigation of the scientific bearings of such exhibits as were submitted to them, and it is intended to reward meritorious exhibitors by a publication of these reports, instead of by mere medals and certificates, expressive only of undefined merit. It is one of the greatest charms connected with electrical effects, that they are susceptible of very accurate measurement, and it would be difficult, indeed, to apply this form of energy either to the purposes of telegraphy, or of lighting, or for the transmission of mechanical power, unless at every step accurate measurement and calculation was resorted to, in order to weigh against each other the influence of electrical resistance, of magnetic and voltaic induction, of Foucault currents, and of heat produced by mis-directed electrical energy, in order to arrive at practically useful results. For these purposes, accurate and simple instruments for the measurement of electrical quantities are of the utmost interest, and engage, at the present moment, the attention of leading physicists and engineers in this and other countries.

The International Electrical Congress, which met at Paris in 1881, has done excellent service in laying down what is now commonly called the practical system of electric units, based, in the main, upon the British Association, or C.G.S. system. It is to be regretted that the fundamental unit, that of electrical resistance, has not yet been definitely determined upon by the International Committee charged with that duty; but it is more than probable that the values resulting from the recent careful investigations by Lord Rayleigh and Mrs. Sidgwick, supported by those of Mr. Glazebrook, will prove so perfectly accurate, that standards based upon these determinations may be accepted provisionally by prac-
tical electricians. The limit of resistance, or ohm, is represented by a column of pure mercury, of one square millimetre sectional area, and of a length of 106 millimetres at zero Centigrade. This being fixed, it is only necessary to determine the relative conductivity of any metal or substance to that of pure mercury, in order to introduce into our calculations the value in ohms of any conductor or coil of wire intended for use.

The perfect accuracy with which electrical quantities can be determined, and used in calculation, makes it probable that in dealing with other forms of energy, such as heat, light, and even mechanical effects, the electric unit quantities will be substituted for those in common use. Starting with this assumption, it appears strange that the Board of Trade, in putting forward a normal wire gauge for compulsory use, should have adopted a unit inconsistent with the C.G.S., or electrical unit system, and I hope that it is not yet too late for the authorities of that department to reconsider the measure, before it is brought into compulsory use.

The wire-gauge intended to be imposed for compulsory use, from the 1st of March next, professes to be a compromise between the old Birmingham wire gauge, the gradual and erratic growth of rule of thumb, and the Whitworth gauge, based upon the decimalised inch as the unit measure. The Whitworth gauge has the advantage in its favour of being based upon a rational unit, the tenth of an inch, of which each successive number represents a multiple. It was introduced, together with a system of accurate measurement, by means of the micrometer screw, its author having thereby inaugurated a virtual revolution in the mechanical arts. The Whitworth gauge would, in my opinion, leave nothing to be desired, were it not for the unfortunate circumstance that its author has not based it upon the decimal unit, the centimetre, which, whatever may be urged against it on hypothetical grounds, is undoubtedly making steady and continuous progress towards universal adaptation throughout the world. It possesses this great advantage over the decimalised inch, that it connects units of linear with those of cubical measure and weight, that it has been adopted by the European nations for common use, and that, in this country, it is employed in all scientific investigations, owing to the facilities just indicated. Legally speaking, its use is authorised by Act of Parliament, but its practical employment...
in commerce is rendered impossible by the fact that the Standards Office refuse to affix their stamp to any particular rod divided metrically. The legality of metrical measurement is further substantiated by the important fact that England was officially represented at the Paris Electrical Congress, which has adopted for all electrical—and I may therefore almost say for all accurate—measurements of the future, the C.G.S. (the centimetre-gramme-second) system, proposed, not by our neighbours on the continent, but by a committee of the British Association, comprising leading men of physical science, and as the result of many years of arduous labour.

The electrical conductivity of a wire varies, as is well-known, in the exact proportion of its sectional area, and in all questions of electric quantity and measurement, the diameter of the wire is, as it were, the starting point. Great indeed will be the complication that must arise if a wire gauge is practically enforced which has absolutely nothing in common with the fundamental measures employed in all scientific work, and that are of universal application as regards electrical measurement. Nor can it be said that the proposed wire gauge is based upon a system possessing rival merits, its leading feature being that it expressly disregards all system whatsoever. In examining, for instance, the current numbers of the new wire gauge from 1 to 12, we find that the successive increases of diameter from number to number are represented by the decimals \(0.024, 0.024, 0.020, 0.020, 0.016, 0.016, 0.016, 0.012, 0.012\) of an inch, or \(0.06095952, 0.06095952, 0.0507996, 0.0507996, 0.04063968, 0.04063968, 0.04063968, 0.03047976, 0.03047976\) of a centimetre; it is thus clear that the authors of the gauge did not aim at making the numbers advance according to a uniform increment of progression of diameter. But it will be said that they may have been guided by a desire to establish a uniform progression according to the sectional areas of the wires; but in calculating those areas I find that the increments of increase are \(0.010858, 0.009952, 0.007603, 0.006974, 0.006346, 0.004624, 0.004223, 0.003820, 0.003418, 0.002300, 0.002073\) of a square inch, or expressed in square centimetres, \(0.07005038, 0.06420538, 0.04905075, 0.04499276, 0.04094121, 0.02983173, 0.02724468, 0.02464473, 0.02205122, 0.01483845, 0.01337395\), showing that neither had the projectors of the new gauge any intention.
to make each successive number represent an equal increment, or an equal progressive proportion of the sectional area.

In ordering wire according to the new Board of Trade wire gauge, the engineer would have to make a lengthy calculation in the first place, in order to express its diameter, its weight per unit length, or its conductivity in rational measure; but the greater drawback will arise in the practical use of each wire, to determine either its strength per square inch or per square centimetre, its electric conductivity, or the space it will occupy in a coil. Elaborate calculations will continually have to be resorted to, too complex to impress the mind with those direct perceptions of fitness and proportion which shorten the work of an experienced practitioner. It may be said, however, that the new gauge was not designed for engineers and scientists, who are quite capable to find their way out of any difficulty which may be imposed upon them, but for practical wire-drawers, manufacturers of bird cages, or other humble users who do not care for accuracy, but require some nomenclature, which, although representing different sizes from those in the old Birmingham wire-gauge, they, in their rough and ready practice, will hardly be able to find out the difference.

As regards the wire-drawers, it can easily be proved that they have long been in the habit of drawing their wire according to specifications in which the diameter is expressed either in decimals of the inch or centimetre; and being myself connected with a firm of telegraph engineers, who have been large users of wire, I may state it as a fact, that for at least the last nine or ten years the contracts given out by them have always been stated according to diameter ascertained, not by a wire gauge, but by means of the infinitely more correct and more convenient micrometer screw, of which a specimen stands before me. It may perhaps be worthy of notice that the pressure of the wire, when pinched in between the two steel faces is limited by means of a spring-ratchet, which yields when resistance is encountered, and thus prevents inaccuracy through flattening of the wire to be measured.

As regards the bird-cage maker, and other rough users of wire, I should say that the sooner they were taught to use their wire according to measurement, instead of having only the vague notion of the size given by the existing Birmingham Wire Gauge,
the better it would be for the character of the work they produce; and I cannot sympathise with the benevolent desire to save them the trouble of becoming familiarised with a national gauge. I venture to assert, on the contrary, that the greatest merit of any system of measurement is its capability of approaching high standards of accuracy, and of conveying in its units the most definite conception of quantity; and this certainly cannot be said of a wire gauge, the numbers of which coincide with no definite units, either of diameter or sectional area, and are supposed to be verified by the rough and ready method of passing the wire through the corresponding notch of a gauge plate, which can only be expected to be accurate after allowing for a considerable margin of error.

The objections to the Board of Trade gauge are already making their appearance, and I observe that the American Ohio Auxiliary Society recommend, at the suggestion of one of their members, Mr. Davies, a modification of the Whitworth gauge for general adoption in America. The same influential body have advocated for some years the measuring of dry goods by weight, instead of by the most uncertain measure, the bushel, and this very rational advance toward accuracy has actually been adopted by the Cleveland Board of Trade. There would be great danger, therefore, in my opinion, that the adoption of the new wire gauge in this country will not only place our system of measures at variance with those of the continental nations of Europe, but that the United States will also separate from us on this question, and raise another impediment to the importation of British wire and sheets, we thus aiding the protectionists of that country by supplying them with an objection against the introduction of English goods.

The desire for the introduction of a national system of measurement of universal application, has given rise to the assembly of an International Geodetic Congress, which met last month at Rome. The conclusions arrived at by this Congress, at which England was officially represented, are of a very important character. The second resolution is to the effect, "That the Conference propose to the Governments to choose for their initial meridian that of Greenwich, inasmuch as that meridian fulfils, as a point of departure of longitudes, all the conditions required by science;
and that being already actually the most extensively used of all, it presents the greater probability of being generally accepted.”

The third resolution is a corollary of this, and runs thus:—

“That the longitudes should be reckoned from the meridian of Greenwich, in the sole direction of from east to west, and from zero to 360°, or from zero to 24 hours; the meridians on the charts, and the longitudes in the registers, should be indicated everywhere in hours and minutes of time, with liberty of adding the indication of the corresponding degrees,” and this country has every reason to be satisfied with the international deliberation.

Another resolution was passed, however, “expressing a hope that England will take another step towards the unification of weights and measures, by contributing to the labours of the Metrical Convention.” This international convention is, as is well known, established at Sevres, and constitutes a laboratory on a large scale, for the development not only of accurate measures of length, weight, and bulk, but at the same time an interesting school for the cultivation of the art of measurement, and although England is not at the present time represented upon that commission, it so happens that, at the present time, it is employed chiefly upon the verification of standards for use in Great Britain. It may, therefore, be confidently expected that the desire formally expressed by the Geodetic Conference may soon be fulfilled, the more so as joining the Metrical Convention does not imply an absolute intention to adopt metrical measurement for commercial purposes, for the adoption of which, I fear, we shall have to look forward to a future time.
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Fig. 1. 
VARIATION OF RESISTANCE WITH TEMPERATURE. 
GUTTA-PERCHA. 
(Alta Alexandria Cable.)

Fig. 2. 
VARIATIONS OF RESISTANCES WITH PRESSURE. 

Fig. 3. 
VARIATION OF RESISTANCE WITH DURATION OF CURRENT. 
GUTTA-PERCHA.

Fig. 4. 
Sections of Bottom.
TESTING ELECTRIC CABLES.

Plate 2.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

(Excerpt from Journal R. U.S. Institution Vol. 10)

Fig. 1.

GAS PRODUCER.

REGENERATIVE GAS FURNACE.

Fig. 2.
DYNAMO-ELECTRIC MACHINE.
Fig. 1.

Fig. 2.

Section on line A.B.

Fig. 3.
CIRCULAR GAS PRODUCER.

Section at A.B.

Section at C.D.

Fig. 4.
MAGNETIC FIELD OF DYNAMO MACHINE.

Fig. 1.

Fig. 4.

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