TRANSACTIONS

OF THE

ROYAL SCOTTISH SOCIETY OF ARTS

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CONTENTS TO VOLUME XVI.

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On Improved Röntgen Apparatus. By DAWSON TURNER, M.D.*

The apparatus for developing Röntgen rays has during the last three years undergone no striking modification, the essential instruments remaining the same; but there has been a steady improvement in the details.

Firstly, taking the case of the tubes. The older tubes used to heat, and the resistance used to increase, so rapidly that the quality of the rays they emitted was always varying, and the tube soon became *hors de combat*, either from the rise in the resistance or from a puncture received in endeavouring to force an electric current through them. These difficulties have been overcome by making the tubes much larger, so that they have a greater residual atmosphere to draw upon, and by backing the anticathode with a large surface of metal. The effect of the latter is that the heat generated by the impact of the cathode rays on the anticathode is dissipated away by the large surface of metal.

Secondly, the photographic plates. Many attempts have been made to prepare a negative which should be more sensitive to X-rays than plates coated with the ordinary emulsion. From a large experience, in the Electrical Department of the Royal Infirmary and elsewhere, of Lumières X-ray plates, of Cathodal X-ray plates, and of others, the author cannot say that he has found these on the whole superior to other plates that have not undergone any special preparation. He made, with regard to the effect of the rapidity of a plate

* Read and illustrated before the Society on 9th December 1901.

on its sensitiveness to X-rays, a series of experiments with a well-known brand, and found, to his astonishment, that the ordinary, as opposed to the rapid and extra rapid, gave the best results; this is doubtless due to their greater thickness of film.

Thirdly, the induction coil and its contact-breaker. The important part that the contact-breaker plays in obtaining powerful electrical discharges has not hitherto been sufficiently recognised; the old form of Neef's hammer, though well adapted for small coils, is entirely out of place in breaking the circuit of the large and powerful coils nowadays required; it heats and sticks and burns up exceedingly rapidly.

The other kinds of interrupters may be classified into three groups:—

1. The Mercurial.
2. The Electrolytic.
3. Mechanical rubbing contact between solids.

1. Of the mercurial, there are three principal forms:—

A. *The old form of "dipping contact."* The disadvantages of this instrument are that it is too slow, a reciprocating motion cannot be made as rapid as a purely rotary one, and further, the mercury is thrown into waves so that a complete break at high speeds is not obtained.

B. *The Mackenzie Davidson interrupter* has a purely rotary motion, and can be made to close and open the circuit with any desired degree of rapidity.

It is thus very superior to the dipping contact instrument, particularly when it is desired to run the coil at the high voltages obtainable from the main; but the mercury is still liable to be thrown into waves, so that the break is not so sudden as it might be.

C. *The mercury jet interrupter.* The contact in this instrument is made by directing a jet of mercury against a revolving cylinder.

2. The second group of interrupters are *electrolytic* in nature. The one exhibited to the Society was a copy of the original form described by Dr Wehnelt. The negative electrode is a lead plate, and the positive electrode is a platinum

wire. These are immersed in dilute sulphuric acid. When a difference of potential of not less than 30 volts is maintained between these electrodes, the current that passes is interrupted very frequently—it may be about 1000 times a second. In consequence of this rapid rate of interruption, very powerful secondary discharges are obtained, and these are of an almost continuous nature. There are, however, some objections to its use. It is not a steady and reliable interrupter; sometimes it will give no trouble, while at other times it will scarcely work at all. Further, it soon tires and the acid becomes hot; the secondary discharges are also very liable to melt the anticathode of the tube. It will not give a long spark.

3. The other interrupter exhibited to the Society was a rubbing contact interrupter, which the author had been at work upon for a considerable period (Fig. 1). Believing that a rubbing contact between solids gives a better contact and a much cleaner and more sudden break than any contact and break between a solid and a liquid, he had endeavoured, in the following manner, to get over the difficulties that presented themselves. The chief difficulty to be overcome is the burning away of the surfaces at the point where the current is broken. This can be diminished by immersing the separating surfaces in alcohol or petroleum, but it cannot be entirely prevented, and a deep pit or groove is soon eaten out of the contact pieces. The pitting can also be diminished by employing platinum or iridium surfaces, but the objection to this is the great expense of these materials. A fixed contact-breaker, then, cannot be used for any length of time. The author next tried a roller, and found that so long as it was rotated so as to cause it to continually present a fresh separating surface, it wore away evenly all around, and that it could thus be employed for an indefinite length of time. He made both the contact pieces of brass rollers held together by a spring, and arranged a lifting cam in such a way that while it separated the rollers, it also caused them to rotate, for this latter point is essential.

When this interrupter is used in air, the secondary discharges are feeble; immersed in water, a much better effect is produced; but by far the best effect is obtained when it is plunged in petroleum. The problem of devising an interrupter with solid rubbing surfaces which should not be rapidly destroyed by burning away was now fairly solved. It remained merely to ascertain what the tension of the

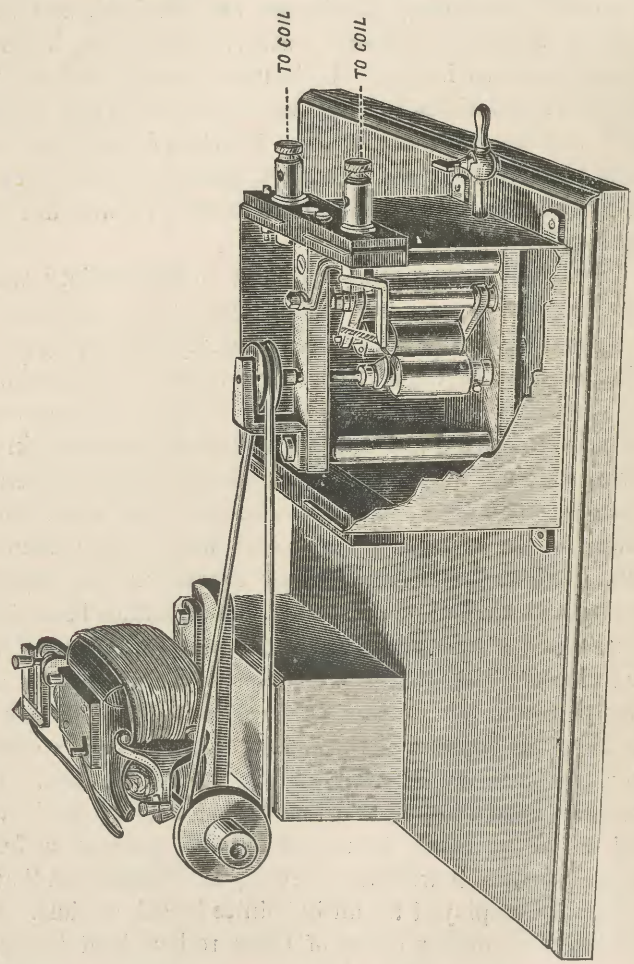

Fig. 1.

spring holding the rollers in contact should be, and how large the cam should be (what should be the proportion between the make and break). The author found that this was largely a question of the voltage employed; the higher the voltage, the less time need be devoted to the make.

This interrupter is particularly adapted for use with strong currents at high voltages from the mains; for small currents and low voltages, the ordinary Neef's hammer will suffice.

It has the following advantages over the mercurial interrupters:—

A. The metallic contact is more perfect.

B. The break is more complete and sudden (owing to there being no waves set up in a liquid conductor).

C. It is more efficient; it gives better secondary discharges for the same number of watts.

D. It is more rapid; its frequency may even approach that of the Wehnelt, while it has none of the disadvantages of the Wehnelt.

E. It is very portable, for water can quite well be employed, while the Davidson break requires 12 lbs. of mercury as well, and the turbine 15 lbs. of Hg, and the Wehnelt, sulphuric acid; nor is there any glass vessel to break.

F. It is the only high voltage interrupter in which the actual instant of the break can be ascertained, and, if desired, made use of.

It has enabled the author to very much shorten the exposure of Röntgen photographs. Very much sharper photographs can thus be obtained owing to the secondary Röntgen radiation being unable in the short time of the exposure to affect the plate. Further, the shorter the exposure, the more evident are the shadows of the soft parts.

REPORT BY COMMITTEE.

Your Committee have carefully considered this communication, the chief interest of which is the description of a novel form of Contact-Breaker for use with the Induction Coil in X-ray work.

It appears to us that the Author has succeeded in devising a contact-breaker which has distinctive advantages. The special feature of its construction consists in the contact being made in a petrol or other suitable liquid bath between two comparatively massive metallic surfaces, which, by a mechanical device, are in constant rolling motion, thus avoiding the destructive effect of a succession of sparkings occurring at the same point on the surface.

The apparatus is mechanically strong, and is not likely to go out of order in ordinary working, and it seems to us to justify the claim of the Author that it provides a sudden sharp break, thus yielding an effective spark; that it is economical in working in using a minimum amount of energy; and that it enables photographs to be taken with a minimum exposure period. It is, moreover, portable and easily adjusted.

We have pleasure in recommending the communication to the consideration of the Prize Committee.

R. Milne Murray, *Convener.*
Archibald Wilson.
E. M. Horsburgh.

On an Apparatus for Measuring the Electrical Resistance of the Blood, with some Deductions therefrom. By Dawson Turner, M.D.*

It is no easy task to measure the electrical resistance of the blood of a living individual. The principal difficulty depends upon the fact that only very small quantities of blood can generally be obtained at a time. During the last five years many attempts have been made by the author to obtain trustworthy and consistent results; various methods and forms of apparatus have been employed and subsequently rejected. At one time a method of dilution was tried; 5 cubic millimetres of blood were diluted with 995 cubic millimetres of distilled water, and the resistance of the solution measured in a vessel which exactly contained a cubic centimetre. This method was not sufficiently sensitive. It became evident that no watering of the blood was permissible, and that pure blood alone would have to be employed. Attempts were now made to measure the resistance of the blood directly by placing a small portion between a gap in two

* Read and illustrated before the Society on 9th December 1901.

metal electrodes. Variable results were, however, obtained, which were traced to the difficulty of getting a good contact between the blood and the metal. This was remedied by coating the metal terminals with spongy platinum. The method which gave the best results, and which is now employed, is the following. Five cubic millimetres of freshly drawn blood are placed between two cup-shaped electrodes 3 millimetres in diameter, coated with spongy platinum and fixed at 0·75 mm. apart. The average resistance of normal blood at 60° F. measured by Kohlrausch's method in this apparatus is 550 ohms. A striking change may be observed in pernicious anæmia, the resistance in this disease being sometimes diminished to about one half that of normal blood. The deduction is that the blood in pernicious anæmia contains an abnormal amount of salts, due to the destructive metabolism going on. It is probable that changes will be found in other diseases where the blood is affected; in diabetes mellitus the resistance is increased, probably connected with its increased viscosity. The time taken for ingested sodium chloride to reach the blood can also be easily ascertained; in a series of 5 experiments with four individuals to test this point, it was found that after a dose of 30 grains of sodium chloride, an average of 15·4 minutes elapsed before the resistance of the blood began to fall, while an average of 21·4 minutes elapsed before the maximum effect in lowering the resistance was produced; in these experiments the resistance of the blood was measured twice before the ingestion of the sodium chloride, and at intervals of 5 or 10 minutes afterwards for some 45 minutes to 1 hour and 25 minutes. The resistance of the blood frequently exhibits a preliminary rise after the ingestion of the salt, as the author has also observed it to do after a meal, due no doubt to the secretion of hydrochloric acid into the stomach; this might be of service in the diagnosis of gastric cancer.

REPORT BY COMMITTEE.

The Author appears to have solved the problem of getting good contact between metallic plates and small quantities of blood by the expedient of coating the former with spongy platinum.

The experiments recorded seem to show that the method is sufficiently reliable to give comparative results, and that with care it may prove a means of clinical investigation of considerable value.

R. Milne Murray, *Convener.*
Archibald Wilson.
E. M. Horsburgh.

On an Experiment with Ultra-Violet Light.

By Dawson Turner.*

It has long been known that the oscillatory discharge of a condenser produced a very brilliant spark which was likely to have strong actinic qualities. It was recently suggested to the author by Mr Leslie Miller that such a spark might be of service in the production of the Ultra-Violet rays for the treatment of disease according to Professor Finsen's method.

The author accordingly commenced by performing a number of experiments to ascertain the physical nature of the radiation, and one or two of these experiments he desires to bring to notice.

The Ultra-Violet rays may be recognised by the following properties:—

A. They are powerfully actinic.

B. They can excite fluorescence.

C. They can discharge an electrified body (Hertz), provided the body is negatively electrified.

D. They have a special action on the skin of the higher animals, and on the entire tissues of the lower animals and plants.

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* Read and illustrated before the Society on 27th January 1902.

E. They can produce nuclei for cloud condensation in moist air. (Wilson.)

The chief difficulty that presents itself in dealing with these rays is due to the fact that glass is quite opaque to the extreme part of the ultra-violet. Hence glass lenses and prisms must be discarded, and to produce a spectrum by refraction some other substance must be made use of.

The author's experiments have consisted in comparing the ultra-violet radiation of an arc lamp with that of the spark.

A. The difficulty of comparing the photographic effects led me to discard such an attempt.

B. To compare the fluorescent effect, some quartz lenses and prisms were made, and the spectrum of the two sources of radiation projected by their means.

A screen of barium platinocyanide and one of potassium platinocyanide now, by glowing with a pale blue light in the ultra-violet region, served to double the length of the visible spectrum as yielded by the arc light; in the case of the spark spectrum, the barium salt did not fluoresce at all, but the potassium salt drew out the original spectrum to three or four times its original length; calcium tungstate produced the same extension, but with a dark band intervening. The calcium salt did not fluoresce at all in the arc spectrum.

There are, therefore, some remarkable differences between the arc spectrum and that of the spark, chiefly in the direction of the latter's possessing a radiation of shorter wave length and greater frequency (more ultra-violet).

C. The property of discharging an electrified body is the most easily tried.

The radiation of an arc light will at ordinary atmospheric pressure only discharge a negatively electrified body and the body must have a freshly cleaned surface of zinc.

Experiment.—If + charged, no effect will be produced.

The same experiment may be attempted with the spark gap radiation. The electroscope will be discharged whether + or − charged, and whether provided with clean zinc or not. The discharging is, however, more rapidly produced if the electroscope be charged negatively, and also if a piece of zinc be put on to the electroscope, so the difference may be one mainly of degree. Judging also from the length of time required to produce the discharge, the spark gap radiation is far more potent than the arc light.

The author next attempted some experiments on transparency and opacity, a short account of which is appended; but the results may be summarised by stating that these experiments lead to the conclusion that there are two degrees or qualities of radiation, the one yielded by the arc light and the other by the spark discharge, and that the wave length yielded by the former is at its shortest considerably longer than the wave length of the latter at its shortest. The arc light yields one quality of ultra-violet; the spark yields that and also another one of a higher frequency.

The already noted and the appended experiments will serve to contrast the two. Thus the arc will discharge a negatively charged electroscope if it has a zinc cap, and quartz and water are fairly transparent to its radiation, and barium and potassium platino-cyanide fluoresce (calcium does not).

The spark radiation will discharge a − or a + charged electroscope, whether fitted with zinc or not, but more rapidly if − charged, and if with zinc still more rapidly.

Quartz and water only allow the lower frequency radiation (that of the arc) to pass through, and are quite opaque to the higher frequency radiation, which is yielded in abundance by the spark. Barium platinocyanide does not fluoresce in the spark spectrum, but the potassium salt and calcium tungstate do, and both draw out its spectrum to twice the length that the barium and potassium salts can draw out the arc spectrum.

With regard to the transparency of matter to the higher radiation of the spark discharge, the author finds that dry ice and dry rock-salt are the most transparent of the bodies he has tried; semi-transparent bodies are grape-sugar, bone, and rubber; glass $\frac{1}{25}$ inch thick is quite opaque; a film of moisture on the rock-salt makes it quite opaque; water is opaque; so are mica and ebonite in sheets of $\frac{1}{50}$ inch in thickness.

Owing to the film of water with which ice is covered, it is rapidly rendered opaque to the higher frequency radiation.

Concluding from these experiments that the spark gap radiation is far more powerfully ultra-violet than that from an arc light, and also that water and rock-crystal (quartz) must be, if possible, avoided as cooling and transmitting media, the apparatus was put into operation in the Electrical Department of the Royal Infirmary in the treatment of cases suitable for the Finsen rays, and so far with very successful results, an exposure of 2½ to 5 minutes only being required as compared with one of ¼ to 1 hour required when the Finsen arc light is made use of. The results obtained in the Royal Infirmary in the treatment of lupus have been remarkable.

The following is a list of some of the chief experiments with the electroscope; the latter was placed with its disc facing the spark discharge and usually 5 inches away; the electrodes between which the spark passed were ¼ inch apart except where otherwise noted, and were, in all the experiments except where otherwise noted, of iron.

Electrodes of	Distance of Electroscope.	Charge.	Result of Radiation on the Electroscope.
1. Fe	5 inches	+	No effect.
2. Aluminium . .	,, ,,	+	,, ,,
3. Fe	,, ,,	−	Discharge.
4. Fe	,, ,, zinc cap	+	No effect.
5. Fe	2½ ,,	+	Discharge.
6. Fe	,, ,, zinc cap	+	Same effect.
7. Fe	5 ,, ,, ,,	−	Quick discharge.
8. Fe	5 ,,	−	Discharge in 10 sec.
9. Fe	5 ,, zinc cap	−	Discharge in 5 sec.
10. Magnesium . .	5 ,,	−	Slow discharge.
11. Burning magnesium	wire produced no	effect.	
12. Aluminium . .	5 inches	−	Slow discharge.

Experiments on Relative Transparency.

In the following experiments the electrodes were always of iron; the electroscope was always placed 5 inches away, and was negatively charged.

Interposed Object.	Result of Radiation on the Electroscope.
Mica $\frac{1}{50}$ inch	Very slight effect.
Mica $\frac{1}{100}$ inch	,, ,, ,,
Glass $\frac{1}{25}$ inch	No effect.
Rock-salt $\frac{3}{16}$ inch thick	Discharge.
Rock-salt wet $\frac{3}{16}$ inch thick	Very slight effect.
Rock-salt $\frac{1}{2}$ inch thick	Discharge.
Sheet of note-paper	No effect.
Red gelatine film	,,
Green gelatine film	,,
Violet gelatine film	,,
Bone $\frac{1}{4}$ inch thick	Slow discharge.
Rubber $\frac{1}{4}$ inch thick	,, ,,
Rubber $\frac{1}{2}$ inch thick	Very slow discharge.
Silk handkerchief	Slow discharge.
Sheet of blotting-paper	No effect.
Quartz $\frac{3}{16}$ inch thick	Slow discharge.
Plate of grape-sugar $\frac{1}{4}$ inch thick	Discharge.
Hand	No effect.
Paraffin $\frac{1}{4}$ inch thick	,, ,,
Empty iron tank with windows, $1\frac{1}{2}$ inches in diameter, of quartz about $\frac{3}{16}$ inch thick each	No effect.
The tank was now approached so that the electroscope was only 4 inches from the spark	No effect.
The zinc cap was now put on to the electroscope, everything otherwise being the same	Discharge.
The tank was now filled with water, the layer of water being $\frac{7}{8}$ inch thick	Slow discharge.

These latter four experiments exhibit the opacity of quartz to the higher radiation, and its transparency to the lower radiation (arc light radiation).

Caution is required in drawing deductions from the electroscope experiments, because the author has noticed that if the electroscope be near the coil, it may be discharged by the action of the coil alone, particularly by an unsuccessful attempt on the part of the coil to generate a visible discharge. (The author is not aware that this has been previously noticed.)

REPORT BY COMMITTEE.

In this communication the Author describes a series of experiments by which he demonstrates some of the differences between the radiation from the electric arc and that from a spark

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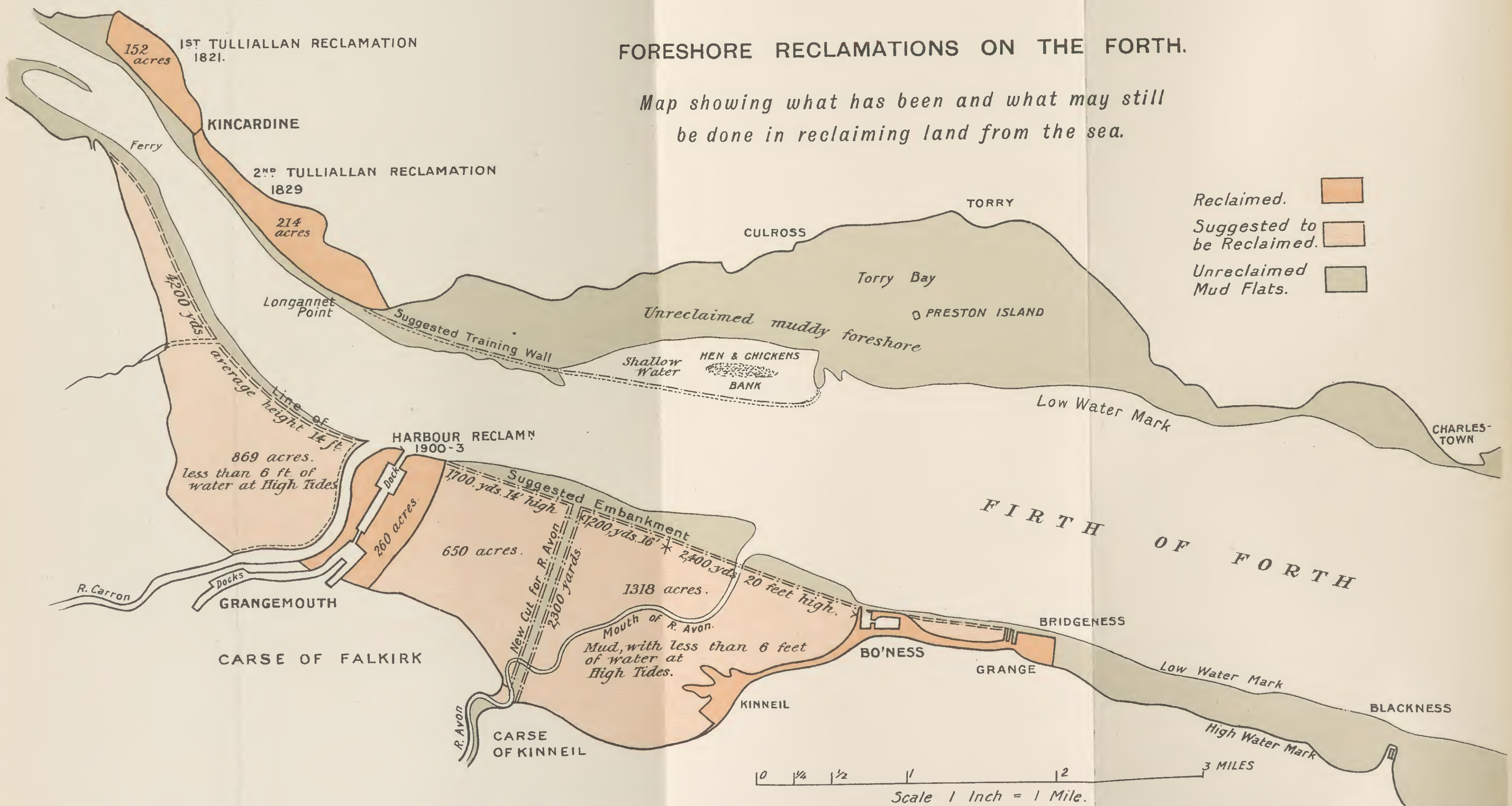

Mr H. M. Cadell, of Grange, B.Sc., F.R.S.E., on Foreshore Reclamation on the Forth.

gap with a condenser in the circuit. His experiments consist in comparing:—

1. The action of the radiation on fluorescent screens.
2. Their effects in discharging an Electroscope.
3. The transparency of matter of different kinds to the radiations.

The experiments recorded seem definitely to prove that the spark gap yields a radiation more abundant in shorter wave lengths and of more rapid period (ultra-violet light) as compared with the arc. The experiments, the results of which are detailed in the paper, demanded considerable care and ingenuity in carrying out. Since the communication was made, they have been confirmed by other workers.

The difference in the character of the radiations suggested that those of the spark gap were probably of higher value in the treatment of certain disorders for which the arc has specially been used, and this suggestion the Author has been able to confirm in the Electrical Department of the Royal Infirmary.

We beg to recommend this communication to the consideration of the Prize Committee.

R. MILNE MURRAY, *Convener.*
ARCHIBALD WILSON.
E. M. HORSBURGH.

Foreshore Reclamation on the Forth. By HENRY M. CADELL, of Grange, B.Sc., F.R.S.E.* (With 4 Plates.)

This country depends largely on its external commerce, and on the facilities that exist or can be artificially produced for carrying on its volume of trade with other countries by means of the various seaports scattered round the coast. Our most important seaport towns are built on the so-called 25-feet beach—a flat terrace that fringes the coast at many places a few feet above the high-water level, and provides ground for harbour works, railways, and public buildings.

* Read and illustrated before the Society on 10th February 1902, with a few corrections added in November 1903.

When the rise and fall of the tide is considerable, as it is on the east coast of Scotland, a long flat foreshore with shallow water outside is obviously disadvantageous for harbour works, and therefore, in the interests of commerce and navigation, the best places for harbours are those sheltered spots where the coast is flat enough for railways and public works, and at the same time steep enough along the seaward face to allow vessels to leave the harbour and move into deep water at once. Such conditions are not common with us. Where the shore is flat, the foreshore is also long and flat as a rule; and where the water is deep and the foreshore narrow, the coast is, for geological reasons, steep and rocky, and badly adapted for railways, streets, and level sites for public works. Both of these drawbacks may often be mitigated by reclamation works at suitable places. A flat terrace can thus be formed with a steep face sinking rapidly into the sea, and shallow foreshores with gentle gradients can be raised above the water and turned to valuable commercial uses.

To exemplify the advantages of foreshore reclamation where the necessary conditions for success are present, the author will describe a small experiment engaged in during the last fourteen years, not by way of claiming any great achievement, or pointing out any engineering novelties, but merely to illustrate by a model, so to speak, how the process might or might not be successfully carried out on a very much larger scale at other places.

The old seaport of Bo'ness (or Borrowstounness, as it used to be called when time and space were not so valuable) is situated on a narrow fringe of land at the base of the steeply sloping coast of Linlithgowshire, where the Firth of Forth at high tide is about 3 miles in width. To the east the foreshore is only about 300 or 400 yards in breadth, and the land begins to rise almost immediately above high-water mark, till it reaches a height of 250 feet or more. The steep bank as it is followed westwards recedes from the sea, and between high-water mark and the foot of the slope a perfectly flat tract of carseland begins, which widens out till it attains a breadth of 3 miles opposite Falkirk. Outside the Carse of Falkirk the foreshore also widens out to a mile or a mile and a half at places, and a glance at the map shows at once that the site of Bo'ness Harbour has been chosen three centuries ago because of the comparative narrowness of the foreshore and the nearness of the low-water line to the coast at that spot.

The private harbour of Bridgeness, a mile farther east, is situated opposite a rocky promontory—the eastern termination of the Wall of Antoninus—where originally the distance between high- and low-water mark was only 200 yards, and the foreshore was therefore still narrower than at Bo'ness. To the east of Bridgeness the coast recedes a little, and the foreshore widens to from 350 to 500 yards at places, and is not broken by any promontory except that of Blackness 3 miles farther down the Firth.

The foreshores here are claimed by the Crown, but after long negotiations H.M. Woods and Forests Commissioners agreed in 1868 to sell to the author's father, the late Mr Henry Cadell, the Crown's rights to the part of the foreshore *ex adverso* of his estate of Grange on each side of Bridgeness Harbour, amounting to 86 acres altogether, for purposes of reclamation. Bridgeness Harbour, belonging to the Barony of Grange, in 1860 consisted of a single stone pier running from the shore at the point of the promontory to near low-water mark, exactly one mile east of Bo'ness Harbour. It was originally constructed by the writer's ancestors about 1774, and was extended in 1828, but was unprotected by breakwaters till after 1860. It is principally used for shipping coal from the colliery at Bridgeness, and since 1888 has been owned by the writer, and extended from time to time to suit the larger class of ships in which the coal is now exported to Scandinavia, the Continent, and east coast towns.

About 1862 the first steps were taken to reclaim the piece of foreshore to the east of the harbour, extending to some 35 acres, by running out an embankment parallel to and about 200 feet distant from the pier, so as to form a breakwater and afford some shelter from the easterly gales. The original intention was to turn this embankment eastwards along the outer boundary, then shorewards, or to construct a dyke of stakes and wattles faced outside with stone so as to form a settling pond where the sea could deposit its mud and gradually raise the level of the foreshore by warping. This plan was never followed, and up till his death in 1888, the author's father followed the quicker and simpler method of depositing the ballast from the harbour and the colliery *débris* along high-water mark, and pushing the sea back in the old-fashioned direct style.

The original plan, although slower at first, was, however, the better of the two in the end from the broad economic point of view, and it was left to the writer to try to carry it out. It is well to mention that Bo'ness has grown considerably of late, and a steady process of embanking rubbish along high water has been in operation for many years. In fact, but for the land thus gained, the principal industries which now employ the bulk of the population would not have come into existence. The large import trade in pit-wood from Scandinavia and Finland, of which Bo'ness is the Scottish centre, requires much room for timber-yards, and all these are situated on land reclaimed within the last half century. The potteries, chemical works, foundries, etc., are likewise chiefly built on this new land, and a large piece of foreshore was taken in when the new dock was constructed in 1885. The reclaimed land has thus been turned to good account, and as the demand still continues for more ground for public works, there is encouragement to go on in the hope of being able to obtain some material satisfaction, as well as the moral and intellectual satisfaction every patriot must feel at the thought of magnifying the dimensions and extending the borders of his own native land.

The process of reclamation by "warping," as it is called in England, or sedimentary accretion is very slow at first, and for a good many years involves capital outlay with no return. But scientifically it is, as I have said, the most economical in the end, since the tide assists the engineer by raising the level of the intake while he is working at the embankments, and indeed it is, as a rule, the only practical

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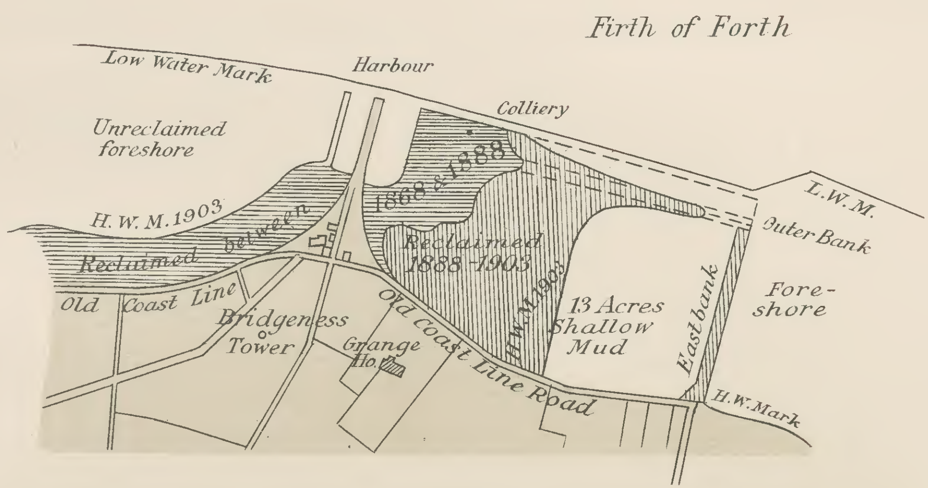
FIG. 1.

SKETCH OF RECLAMATIONS AT BRIDGENESS.

Scale—6 INCHES=1 MILE.



Mr H. M. CADELL, of Grange, B.Sc., F.R.S.E., on Foreshore Reclamation on the Forth.

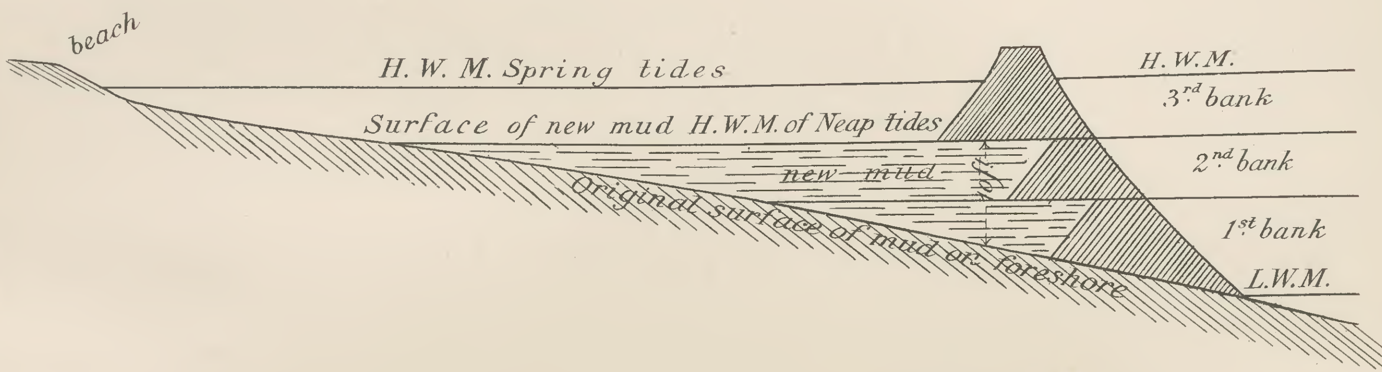
method that can be followed when large areas are to be profitably taken in. To reclaim a foreshore by emptying out rubbish requires rubbish waiting to be disposed of, and it is only at certain favoured places that this can be obtained sufficiently cheaply to make the operation worth while attempting. In this connection considerable quantities of ashes and rubbish have been sent to Bridgeness by the North British Railway Company during the last two or three years, in waggons which are emptied and generally returned loaded with coal. The emptying is done for a shilling a waggon holding 6 to 8 tons, or less than 2d. a ton, and at this price a good labourer can make from 5s. to 8s. a day. Besides the actual work of emptying, some labour is necessary in connection with the lateral slewing of the temporary rails so as to keep the trucks at the edge of the bank as it is extended sideways. Such circumstances are, however, exceptional, and if there were not a return freight for the railway waggons, the company might not be willing to send so many ballast trucks here to be discharged. The facilities for getting materials from a distance for this reclamation depend thus on the proximity of the colliery, which provides every day a considerable quantity of heavy redd or *débris*, which is not easily washed away by the waves, and is with the heavier quality of slag adapted for the outer slope of the embankment, the light slag and ashes being kept for the inner side.

In the beginning of 1889 there remained, as sketched on fig. 1, about 30 acres of foreshore to the east of Bridgeness, on which the author began to make experiments to find out which method of reclamation was likely to prove the most effectual and economical. As has been already stated, an embankment about 750 feet long had been run out about 1862 from the shore to low-water mark, some distance east of Bridgeness Harbour. In 1878 a pit was sunk to reach the coal below the sea near the end of the embankment and close to the low-water line of ordinary springs. As time went on, the mouth of the shaft—which was cased with iron cylinders, and entirely surrounded by the sea, so that boats could lie alongside it—as time passed, and the colliery developed, an insular and then a peninsular area grew outwards from it as the surrounding water was gradually turned into land by the deposit of refuse from the workings.

In 1889, instead of continuing to make land in this way, the author began to use the colliery "redd" in the construction of a low bank 300 yards in length which was run parallel to low-water mark as far eastwards as his surface rights extended, and then turned shorewards for a short distance along the top of an old gravel bank laid down at a time when ships were permitted to empty their ballast outside the harbour. This embankment was deposited on softish mud, and the top of it was, when completed, about 3 feet above the surface of the mud on the landward side. It was about 20 feet broad on the top, and was wide enough for the double line of 3-feet gauge colliery railway by which it was constructed. The materials used were chiefly heavy colliery redd, and no attempt was made to render the bank water-tight at first. The work could only be done at low tide, as the rails were covered by 6 feet of water when the tide was full. After going out about 100 yards, a difficulty arose from the scour of the tide ebbing from the bay. This constantly excavated a gully round the point of the bank which required to be filled up every day before further progress could be made. This difficulty was, however, obviated by the construction of a platform of branches and old overgrown thorn hedges laid on the mud some 20 or 30 feet in advance of the embankment, and kept down temporarily by pieces of heavy stone. This had the effect of breaking up the stream and protecting the mud till it was covered up permanently. The layer of saplings and bushes also helped to form a solid bed for the bank to rest upon, and prevented it from sinking so far into the mud as it might otherwise have done at the beginning. Before the bank was closed, however, a temporary wooden bridge was made at one place to relieve the rush of the ever-increasing stream round the point, and after the whole work was finished and the eastern end turned shorewards till it levelled itself out, the bridge was filled up so that the impounded water lay quite tranquil, and could deposit its

FIG. 2.

SKETCH SHOWING ACCUMULATION OF SILT WITHIN SUCCESSIVE EMBANKMENTS AT BRIDGENESS.



Mr H. M. CADELL, of Grange, B.Sc., F.R.S.E., on Foreshore Reclamation on the Forth.

sediment equally at every place within the enclosure. This embankment took a year to complete, and long before it was finished, the sedimentation inside was in rapid progress. The mud had risen from 1 to 3 feet, and accumulated steadily at the rate of an inch per month over a considerable area. By the end of 1891 the sediment had risen to the top of the bank, and the latter could no longer be seen from the shore 300 yards off. The bank was made up of loose rubble, and was therefore quite porous. At first the sea ran through it as through a sieve, but however muddy the water inside might be, it issued on the outside face in springs of comparative purity. By-and-by these decreased and finally disappeared. The filter had become quite clogged up, and the bank was so impervious, that the retreating tide poured over it in a long thin cascade like the tidal waterfall at Connel Ferry.

This first experiment was quite successful, and in order to continue the process, a second bank (No. 2, fig. 2) was started 4 feet above the level of No. 1, over which the tide could also flow for some time daily. No. 2 bank was run eastwards on this foundation, so that no brushwood was wanted; and after reaching the eastern boundary, it was run shorewards 65 yards till it levelled itself out on the surface of the mud. By the end of 1892 the enclosed mud had risen 6 feet in places during the preceding four years, and was still rising steadily in the deeper parts of the basin. For a few years nothing was done to the outer embankments beyond keeping them in repair and filling up the breaches made by storms. As the mud had made the foreshore so much shallower, it was now easier to gain new ground by the ordinary process of dumping down rubbish inside the enclosure at high-water level, and in this way several acres were soon gained and turned to good account.

In 1897 operations were resumed, and the eastern bank was joined with the shore by means of carts, which brought large quantities of rubbish from old buildings being demolished in the town. The mud had risen 9 feet altogether in the north-west corner of the enclosure, and No. 2 bank was at places almost smothered on the landward side, so that it was nearly time to think of excluding the tide by a third and final embankment.

No attempt was made till 1900 to finally exclude the sea from the 16 acres of mud that remained under water at high tide. At the end of that year the mud-gauge showed that the deposit had now accumulated more than 10 feet, and except at the north-east corner it had risen above the high-water level of neap tides, and nearer the shore was often left dry for several days in succession between the periods of the springs. Early in 1901 the third and last embankment was finished from end to end, the upper surface being about 3 feet above the level of spring tides. Before the second bank was covered, however, three large pipes, 3½, 3½, and 4 feet in diameter respectively, were laid across it and connected with sluices, the bottom of the pipes being laid on a level with high water of neap tides.* When the embankment was finished, the sluices were closed against the rising tide so as to dry up the mud inside; but as the bank was chiefly made up of porous materials and had no puddle wall in the centre, the sea percolated through it at high water, and covered the lower part of the enclosed foreshore. The upper part of the intake was, however, left quite dry for some months, and soon became hard enough to walk on, and was split up with a network of deep sun-cracks. Grass was sown over the highest part next the beach, and began to grow fairly well at places, and might have steadily spread over a larger area, as the salt was gradually washed away by the rain.

On the 28th October an unusually high tide invaded the Firth and burst through the embankment, sweeping in all the materials and spreading them over the interior of the enclosure in a wide circle. Several days of extremely stormy weather and strong easterly gales followed, which widened the breach and damaged the bank at other places, putting an end to all further agricultural experiments that season.†

* These pipes or culverts were originally intended for experimenting on the utilisation of the power of the tides, but as the experiments are not likely to be carried out soon, any further reference to the subject is not necessary at present.

† On the 13th of November, when these gales reached their height, H.M. Revenue Cutter "Active" was driven against Granton pier and totally wrecked, with a loss of twenty lives.

Happily the materials were washed inwards and not outwards, and thus helped to strengthen the inner side of the bank; and as the tide retired, the broad cascade that gushed down the stony slope on the face did little to injure its stability. The gap, which has lately been widened, will not be filled up for some time, as all the available material is now being used to fill up the west end of the basin, so that the ground can be let and made to yield a return on the outlay as soon as possible.

On paying a visit to the extensive reclamation works being carried on at Grangemouth, where the Caledonian Railway Company have taken in about 260 acres in connection with the new docks, it was found that the same forces of nature had burst through the outer embankment at the same time, so that the small bit of engineering at Bridgeness was, for its size, in one respect not much behind its big neighbour which had cost perhaps 100 times as much, and was carried out by a staff of famous engineers and contractors with the best of modern appliances.

The first embankment at Bridgeness was almost entirely constructed by a waggondriver and horse, assisted by an old man and a woman. These represented the contractor's principal staff during the first ten years of the work at Bridgeness, and nobody can say they were too numerous or expensive a squad. Of course other hands had to be employed carting and filling up the shallow part of the basin, and the construction of the sluices already referred to entailed a good deal of skilled labour, while the materials used had to be paid for. But no more was paid than necessary, and many thousands of tons of rubbish were emptied by carts at less than 6d. per ton. Up to the end of 1900 a total of over 41,000 tons, in addition to the regular daily quotum of colliery refuse, had been so disposed of at a price of £640, or less than 4d. per ton on the average. The ground that was raised above high-water level, when not needed for wood-yards and public works, was completed by being covered with about a foot of good soil, which was sown down with permanent pasture grass.

Up till the autumn of 1903 about 17 acres on the east side of Bridgeness Harbour have been completely reclaimed since 1862, 10 of which have been filled up above high-water level since 1891. This ground is partly feued for public works, partly let for wood-yard purposes or grazing, and partly used for colliery works and railway sidings. About 13 acres more are partially reclaimed, being surrounded by the banks just described, and are in process of gradual filling up.

The reclaimed ground has not yet for æsthetical reasons been all let for commercial purposes, but could be let or feued for from £12 to £30 per acre, producing a good revenue, the capitalised value of which is considerably over the sum of £3000, which this reclamation has cost altogether since 1888.

While operations were in progress, it was frequently noticed by the author, especially during the first years of the experiment when the impounded water was still comparatively deep, that siltation was almost suspended in calm weather, and it was during the stormy winter months that accretion went on most vigorously. Occasionally samples were collected of the turbid water, and it was found that the most muddy tides contained in suspension from 24 to 36 grains (dried at 212° F.) per gallon, equal to about from 9 to 13½ ounces of dry sediment in every cubic yard of water. The mud was apparently derived entirely from the lashing of the waves on the slob land at other places, and not to any appreciable extent from the water of the river directly.

The author may in this connection mention that before the outer embankment was begun, he, with the consent of the neighbouring riparian proprietor, applied to the Board of Trade representing the Crown as proprietor of the adjacent foreshores, and asked to be permitted to buy the Crown's rights over about 33 acres of unreclaimed mud to the east, but the request was refused in the alleged "interests of navigation." The writer pointed out that some proof should be given that work of this sort would really damage the navigation of the Forth, and was told to wait till the new Admiralty Chart showing recent soundings should be published. After about eight years the Chart appeared, showing that the navigation had become better instead of worse, as the channel had deepened since 1860, when the old soundings were taken. The author again asked for a little more ground to reclaim, but the request was again refused, and at an interview at Whitehall with the head of the department, he was told that the Admiralty were very sorry that his father had been allowed to purchase the Crown rights over the foreshore *ex adverso* of his estate at all! Had that been their decision in 1863, the great pitwood industry, now one of the largest single branches of trade at Bo'ness, and several other important industries, would never have come into existence here, for it was the ground made available by reclamation on the west side of Bridgeness along the shore that provided the necessary land for these undertakings. It would be interesting to know on what scientific principle a grant of 260 acres has lately been made of the foreshore for the new docks and reclamations at Grangemouth, 5 miles farther up the Firth, where the low-water channel is not half so wide as at Bridgeness.* If a paltry patch of 33 acres was likely to be injurious, a tract of 260 acres of foreshore rescued from the waves must be positively disastrous to the navigation of the Forth. That, however, is a point on which doctors may differ, and in some cases the cure may be worse than the disease. Navigation is not of much use without trade, and to strangle trade for the sake of navigation is rather a strange policy for any sane man, to say nothing of any Government Department, to uphold. The author's belief is that in the Estuary of the Forth, whatever may be the case elsewhere, reclamation works will not only be found quite harmless to the shipping industry, but will prove positively advantageous in more ways than one, and within certain limits the greater the scale on which these are carried out, the better will the navigation become.

The Firth of Forth above Queensferry lies in a trough cut in the rock to a depth which is known at places to be at least 600 feet, the bottom of which is generally lined with hard boulder clay covered by plastic clay, on which there is a thick bed of recent mud or fine sandy silt. Little or no heavy gravel occurs there, only occasional stony beds; and at

* And in the same way how the proposed large reclamations at the new naval base can be reconciled with this principle.

places in the fairway the silt has been proved by boring to be not less than 120 feet in depth, without a single hard stratum in it. Such superficial banks of gravel as exist are mainly old ballast deposits which vessels up till 35 years ago were permitted to throw out before they entered the harbours. This can be proved by walking at extreme low tide along the low-water line, when some of the banks are bare and are seen to consist chiefly of flints and pieces of chalk from the south coast of England, and of other stones quite foreign to the country. The Admiralty about 1865 wisely prohibited the continuance of this pernicious custom, and compelled the ships to discharge all their ballast on shore, otherwise the banks would have grown much larger. Above Blackness there is less sand than mud, and above Bo'ness there is almost nothing but mud for the waves to work on. The waves do not "fret" the coast very much at high tide, and the shore-line has not been appreciably eaten away for at least half a century. In these circumstances any injury to navigation is due to the suspended silt with which the water is heavily loaded in stormy weather. The mud is not derived nearly so much from the river as from the adjacent "sleeches" or "slob lands," a fact that can easily be proved by going out a few hundred feet in a boat in rough weather, when the brown muddy zone fringing the shore is seen to give place to comparatively clear water out in the fairway. Now, if this muddy fringe be removed by constructing reclamation banks that will not only prevent the waves lashing the slob lands, but will help to abstract the suspended matter already in the water, it is clear that the sea will become less turbid, and there will be no reservoir, so to speak, of silt left from which the harbours are replenished with mud, the constant dredging of which lays already such a heavy burden on the navigation of the estuary. Mr David Stevenson, in his well-known book on *Canal and River Engineering*, mentions this very circumstance.*

Again, it has been urged as an objection to reclamation works that they diminish the capacity of the estuary for admitting the tidal water, which on ebbing is required for the scouring out of the channel. This objection is no doubt valid

* 1st edition, p. 139.

for some rivers, but it has little if any force in the case of the Firth of Forth, because the low-water area is already large in the upper part of the estuary, and the constriction at Queensferry will always cause a swift current to flow outwards and keep the channel below the bridge clear enough for all practical purposes. So strong is the tide at and above the bridge, that the soft bottom of the ancient river valley is scoured out at one spot to a depth of no less than 41 fathoms. This deep hole is situated about midway between Bimar Rock and Inchgarvie, and has not diminished in depth since the first Admiralty Chart was made in 1851. It was sounded when the estuary was re-surveyed by Captain Usborne Moore, R.N., in 1898, and the fact that it had not after 47 years changed in depth proves what has been already noted, that very little heavy sediment is rolled along the bed of the estuary; and that although hundreds of acres of tidal water have already been abstracted by reclamations higher up, the current is quite strong enough to keep its own channel clear—so strong that there is ample margin to spare, even if all the available land were reclaimed and a corresponding reduction made in the volume of tidal discharge. From careful calculation this would only be 5 or 6 per cent.

The author will now endeavour shortly to indicate what he thinks might be a feasible and financially attainable scheme of river conservancy that would combine the improvement of the navigation with the reclamation of the large area of foreshore in the vicinity of Grangemouth. A sea wall 5300 yards in length, running in a straight line from the frontage of the Grangemouth Dock to Bo'ness a short distance above low-water line, would define the current on the right bank, and at the same time provide a receptacle for the silt, very much as Messrs Meik proposed in their plan of 1880. This dyke would be continued up the river from Grangemouth to Kincardine Ferry, a distance of 4200 yards farther.

The only novelty in the execution of the work that might be suggested would be in the method of making this bank. Mr Thomas Stevenson's experience is all in favour of training walls, and it seems to the author that this would be the wisest course to follow for some years here, both from the point of view of the conservancy of the river and the reclamation of the foreshore. If a long bank of rubble were deposited on or near the line suggested, and about 6 feet high, the mud would silt up behind it in a few years in accordance with the results of the author's experiments, until the top of the mud was level with the crest of the bank, and higher than this towards the shore. Four to six years should see that part of the operation completed, if the mud, as is to be expected, continued to rise at a rate of 1 foot per annum. It would then be time to make a second bank, say, 4 or 5 feet higher than No. 1, founded partly on the top of No. 1, and partly on the mud behind it. At the end of four or five years more the mud might be expected to top No. 2 bank, and by that time the foreshore near the beach would have become so shallow as to be above the level of all but high spring tides, and capable of being sown down in pasture so as to begin to yield some rent. The low-water channel would also have become deeper to the south side and better defined, and the deposit of silt in the adjacent harbours would have greatly diminished, so that the harbour authorities would see the advantage of the conservancy works, and pay their modest dues all the more willingly.

At the end of eight or ten years the third and final sea-wall might be made, with a few openings and sluices to let the tide in or shut it out as might be desired. The water would then probably have become comparatively clear, the bulk of the mud-producing ground having been enclosed, so that no further rapid silting could be expected to take place within a reasonable time, the whole area being now above the level of high water of neap tides. The final closing of a sea-wall is always attended with difficulty, especially if the intake is a large one and the volume of water to be stemmed heavy. By making the bank in successive strata, this difficulty is easily overcome, as the depth of water to be finally shut out is trifling, and the operation can be finished at a time of neap tides without much difficulty.

By proceeding slowly and steadily in an inexpensive style, and utilising the large supplies of colliery and other rubbish obtainable cheaply at Kinneil and other places on the shore, the embankments could probably be made much under the sum estimated in connection with the late Mr Livingstone Learmonth's scheme of reclamation in 1875. It is not, of course, suggested that nothing but a couple of men and an old woman such as were employed at Bridgeness would be sufficient, but a light 3-feet railway with a train of tip waggons, worked by a very few hands, would not be long in making the first bank, and the prime cost of the materials would be small. Failing this, a tug with a string of hopper barges, loaded in the nearest harbour, could steam along the line at high tide, and lay down the first heavy bank or its foundation. Allowing nothing for price of materials, the first bank at Bridgeness, 20 feet broad, about 5 feet deep on the average, and 300 yards long, did not cost more than £100, or 6s. 8d. per lineal yard. No. 2 bank, 365 yards long, 4 feet high, and 20 feet broad, cost only about £150, or, say, 8s. per lineal yard for labour; but the last bank, which was higher and broader, was a good deal dearer. The material does not need to be equal in quality to that required for concrete, and a concrete facing and parapet are not absolutely necessary on the outer face. At the Bo'ness end, where the embankment is highest, plenty of colliery and quarry rubble and redd can be easily and cheaply got, and the necessary light railways to be laid will not be 3 miles in length to the most distant point. The embankment west of Grangemouth can likewise be constructed of colliery rubbish, as several collieries are situated near the shore within 2 miles of the farthest extremity of the bank.

While the banks are low, the rate of deposit behind them could be greatly hastened by using the mud dredged from Grangemouth and Bo'ness. At Bo'ness some 70,000 cubic yards are dredged out every year and taken in punts or hopper barges to deep water, to be dropped near Queensferry, 9 miles off, but partly, no doubt, to be washed back again at next flood tide. At Grangemouth the figure must be far larger. This mud might very well be utilised to hasten the work at first along the outer border of the intake; 70,000 cubic yards 1 yard deep would cover nearly 15 acres behind the sea-wall. If the method of three banks were followed, and no useless extravagance introduced, the whole work could be done, the author thinks, for £100,000, and this conclusion is based on the estimates soon to be given.

But first it must be made clear that it will not be possible to do the work for this price unless the method proposed of making the embankments be adhered to, and advantage be taken of the assistance given by the sea itself during the progress of the operation. If this method were to break down, the following estimate of the cost must become unreliable; but as the author has experimented on a sufficiently large scale at Bridgeness during the last thirteen years, and established the validity of his theory on a practical basis, it is probably safe enough now to base calculations on the results, and apply them to a much larger reclamation.

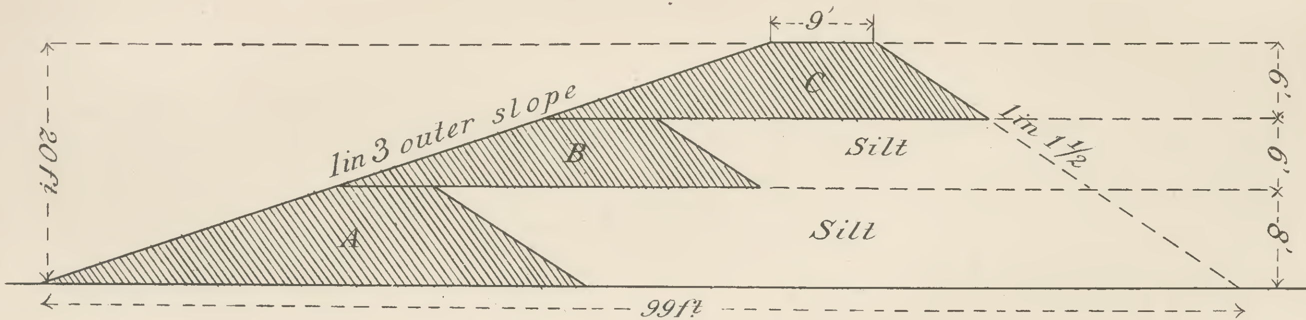
To show the economy of the author's system of "banking," an example may here be given. Fig. 3 is a section of the highest part of the embankment necessary for the enclosure of the part of the foreshore next Bo'ness on the west. For a distance of 2400 yards from Bo'ness pier the outer embankment requires to be on the average 20 feet high, and the proposal contemplates a breadth on the top of 9 feet, with an outer sea-slope of 1 in 3, and an inner slope of 1 in $1\frac{1}{2}$. The sectional area of this bank, if made in one operation, entirely of material to be supplied, is 1080 square feet, or 120 square yards. But, by beginning with a bank (A) (fig. 3) 8 feet high, and waiting till the mud behind has risen level with the top of it, then following with another (B) 6 feet high, and waiting till it in turn is smothered, and finally excluding the tide by a third bank (C) 6 feet high, it is found that the sectional area of material required is reduced to 54 square yards made up as follows:—

Sectional area of	top	bank C	= 135 sq. ft.	= 15 sq. yds.
" "	middle	" B	= 135 "	= 15 "
" "	bottom	" A	= 216 "	= 24 "
			486 sq. ft.	= 54 sq. yds.

The estimate about to be given depends on the economy due to this method of embanking, and also on the assumption that the material to be brought could be emptied

FIG. 3.

Section of Suggested embankment.



Mr H. M. CADELL, of Grange, B.Sc., F.R.S.E., on Foreshore Reclamation on the Forth.

along the embankments at a cost not exceeding 2s. a cubic yard.

Of course it must not be supposed that the newly deposited mud behind the bank becomes so solid as to bear the weight of the superincumbent bank No. 2 without sinking at first. The second bank will sink into and cause this mud to bulge up on the landward side, till equilibrium is restored and the new mud under it is squeezed fairly solid. These embankments, however, are not meant to be very heavy or bear great weights, and as the base is broad, the pressure per square foot of surface is not large, so that sinking should not be so great as in the case of a railway embankment with steep sides. In the estimate 25 per cent. has been added to the quantity of transported material, to cover subsidence and settlement during or after the construction of the banks, which is probably sufficient, and is about the proportion required in other recent works of a like nature on the Forth.

Estimate of Cost of Reclaiming 2837 Acres of Foreshore between Bo'ness and Kincardine Ferry.

I. *Embankments.*

A. *Material Required.*

	cub. yds.
No. 1. Outer bank from Bo'ness to mouth of new cut for River Avon, 3600 yds., viz. :—	
a. 2400 yds. next Bo'ness; average height, 20 ft.; cross-section 3 banks, {6 ft., 6 ,,, 8 ,,}	
54 sq. yds. × 2400 = . . .	129,600
Add 25 per cent. for settlement . .	32,400
Total cub. yds. required . . .	162,000
b. 1200 yds. next Avon; average height, 16 ft.; section 3 banks, {6 ft., 4 ,,, 6 ,,}	
38 sq. yds. × 1200 = . . .	45,600
Add 25 per cent. for settlement . .	11,400
Total quantity required for No. 1 .	219,000

No. 2. Outer bank from new cut for Avon to Grangemouth, 1700 yds., 14 ft. high.	cub. yds.
Cross-section 3 banks, { 6 ft. / 4 ,, / 4 ,, } 31 sq. yds. × 1700 =	52,700
Add 25 per cent. for settlement . . .	13,175
Total quantity required for No. 2 . . .	65,875
Nos. 3 and 4. Banks at sides of new cut for Avon, each 2300 yds. long; average height, 10 ft.	
Cross-section 2 banks, { 5 ft. / 5 ,, } $18\frac{1}{2} \times 2300 \times 2 =$	85,100
Add 25 per cent. for settlement . . .	21,272
Total quantity required for Nos. 3 and 4 .	106,372
No. 5. Outer bank Grangemouth to Kincardine Ferry, 4200 yds.; average height, 14 ft.; @ 31 sq. yds. = ...	130,200
Add 25 per cent. for settlement . . .	32,550
	162,750
No. 6. Bank at west side of Carron on top of the existing bank, 2300 yds., 10 ft. high; no allowance for subsidence. Material required, say, ...	46,000

B. *Cost of Embankments.*

No. 1. (*a*) 162,000 cub. yds. at 2s. . .	£16,200	
(*b*) 57,000 ,, ,, . .	5,700	
Cost of No. 1 bank, 3600 yds. Equal to £6, 15s. per lin. yd. for (*a*). ,, £4, 15s. ,, ,, (*b*).		£21,900
No. 2. 65,875 cub. yds. @ 2s. . . . . . Equal to £3, 17s. 6d. per lin. yd.		6,588
Nos. 3 and 4. 106,372 @ 2s. . . . . . Equal to £2, 6s. per lin. yd.		10,637
No. 5. 152,750 cub. yds. @ 2s. . . . . . Equal to £3, 17s. 6d. per lin. yd.		16,275
No. 6. 2300 lin. yds. at £2 per lin. yd. . . .		4,600
I. Total cost of embankments . .		£60,000
II. Making new cut for Avon 2300 yds. long, 20 yds. wide, and 2 yds. deep @ 1s. per yd. .		4,600
Carry forward . .		£64,600

	Brought forward . .	£64,600
III.	New roads, say 6000 yds. @ £1	6,000
IV.	Drainage of 2800 acres @ £3 per acre . .	8,400
V.	Building 3 farm-steadings @ £3000 . .	9,000
	Bridge across Avon, say	1,000
VI.	Sluices and tidal valves to drains . . .	500
	Engineers' fees, etc.	5,000
	Total engineering estimate . .	£94,500
VII.	Contingencies, Parliamentary outlays, etc. .	5,500
	Total estimated cost . . .	£100,000

This estimate, it will be observed, makes no allowance for compensation to frontagers, who would be fairly treated by receiving $\frac{1}{12}$ to $\frac{1}{15}$ of the value of the land reclaimed. If they got instead, as suggested above, this proportion of the new land itself, they should be equally well off, and might sell it in the best market. In order to save actual cash outlay, this method might be followed, and say 237 acres, or about $\frac{1}{12}$ of the whole, equal in value at £50 per acre to £11,850, allotted as compensation to the various proprietors *pro rata.*

The whole area left would be thus about 2600 acres, the cost of reclaiming which, at £100,000 for the lot, would work out at £38, 9s. per acre.

If merely let for agriculture after the ground was once in good condition, at say £2 per acre, the gross return would be £5200 on the whole estate, or over 5 per cent. on the investment. But round Bo'ness and Grangemouth land for wood-yards, etc., is worth much more than this, so that in time a better rate of interest might be anticipated. Level ground close to low-water mark would attract traders and shipbuilders, and as the Baltic ports with their large timber trade are naturally adapted for commercial relations with this side of Scotland, and especially with the Firth of Forth, a reclamation of these foreshores might be expected to give a new impetus to the trade of the Firth.

In order to improve the navigation still further, a low training wall of rubble might be run at a subsequent time on the north shore from Longannet Point to the south side of the Hen and Chickens bank, a distance of 2½ miles. (See map.)

This would have the effect of defining the low-water channel, here about a mile in breadth, and of guiding the tidal current so as to deepen its bed along the southern side, which, as already stated, is very shallow, and is in need of improvement, especially off Bo'ness.

Since this paper was read, Government have decided to establish a great naval base at Rosyth on the north shore, and in connection with this national work, the old proposal to construct a ship canal between the Forth and the Clyde has been revived. If the canal be ever cut, the Forth conservancy scheme suggested in these pages will become a practical question, and the feasibility of the reclamation of the south foreshore will be greatly increased. The need for a deep channel for large warships above Bo'ness will become greater, and the materials excavated from the canal can be profitably employed in raising the level of the ground within the proposed embankments, or in making the embankments themselves. With such a good receptacle for spoil, the feasibility of the canal itself will be increased, and both schemes could therefore be carried on at the same time in connection with a river conservancy that would prove of mutual advantage to all interested parties.

REPORT BY COMMITTEE.

Mr Cadell's paper is a most interesting one, and he has discussed the problem of Foreshore Reclamations with much knowledge and in great detail.

He, however, appears to feel that the crucial test of all such works must in the end be that of finance, and in this your Committee agree with him.

Unless such reclamations can be made to yield a fair return on the outlay, it can hardly be expected that they will be carried out on an extensive scale, although enterprising landowners like Mr Cadell may make reclamation experiments on a small scale without the prospect of an adequate return.

Mr Cadell was fortunate in having close at hand a very large supply of colliery refuse and other rubbish which could be got for practically nothing except the cost of carriage and deposit, which appears to have ranged from 4d. to 6d. per ton; but everyone who knows anything of such schemes is aware that for works carried out on anything like an extensive scale, such low prices are quite out of the question.

Even with everything in his favour, Mr Cadell brings out the cost of his little scheme at about £2000 for 15 acres wholly, and 16 acres partially, reclaimed; and it is only by assuming that he can feu the ground at £15 or £20 per acre, that he brings out a fair margin of profit. If he could only get agricultural rent of, say, 30s. to 40s. per acre, the financial return for all his outlay would be but a poor one, and he would have to look for his profit to the moral and intellectual advantages which he had gained by his interesting work carried out during the past dozen years.

A considerable portion of his expenditure has been caused by the raising of the ground above high-water mark of ordinary spring tides, which, of course, could not be done by the action of the silting, and had to be effected by dumping down rubbish and afterwards covering it with soil. Such a method of reclamation your Committee think could never be made to pay unless the reclaimed ground is available for feuing purposes. Even 6d. per square yard for filling up and soiling is equivalent to £120 per acre, an absolutely prohibitive price for ordinary agricultural land.

The only chance, therefore, of any land reclaimed for agricultural purposes yielding even a moderate return is to exclude the water after the silting up has practically ceased, to drain the reclaimed land by means of sluice valves opened only at low tide, and to trust to the silt being suitable for cropping without the addition of any other soil.

This plan was adopted in the two reclamation schemes above and below Kincardine-on-Forth,* when 350 acres were reclaimed at a cost of about £19,000, and are worked as arable land at a level of about 5 feet below high-water mark of ordinary spring tides. These schemes, carried out with every local advantage, cost nearly £60 per acre, and it is very doubtful if they have ever yielded even a moderate return for the outlay.

Mr Cadell bases all his calculations on the very inexpensive method adopted in forming his embankments, these being practically merely mounds of colliery refuse. This may do fairly well if the ground is all filled up to a level considerably above high-

* Highland Society's Prize Essays, vol. xii.

water mark; but if the ground is to remain permanently at the top level of the silting, it is very doubtful if such a bank would be sufficient. Even if it became in course of time water-tight, it is almost certain that it would require to be covered on its outer face with pitching, and this would add very greatly to the cost. This was found to be necessary on the Kincardine embankments, which are situated much higher up the river, and are consequently far less exposed than are Mr Cadell's existing or proposed embankments.

Mr Cadell's proposal to expedite the silting by utilising the tides to suck up deposited dredgings is most ingenious, and your Committee hope that he will give it a fair trial. At the best, however, it can only save time, and cannot possibly raise the surface of the ground above high-water level.

Your Committee doubt if Mr Cadell's scheme for a Conservancy Board, with power to levy rates on shipping in order to pay for reclamation schemes, is within the range of practical politics. They fear that the shipping interest would look at the question from quite a different point of view. In regard, however, to his proposed scheme of Training Walls, your Committee believe that if large quantities of refuse from collieries and iron works adjoining reclaimable lands could be deposited in the formation of such training walls instead of being thrown out in immense bings, much valuable land might be ultimately reclaimed at very small expense.

Your Committee consider that there is much in Mr Cadell's paper that is worthy of consideration both by engineers and by the general public, and they have much pleasure in recommending it to the favourable consideration of the Prize Committee.

David M. Westland.
Peter Whyte.

ADDENDUM TO COMMITTEE'S REPORT.

While agreeing with much that is in Mr Cadell's paper and in the Report by the Committee, I should like to add a few independent remarks on points that I think are not touched on, and that have come under my view in my professional experience.

The uses reclaimed land will be put to ultimately cannot always be foreseen when the works are first undertaken, especially in a district where there are many industries, and which has advantages of position and mineral wealth. For example, I have carried out reclamation works costing £1000 per acre, and the proprietors, I believe, now only regret that they did not proceed on a more extensive scale. Also, besides the direct return, there is the improvement in the amenity, healthiness, or salubrity, and therefore in the value of the adjoining districts. It has been proved that a year or two after reclamation works are completed the salubrity of a district is much improved. So that I think the value of such works is more than the agricultural return.

As to the works, apart from the cost, the vital matter is the consent of the Board of Trade. To obtain it, I think the scheme should be devised on more modest lines, making the reclaiming embankment not on the low-water line, but, say, at half-tide level or even above it, and by agreeing to take the material required from parts of the navigation channel where additional depth is required, so as not to diminish the tidal capacity, and even facilitate the progress of the tidal wave.

The execution of such dredging and depositing is now generally done by the sand-pump dredgers, some of which are capable of dredging 1500 cubic yards per diem, and discharging the sand through pipes a distance of say 500 yards and 8 feet above water-level, at a very small cost per cubic yard. This is a better plan than that suggested by the Author of a perforated mud-gathering pipe in a low-water basin for collecting silt, which for various reasons will fail; one being the small power of scour in deep water, and its inability to gather silt except from the pipe and its immediate surroundings, especially with such a small head to drive the water into the pipe. The Author's embankment system is also wrong; a study of reclamation banks in Holland, as well as in England, shows that a sound bank is the first requisite. I may add that in many parts of Holland they do not raise the level of the land reclaimed, but simply form the embankments of facines, mattresses, and stonework, and trust to pumping to keep down the water-level inside them.

The loss of time caused by the slowness of the warping process, and the consequent loss of interest on the original outlay for the embankments, should be kept in view in comparing it with other systems. The work described in the paper seems to have occupied forty years.

Wm. Dyce Cay.

On a "Ball Valve Flushing Cistern."

By Thomas Roger Proctor.* (With Plate.)

The object of this invention is to dispense with the use of the syphon, which is the cause of objectionable noise when in use. Greater ease and simplicity in operating or moving parts, a more effective and direct flush and silence, are obtained. These are attained by the employment of a hollow india-rubber ball of suitable size, adjusted to a metal valve seat attached to the bottom of the cistern, from which the ball rises at discharge and returns and closes the seat when the cistern is filling or full.

A wire cage is fitted on to keep the ball in position, and a moving ring slides up and down the wire of the cage attached to the usual lever with pull.

When the lever is pulled, the attached ring unseats the ball, which rises at once to the top of the cage and goes down with the lowering of water in cistern.

The ball is pulled into the seat by the weight of water in supply to basin.

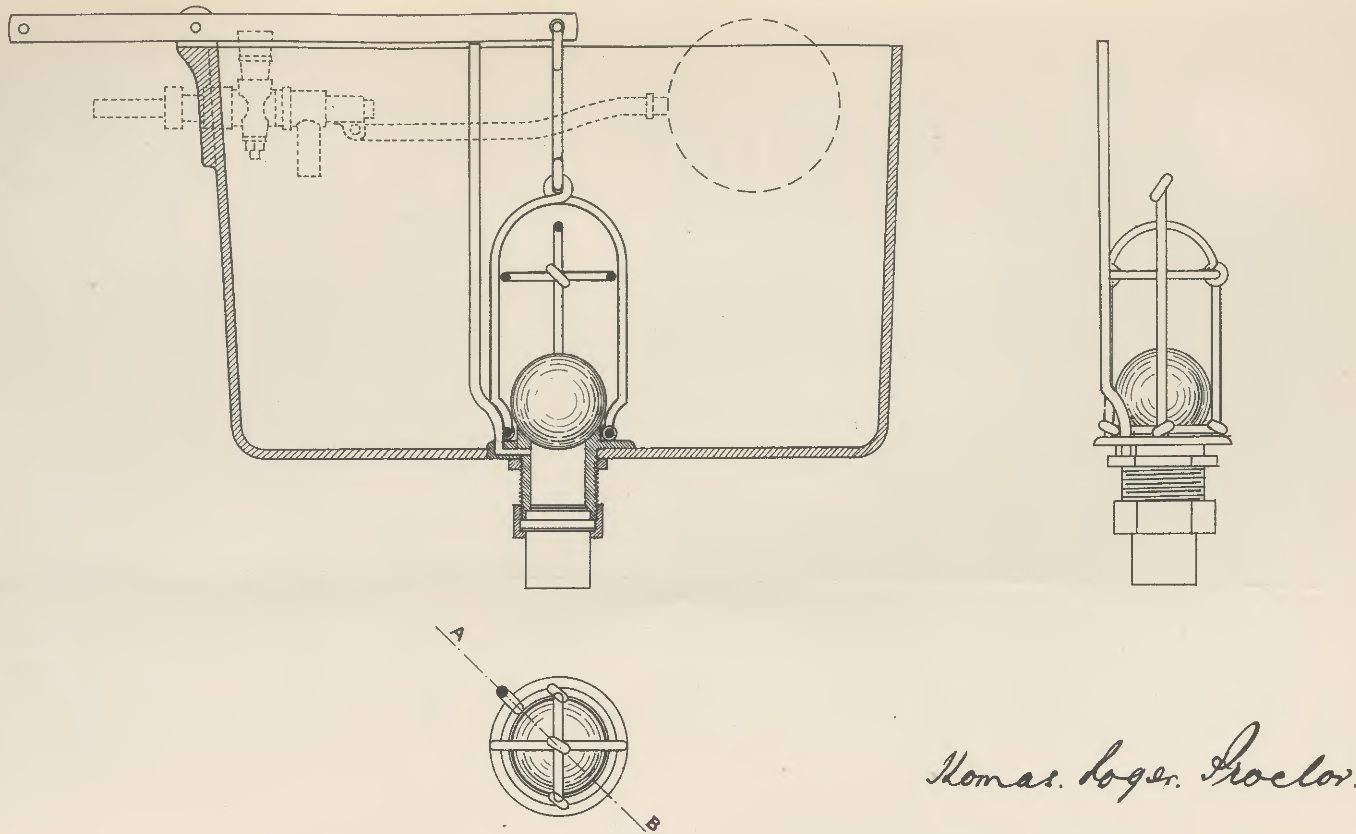
A small air-pipe is attached to the under side of the seat to a position above the water-line. This allows the supply-pipe, after the ball is home on the seat, to empty slowly, thus securing a good after-flush.

REPORT BY COMMITTEE.

In accordance with the remit by the Royal Scottish Society of Arts on the above communication, we have examined, at Mr Proctor's workshop, a movable model and a fixed working sample of the Flush Cistern. It consists of the now commonly used three-gallon cast-iron box, fitted in the usual manner with ball and ball-tap, overflow, lever for pull, and flush pipe, but without the accompanying syphon pipe attached to the flush pipe.

In lieu of the syphon pipe, the head of the flush pipe is left open. The open end is shaped slightly in trumpet-mouth form,

* Read and illustrated before the Society on 24th November 1902.



Mr THOS. R. PROCTOR, on a Ball Valve Flushing Cistern.

and upon it rests an india-rubber ball, whose extrados meets closely the intrados or concavity of the trumpet-mouthed flush pipe. When the cistern apparatus is not in action, the ball rests in the situation natural to which it falls by gravitation, and is retained there by natural pressure, the balance of pressure between the upper and the lower surface of the sphere being in favour of the upper. When the lever for releasing the water in the cistern is acted on, the ball is simultaneously lifted by a ring, and floats at once to the surface of the water, settling again on the seat of the flush pipe as the water lowers. The ball is kept in situation by a wire cage.

The action is virtually noiseless. The pull need not be sustained. A flush and after-flush can be obtained, and the water can be released at any stage of filling—not possible with syphon action. The construction is most simple, and is not liable to derangement. The special construction can be applied to the ordinary syphon cistern, and the cost of a new cistern with this special fitting will not, we understand, exceed that of the syphon cistern.

The contrivance is the result of a well-calculated application of natural laws, is very ingenious, and, in our opinion, the inventor deserves the favourable consideration of the Prize Committee.

Thomas Hume.
J. B. Bennett.
Hippolyte J. Blanc, R.S.A., *Convener*.

On a Direct Reducing Levelling Staff. By G. W. Herdman, M.A., B.Sc., Assoc.M.Inst.C.E.* (With 3 Plates.)

The object of the direct reducing levelling staff is to lessen the arithmetic necessary to convert the readings of *observations* into *reduced levels,* and with this staff the two last figures at least are the same in each, so that all arithmetic to the right of the decimal point is avoided. The staff differs essentially from the ordinary levelling staff in having a shoe which slides on the end with the maximum graduations, and which can be extended and fixed at any particular hundredth of a foot so as to lengthen the staff

* Read and illustrated before the Society on 8th December 1902.

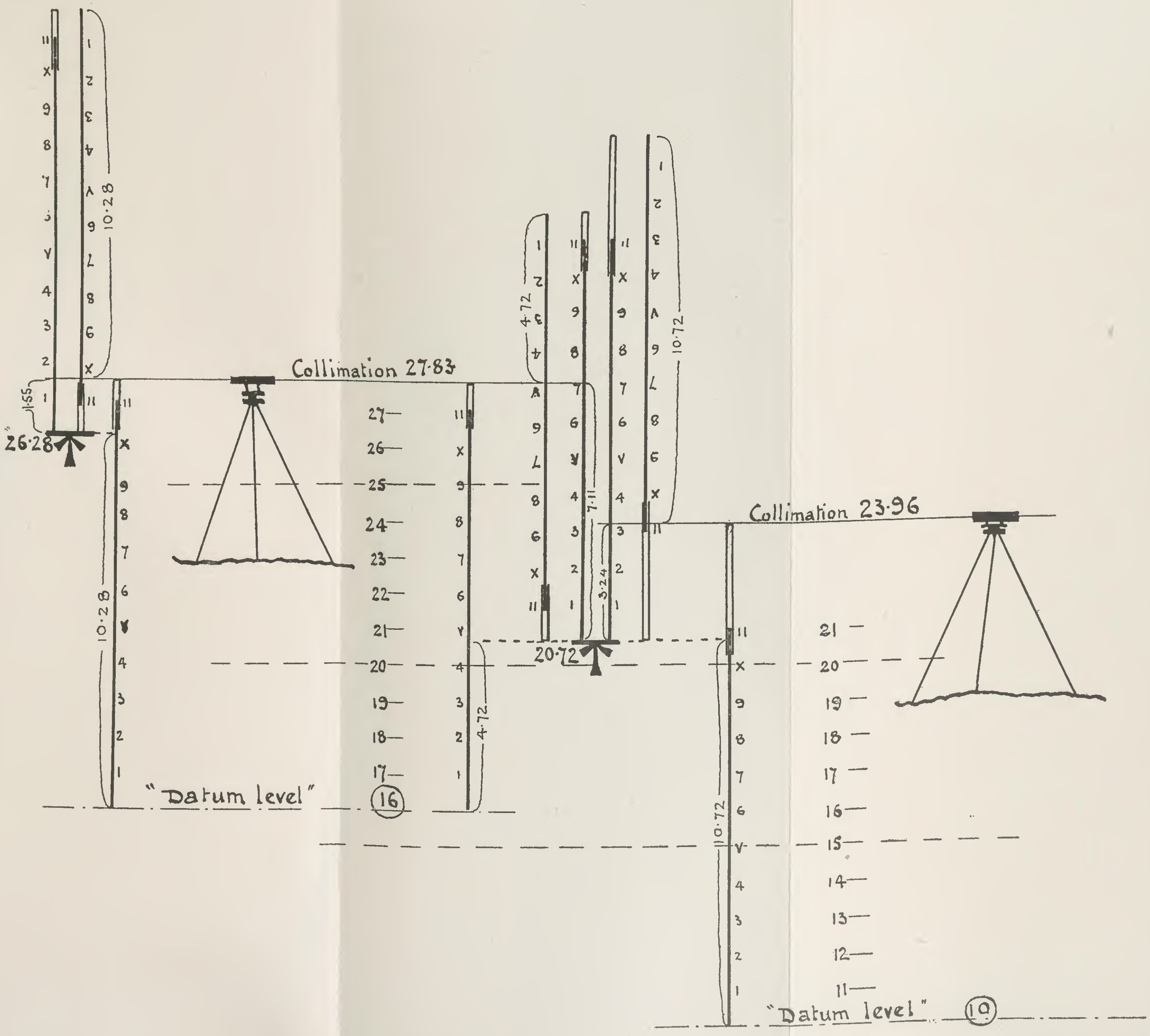
by the amount of that extension. Plate III. fig. 4 shows a 10-foot staff with the shoe set at ·62, making the total length of staff 10·62. Plate II. fig. 1 shows an 11-foot staff, which can be extended for 3 feet and set at any hundredth from 11·00 to 14·00.

The method of using it is as follows: Having set up the level, the height of the instrument above datum, which is collimation level, is obtained as usual by adding the reading seen on the staff to the value of the bench-mark on which the staff is held. (See Plate I. and Field Book in Table.) The shoe is now extended to the amount of the decimals in the collimation level, and in the field book, beneath the collimation level, is written the "datum level," which is the total length of the extended staff less than the collimation level. The "datum level," consequently, is a whole number without decimals. All other observations from this position of the level are now taken with the staff inverted—*i.e.*, the shoe on the ground—and the reduced level is obtained by adding the reading to the "datum level." The amount to which the shoe is extended only has to be altered when the collimation level is altered—*i.e.*, when the instrument's position has been altered.

It will be observed that the staff man has the responsibility of extending the shoe to the correct length, but it will also be seen that an excellent check on him can be made by getting him to hold the staff thus extended shoe-end down on the bench-mark where it has just been held zero-end down. The decimals now read on the staff should give the decimals in the reduced level of the bench-mark.

At important levels—*e.g.*, change points, bench-marks, etc.—if the staff is held with first one end and then the other on the spot, a much better check is got than by merely observing the staff twice in the same position.

The important part of the direct-reducing levelling staff is the shoe with the clamping device to fix it at any required hundredth of a foot. The shoe is of box form as seen in figs. 1 to 4, the front being open so as to expose the staff graduations. On the staff is a metal rack with notches spaced $\frac{5}{100}$ of a foot apart centre to centre, and in the shoe



Mr G. W. Herdman.—Plate I.

Direct Reducing Levelling Staff.

Fig. 1.

Fig. 2.

Mr G. W. Herdman.—Plate II.

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is a rack with five notches spaced $\frac{4}{100}$ of a foot apart centre to centre. A pawl sliding along a rod on the shoe can engage with any one of the five shoe notches, and as the shoe slides along the staff, the pawl can then be made to engage with any one of the staff notches, and thus by vernier principle the extension to any required $\frac{1}{100}$ of a foot can be obtained. A hinged cover, which fixes with a spring catch, protects the pawl and prevents its becoming disengaged. The notches on the shoe are numbered.

TABLE.—*Field Book. Direct Reducing Levelling Staff.*
See Plate I.

Back Sight.	Intermediate Sight.	Fore Sight.	Collimation.	Reduced Level.	Remarks.
1·55			27·83	26·28	on B.M.
			(16)		[staff set to 11·83.
	10			26·28	On B.M. [staff held shoe-end down.
	6			22·25	at 0′ on chain [staff held shoe-end down.
	3			19·60	at 50′ on chain [staff held shoe-end down.
	⋮			⋮	⋮
	4			20·72	change point [staff held shoe-end down.
3·24		7·11	23·96	20·72	change point [staff held solid-end down.
			(10)		change point [staff set to 13·96.
	10			20·72	change point [staff held shoe-end down.
	⋮			⋮	

Note.—The observation of the staff held shoe-end down on the B.M. is 10·28, and is entered 10 in Intermediate Sight column and 28 in Reduced Level column. All underlined figures are observations.

REPORT BY COMMITTEE.

Your Committee beg to report that Mr Herdman's Direct-Reducing Levelling Staff is a very ingenious instrument, but they doubt if it is of much practical use.

The principal advantage claimed for it is that it saves the leveller some labour in adding or subtracting two figures of decimals in reducing the intermediate sights, but as a matter of fact, except in giving levels for actual construction, few intermediate levels require to be read to more than one decimal place, so that the mental effort required to reduce them is of the very smallest, and, as a rule, anyone accustomed to levelling has abundance of time to reduce the whole of his levels while the rodman walks from point to point.

On the other hand this instrument requires that the leveller, after each change of his instrument, and after he has worked out the reduced level of his instrument, should inform the rodman how much he has to raise the sliding shoe, which might be difficult to do if the latter was at a considerable distance, and he has to wait till all this is done before he can take any intermediate levels.

Your Committee, while appreciating the ingenuity of the device, cannot help thinking that the trouble entailed to the leveller, and the danger of error in being misunderstood by the rodman, outweigh the advantages to be gained, at least for such levelling as is required in this country, and with the class of rodmen generally employed.

Your Committee desire, however, to direct the special attention of the Society to the vernier clamp attaching the shoe to the rod. This is, in their opinion, a most ingenious and excellent adaptation which might be used for other instruments, and, as an admirable mechanical arrangement, seems to be worthy of a permanent record in the Transactions of the Society.

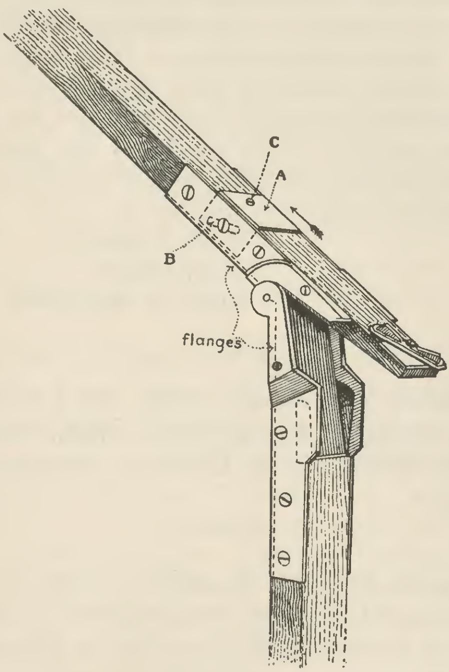
W. B. Blaikie.
Alex. Clark.
David M. Westland, *Convener.*

On a Hinged Joint for Levelling Staves. By G. W. Herdman, M.A., B.Sc., Assoc.M.Inst.C.E.*

This hinge is for a scarfed joint, and is fixed open by a turnbutton on the back of one piece of the staff which engages underneath two flanges on the other piece (see fig.). These

* Read and illustrated before the Society on 8th December 1902.

flanges are inclined so that the further the button is turned the tighter the two scarfed portions of the staff are pressed together. The hinge is designed so that the wood is in all cases in compression, the brass sides carrying the pressure of the turn-button from the back of the one piece of wood to the front of the other, which rests on flanges on these sides.



Hinged Joint for Levelling Staves.

The piece of brass A has inclined slots B through which the screws of the hinge pass, and before tightening them this piece is pushed in the direction shown by the arrow until it presses the wood firmly down on the flanges, and it is then fixed in that position by the screw C.

The Plates illustrating the previous paper show a two-fold staff and a three-fold staff when closed and when partially open.

REPORT BY COMMITTEE.

Your Committee are aware that the weak point in all levelling rods is the joint, and several devices have been suggested from time to time to obviate this.

Mr Herdman's hinged joint appears to be strongly constructed and is certainly convenient to handle, but the turn-button is weak and, with even a slight jerk, might unfasten, with disastrous consequences. Its attachment, moreover, is but a small brass wood-screw which might quickly work loose, especially in hot climates.

Your Committee fear that with tear and wear the joint might become loose, and they cannot see that it has any special advantages over the improved socket joint, where the metal is made to overlap the wood and is not sunk into it.

W. B. Blaikie.
Alex. Clark.
David M. Westland, *Convener.*

On the Evolution of the Japanese Clock. By J. G. Goodchild, of the Geological Survey, F.G.S., F.Z.S., Curator of the Scottish Minerals in the Edinburgh Museum of Science and Art.*

(Abstract.)

The simplest appliance at present in use for measuring given intervals of time, apart from reference to the position of the Sun, is that employed by some of the seafaring Malays. To mark their several "watches" they make use of half a cocoanut shell, which is perforated with a small hole. The cocoanut shell is placed, with the hole downward, in a bucket of sea water, and when it has run full the man on duty records the fact, empties the shell, and repeats the process so many times each watch.

In India a copper bowl, perforated in like manner, is still in use amongst the Brahmins for much the same purpose. They, however, strike the bowl after emptying it and before replacing it in the water, and thus announce the time to

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* Read and illustrated before the Society on the 12th of January 1903.

those within earshot. The Brahmins subdivide the day into sixty intervals, each of twenty-four "minutes" in length.

From this primitive mode of measuring the lapse of time to the next grade in advance the step is easy. Instead of letting water rise into a bowl through a perforation in the bottom, two vessels are used; one placed above is perforated as in the former case, and the lower is not. Water drips from the upper bowl into the lower, and the interval is completed when the lower vessel is filled. Mr S. Couling, a missionary long resident in China, informs the author that a modification of this simple apparatus is in use there still. Five vessels, partly filled with sand, are placed one above the other. The highest is filled with water at a certain time, and the slow filtration of the water from successive higher vessels to the lowermost serves, in a rough way, to equalise its time of filling, in a manner which suffices for the purpose required.

A still further advance upon this rude form of water clock consists in placing a float in the lowest vessel, and, as this rises with the filling of the vessel, its position in relation to an upright gauge, graduated into subdivisions, serves to indicate the minor intervals of time.

Appliances of a very similar nature were long ago in use amongst occidental nations. Even the Romans, who were very late in attaching importance to any exact measurement of time (except in connection with military routine), seem to have had simple clepsydræ or water clocks. Amongst the Greeks these vessels appear to have been employed chiefly as a check upon the time used by public speakers. In the law courts, for example, speakers were allotted time for their speeches proportionate to what suited the requirements of the court. A speaker on an unimportant point was allowed to go on until a certain small quantity of water had trickled from an upper vessel, perforated at the bottom, into a second vessel beneath it; while those whose speeches were of greater importance were permitted to address the court until a larger quantity had run out. This same principle is, of course, that which is (or was until lately) in use in the pulpit, where the speaker had an hour-glass before him to remind him about the time when his congregation wished him to come to the end of his sermon. It may be remarked, by the way, that the sand used in hour-glasses is certainly desert sand in many cases. In such sand the grains are rounded through prolonged bowling by the action of the wind, and are not angular, as are the grains of river sand, or are those from the sea shore. Probably a more equable flow of the grains falling through the neck of the hour-glass is ensured by employing sand grains of a spheroidal form. Of course, one naturally regards this sand as having been brought from eastern deserts expressly for the purpose, as no such sand can be got nearer home (except from ancient rocks of desert origin).

The Egyptians, and probably also the Chaldeans, whose requirements in the matter of time-keeping were of a much higher class, appear to have improved very much, at an early date, upon the rude appliances just referred to. Water clocks of very elaborate mechanical construction, and provided with a rack and pinion attached to the float, and with a circular dial divided as our dials are now, were early in use amongst these people. The plan of construction followed shows that a very close attention had already been directed to various astronomical causes which affect, in various ways, the process of time-recording which they adopted. A people who knew all about the Precession of the Equinoxes many thousand years ago might be expected to be more or less familiar with the causes of perturbation referred to, and, therefore, little surprise need be felt that their clocks were contrived so as to allow for these perturbations, and thus to record the correct time.

From Chaldea, as well as from Egypt, as civilisation advanced, these refinements must have gradually found their way to other parts of the world. Whether these improved appliances were ever known to the people of China and Japan may well be doubted. A trackless desert, difficult to traverse even now, separates the Asian Orient from its Occident; and the few adventurous merchants or travellers who made their way in olden days from the one part to the other would be hardly likely to carry with them any such impedimenta as water clocks. Even if they had done so, there would probably have been but little use for them in a country where, even now, nobody is in a hurry, and punctuality is a virtue of quite recent introduction. Half an hour, one way or the other, is of no consequence to people who, until lately, have had plenty of time upon their hands.

Hence it seems likely that the Oriental Asiatics, having discovered the principle upon which their simple water clocks depend, kept them for centuries much as they were at first simply because they did not need to be more exact, and because these rude appliances served all the purposes required.

It appears to be nearly certain that the Japanese people obtained many of their ideas from the Chinese, and amongst these ideas were those relating to time and the measurement of its intervals. So the Chinese water clock, such as it was, early came into use in Japan; and there is reason for believing that not only the mechanism was copied by the latter people, but that they adopted also the Chinese methods of subdividing their dials. These latter were usually vertical, as might be expected, seeing that the progress of time was marked by the pointer carried by a float, which rose a certain distance in a given interval of each "day."

Here arises an interesting question as to where the "day" is to be considered to begin. Even in Britain we follow two practices: astronomers begin the day at the noon of one day, and count straight on until the noon of the next. Civil time, on the other hand, commences at midnight, goes on to mid-day, and then begins again. The Italians, until the late Sixties, began the day at an hour after sunset, and their clock went four times round from the one sunset until the next. Moreover, it must be obvious that time measured on this principle does not admit of uniform subdivision. In Edinburgh, for example, if we went on this principle, and divided the whole day into twenty-four as we do, the day "hours" at the Summer Solstice would be 93 minutes 55 seconds in length, and, at the Winter Solstice, only 34 minutes 5 seconds. In Rome up to 1869 they were respectively 75 minutes and 44 minutes.

Perhaps it is no more surprising that different peoples should begin the day at different times than it is that they should each begin the year on different days, as we know to be the case.

It is quite clear that only one definitely-fixed time could be employed by those who had no appliances to begin with, and that is, of course, the time when men's shadows were at their shortest, or, in other words, at noon. The other sub-division, such as those measured from sunrise, or from sunset, must have been soon observed to be variable at different times of the year, even within the tropics, and, of course, still more so at places nearer the poles.

The Chinese, and the Japanese after them, decided to take as the starting-point for each day the moment when dawn began to appear. Probably that was chosen as a fit time to rise and begin the day's work. But it must be obvious from the foregoing considerations that time based upon this principle can be of use only to people who have no need to schedule railway time tables, or to keep appointments with others at a distance. Modern Twilight, even in Britain, in this twentieth century, is variously interpreted for different purposes. Civil Twilight is when the Sun is 8° below the horizon, while Astronomical Twilight is reached when the Sun is ten degrees lower than that. The introduction of the bicycle, again, has given rise to yet another twilight, and that is one hour after sunset. So, for each day, even in Britain we have three twilights, each of which is constant only along one meridian, but different from others, and is, of course, different along the same meridian at different times of the year.

However, it seems that the Japanese have got over one of their difficulties by adapting each individual clock to a particular locality, and have met the other by a contrivance to be noticed in more detail presently. A Japanese clock, therefore, is about of as much use when transported to another locality as was the first sundial which was set up in Rome, and which was made in and brought from Sicily. One Japanese clock, described by Rambaut, *Trans. Roy. Dub. Soc.*, vi., part 6, is dialled for the latitude of Tokio, and takes the initial moment of its day from the time when the Sun is 13° below the horizon at the Equinoxes.

The next question that arises is:—what subdivisions are to be made between the dawn and dusk of one day and the dusk and dawn of the next? The Chinese divide the interval from dusk to dusk into twelve, and in this the Japanese have followed them. Why twelve? The usual answer to this is that the early Chinese astronomers—perhaps learning from the Chaldeans (unless they worked the principle out independently)—took their time subdivisions from the movements of the Sun and Moon, and more especially from those of the planets. Dr Wm. Watson tells the author that the Hindoos have chosen the number twelve in this connection because it represents the period of the most conspicuous planet Jupiter. The Chaldeans are said to have fixed upon this as a cardinal subdivision for the same reason 7000 years B.C. At any rate, the Chinese zodiac (like ours) is divided into twelve, though the "animals" are not the same as those used for our signs, and they run in the reverse order. Chinese zodiacs are also used for the points of the compass; and there are many sundials of both Chinese and Japanese construction which are simply zodiacs with an accompanying magnetic needle, and a proper arrangement for a gnomon. Hence it seems to me that we may take it for granted that the Chinese employed the division of the interval between the dawn of one day and that of the day following on the same lines as they divided their zodiacs, their mariner's compass, and their sundials. But as their water clocks are not provided with a rack and pinion movement to convert rectilineal movement into circular, they make use of a straight dial, vertically placed, and divided into twelve, instead of a round one. It may be useful at this point to give a list of these Chinese and Japanese signs with their Occidental equivalents, which the author is enabled to do through the kindness of his friend Mr James Bisset, who knows much about these matters.

The Chinese and Japanese zodiac begins with the Cock—perhaps because Chanticleer heralds the dawn in China as much as he does in the West.

Japanese Signs.	Occidental.	Hours of the Day.
Cock,	Taurus,	5–7 p.m.
Dog,	Aries,	7–9 "
Boar,	Pisces,	9–11 "
Rat,	Aquarius,	11–1 a.m.
Bull,	Capricornus,	1–3 "
Tiger,	Sagittarius,	3–5 "
Hare or rabbit,	Scorpio,	5–7 "
Dragon,	Libra,	7–9 "
Serpent,	Virgo,	9–11 "
Horse,	Leo,	11–1 p.m.
Goat,	Cancer,	1–3 "
Ape or monkey,	. . . .	3–5 "

These intervals are called Tokis, and they are subdivided to suit particular requirements, but usually only into two, each of which corresponds in a general way with one of our hours.

So the pointer carried by the float reaches the sign of the Cock at dusk, moves on to that of the Dog in one-twelfth of the twenty-four hours, and then to the Boar, and so on, until dawn comes round again, when the float has to be readjusted and the water transferred from the lower vessel again to the upper. A clumsy expedient, it will be admitted; but it serves (or did serve) for all the requirements of the people that use them.

The Brahmins, as already mentioned, strike the copper bowl when it has been emptied, and hence, one may suppose, came the use of a bell. The Chinese, of course, use a gong for the same purpose. So did the Japanese. But a difficulty which is not felt in the West comes in at this point. It is one of the many curious and interesting survivals of old customs, much like that of keeping time by "Bells" on board ship, as we still do in the reign of Edward the Seventh. In Japan it is wicked to strike one, two, or three, as these "bells" are only allowed to be used by the military and by the dwellers in convents. So when Mouse Time (11 p.m. to 1 a.m.) comes round, the Japanese think of twelve and deduct three, and so strike nine on their gongs. At Bull

Time they strike eight, at Tiger Time seven, and so on, round to Swine Time, when four is struck, and after that they start again with nine strokes as before. It must seem strange to us—but then, we do many things without any reason that is evident to us, and yet which must seem equally strange to those who have different ways of their own.

A study of the foregoing considerations will elucidate the principle upon which the Japanese Clocks which were exhibited at the meeting have been constructed.* The fundamental idea has been based upon that of the Chinese Water Clock. The subdivisions of the day also are the same, and so are the symbols employed to denote those subdivisions. Clocks which were constructed essentially upon this type appear to have been in general use in Japan down to the advent of Europeans in that country. But in the author's opinion it must be due to the visits of the early Dutch navigators that an important modification of these earlier forms of clocks came about. The Dutch merchant, wanting to deal with the Japanese, found their method of timekeeping not quite in accordance with his own, and he seems first of all to have substituted a 'movement' similar to that in use in his clock at home. This involved the introduction of a weight instead of the water, and of an escapement in lieu of the clumsy and unscientific perforation which served to check the flow of the water in the older water clocks. So instead of a float carrying an index *upwards* he made a pointer attached to the weight move *downwards*, still using the same dial as before. But as it still required some computation to make out the European equivalent of the Japanese Tokis, he caused a circular dial to be placed on the face of the clock, retaining even then, in some cases, the Japanese symbols, but always having in addition the familiar Roman numerals. Still, it seems that the Japanese workmen, when adopting this idea, did not always follow copy, for they made the hour hand (which was the only pointer that

* For the loan of these the author is indebted to Mr Symington Grieve and Mr Alan Clarke of Edinburgh, and also to the Director of the Edinburgh Museum.

was needed) stand still, in a vertical position, and made the circular dial move past it, of course in a counter clockwise direction. Mr Bywater of St Andrews has an interesting clock constructed by a Japanese clockmaker on this principle.

Many of the Japanese clocks which were in use up to the earlier part of the nineteenth century were constructed with the two dials just described. Such time-keepers may be regarded as illustrating the readiness of the Japanese to consider new ideas, and, at an early date, to meet the requirements of merchants from Europe and America, while still adhering to their own time-honoured methods in other respects.

It need hardly be said that the Japanese have seen by this time the advantage of adopting European methods of counting time. The advent of railways, and of other signs of Western civilisation, have gradually taught them the advantage of using clocks similar to ours. So, after adapting clocks of their own pattern more and more to the modern European type, they are now making use of clocks which differ in no essential respect from those which are in general use in other parts of the civilised world.

An interesting feature about this part of the history of the Japanese Clock is the fact that many transition forms of an intermediate character between the old seventeenth century type and the modern European still exist. The author has not yet seen any two Japanese clocks which were quite alike in all respects, and it need hardly be said that the successive steps in the transmutation of the ancient type into the modern one are of hardly less interest than the original type itself. Two of what we may term transitional types are on exhibition in the Edinburgh Museum of Science and Art. One of these has Roman numerals on the vertical dial.

One of the most interesting features connected with the Japanese type of clock is the provision for adjusting the subdivisions of the vertical dial to suit the varying length of the day at different times of the year. The reader who desires to study this subject at greater length than is possible in this brief abstract may turn with advantage to the paper by M. Rambaut, in the *Trans. Roy. Dub. Soc.*, referred to on page 46. But it may be as well if an outline of the chief points of interest is given here. The dial that M. Rambaut describes is very similar to one which is in the possession of Mr Symington Grieve of Edinburgh. It has to be remembered that the problem to be solved in planning a dial adapted to the older mode of time reckoning in Japan is, how to make a pointer which is attached to a weight whose descent is controlled and its rate rendered uniform by an escapement—how to make that pointer indicate one-sixth of the interval between true dawn and a fixed time taken to be dusk, and another sixth between that dusk and true dawn, so as to accord with the Japanese method of time reckoning, It has to be remembered that it is the case that dawn falls at different times on the same day in different longitudes, and also that position in regard to latitude, as well as the time of the year, all have to be taken into account. Oddly enough a Japanese clock will be correct on the same day along any meridian of longitude, because its cardinal hours are regulated by the times of sunrise and sunset. Our clocks, of course, being set to mean solar time, 'go wrong' as we travel either east or west, but keep right as we travel due north or south ; and our clocks also tell correct *mean time* at any time of the year, while in the Japanese clocks the dial is never quite correct throughout the twenty-four hours, not even at either Christmas or the Equinoxes, if we take mean solar time as the standard of comparison.

To get over this difficulty, the better class of Japanese Clocks, such as Mr Symington Grieve's, have a dial with a very complicated arrangement of intervals. Thirteen equidistant vertical lines are ruled on the dial board. The one on the left bears the subdivisions of the whole day proper to some time near the end of December, about Christmas time, probably. The seventh line, which occupies the middle, stands for the Equinoxes, either Spring or Autumn. The right hand or thirteenth line stands for the midsummer. These thirteen lines are each terminated, top and bottom, by horizontal lines, which mark what is taken to be the end of the day, known as Cock Time (5 p.m.). The thirteen vertical lines are crossed by eleven others, which with the bounding line just mentioned make up the twelve Tokis already referred to. These lines are marked on the right side and on the left with the Japanese symbols for the odd numbers, 5, 7, 9, 11, 1, 3, 5, 7, 9, 11, 1, 3, 5. The vertical line corresponding to the winter has the symbol for Hare Time exactly in the middle, and is equally divided into twelve intervals. The upper half of this part of the dial, therefore, stands for the part of the day between that dawn and the dusk of the evening before; while the lower half of this line stands for the remainder of that day up to Cock Time or dusk. This, of course, stands for the winter day and night for the particular locality to which the subdivisions of the dial are adapted. The pointer, carried downwards by the weight, is arranged to traverse the whole distance from top to bottom in the twenty-four hours, which are thus of equal length.

At the Equinox dawn begins, of course, much earlier; so the line which indicates that part of the day is drawn about two-fifths down instead of half. The night part of this has six short intervals, and the day part six long ones, each of either set being of equal length. As dawn begins at the midsummer solstice soon after midnight (in the latitude for which Mr Symington Grieve's dial was graduated), the interval between dawn and the conventional dusk, day end, or Cock Time, is about five-sevenths, instead of half. Hence the six day intervals are longer still, and the night intervals still shorter.

In Mr Symington Grieve's dial, therefore, the starting-point for the year appears to be about Christmas; and the pointer attached to the weight descends from top to bottom in twenty-four hours, beginning when the clock is wound up, at the conventional Cock Time, which corresponds to our 5 p.m., and running down at the Cock Time following. As the intervals on that dial line are all of equal length, the time would be correct by European standards, if the clock went well. But as the weeks go on, and January and February pass, and the Equinox approaches, the days get longer. So the dial is ruled, as already mentioned, by other lines, which mark intervals of about a fortnight each. A curve is drawn across these lines through the three points already referred to as marking the conventional dawn, or Hare Time, respectively, at Christmas, the Equinoxes, and Midsummer, and the portion of the lines above this curve and below it are each divided into six, as was done with the lines before described.

So as the fortnightly intervals come round, the Japanese shift the pointer one line further to the right, until Midsummer comes round, when the pointer is moved back again on the left the width of one space between the lines each fortnight. To enable this to be done the weight carries a horizontal metal bar, which appears in front of the dial, and to which the descending pointer can be moved either way, as required.

Notwithstanding the admirable manner in which this clock is adapted to the needs of a stay-at-home people, it is obvious that its use must entail a considerable amount of trouble and attention; and it is equally obvious that it cannot be used at all under any circumstances where uniform time has to be kept over a large area. Nevertheless the principles upon which it has been constructed are of very great interest, especially to the student of the history of the evolution of ideas connected with Astronomy. To the author the Chinese and Japanese methods of time reckoning, as shown by their clocks, appear to suggest that there has been an independent evolution at not less than two distinct centres, which two may be conveniently referred to as Occidental, as represented by the work done by Chaldeans, and Oriental, when we are considering the independent evolution of astronomical ideas which arose amongst the earlier inhabitants of China.

In conclusion, attention might fittingly be called to a paper by Mr Clements, *Trans. Asiatic Soc. of Japan*, vol. xxx., pt. 1, in which some further observation on this and allied subjects will be found. M. Rambaut's paper is however, the more important in connection with the principal subject of this paper.

On British Manufacture and Foreign Competition.

By Montague T. Pickstone.*

(Abstract.)

We are all aware of the action taken by the Press during the last five or six years, and the general decrying of British manufacturers. It is impossible to say what objects the writers of these popular articles had in view; in all probability these emanated from the larger American advertising houses with a view of booming up the American wares. The reasons for the late stagnations in British industries have been due undoubtedly to three separate influences, which, to the author's mind, are the keynotes to the whole thing.

The three influences at work are, in the first case, political; secondly, financial; and thirdly, internal.

The first, the political head, is that dealing with the all-important question of free trade *versus* protection, of tariffs and bounties.

The second, namely, the one on financial enterprise in supporting home industries, is largely independent of the first or political consideration.

The third, dealing with the internal situation, our methods of transacting business, producing work, and obtaining the same value for money as is obtained by our foreign competitors, will be treated in some detail.

In the first place, it is possible for a small concern to achieve success, providing it is laid down upon proper lines and that these lines are rigidly adhered to. The firm which takes upon itself everything which comes in its way, irrespective of its capacity for turning the work out, is bound sooner or latter to go to the wall. Mechanical work has now arrived at such a pitch of perfection that it is only by specialisation that great results may be achieved. To the author's mind there is very little more sense in a dynamo builder building engines and boilers than, say, a tailor making

* Read and illustrated before the Society on 26th January 1903.

boots. Cheap production, coupled with the greatest perfection, is, therefore, involved in the one word "specialise."

The author's firm * specialises in electric dynamos and motors, and the following are some of the methods they employ, or are about to employ, in their large new works to achieve this result.

In the first place, they consider that it is absolutely impossible to obtain the maximum capacity from their men without allowing them to share in the firm's profits in direct proportion to their own personal efforts. The bonus system of paying wages has therefore been adopted. A minimum wage is guaranteed which is at least equal to the standard wage paid in the district, and all additional energy and special effort put into the work the firm share with their employees.

We are all aware that the British workman is conservative; he objects to being hustled; this is largely due to the management, and not to the men themselves. If we are conservative and slow-moving, how can we expect our men to differ?

In the case of the author's firm, the men, or rather that portion of them whose ambitions lie in that direction, are encouraged to think. With this object in view, notices are posted throughout the shops offering rewards for all ideas which may tend to reduce and cheapen production, all such ideas being directed to the principals of the concern and considered on a fixed date each month, each being rewarded on its merits. Another important feature which has been adopted, and which has been carried out successfully in several of the American and Continental works, is the following:—

The brain department is paid to think, the operatives are paid to work and to get the best results. No operative should be allowed to follow his own ideas or notions as to how to carry out a piece of work. According to the plan adopted, when a man gets his job, it is brought to him together with an instruction card, which card not only tells him the time that he is allowed for the job and embodies the features of the simple job card, but it also gives him strict

* Messrs Bruce Peebles & Co.

instructions as to exactly how he has got to carry out the operation, and by following these instructions to the letter, if he is diligent, he is able to earn fifty per cent. in addition to his ordinary wages without pressing himself in the slightest degree. This instruction sheet, therefore, tells him the method that he must employ to fix his work, the tools he must use for the purpose, the speed at which he must run his machine, the cutting feed he must use, and also the depth of cut. Moreover, it states each operation in detail and the tool to be used on each operation. He is not allowed to grind his own tools, he is not allowed to bring his work to the machine or to take it away; in fact, the man is there as a skilled operative to obtain the maximum possible output out of a machine by steady labour: he is neither a labourer nor a scientist, and by keeping him just in his place, results are arrived at which otherwise, even with the best management, are hopelessly impossible.

One point which must be emphasised is liberality—the very worst policy that any employer of labour could adopt is nearness or stinginess as regards his men. Every encouragement should be shown, combined, however, with the strictest discipline. Special bonuses should be offered to the most diligent men; special bonuses should likewise be given to those maintaining the best time throughout the year and generally the most diligent in their work. A system of this sort is simplicity itself, and naturally encourages the men to do their best. It is quite impossible to expect men to put their very best energy into their work without they themselves share the result. So far, one factor only, namely, a method of extracting the utmost value out of your men and machines, has been dealt with.

The next important point, and one likewise which many firms fail to realise, is the immense amount of money thrown away owing to unsuitable conditions of situation, traffic, handling of raw and finished material, and the passing of work without congestion through the shops. As far as possible, all carting should be absolutely avoided, and with this idea it is necessary for the main railway siding to come directly under the works cranes. The internal arrangements of a modern workshop for rapid production depend, of course, entirely on the articles that are manufactured, but in an engineering works where cheapness of production is of such great importance, it is impossible to spend too much care or thought in the arrangements of dealing with the rotation of work, the suitability of tools for the special objects in view, grouping of machines to give the smallest amount of supervision with the least amount of handling. It is imperative that the material should never move backwards: everything should be in a forward direction as far as possible; and the works, no matter of what class, should be designed in such a way that the finished part or any machine or mechanism is brought through in a continual state of progression to the assembling or erection shops, and from thence they move on to the testing, painting, finishing, and packing departments without a check. Every machine or article brought backwards represents a dead loss, apparently very small; but if a shop is so arranged that it is necessary to move backwards on a certain operation, the block which will occur will seriously impede the output and involve additional supervision and labour which would otherwise be totally unnecessary.

A short description will now be given of the actual system which is carried on in the present works of the author's firm, but this will be modified generally on the lines laid down in this paper when entering the new works. The working out of this system is entirely due to the energy of Mr Arthur Peebles, and any information required can always be obtained, while the smoothness of working is phenomenal.

The financial books used are those generally adopted by all engineering or manufacturing firms, namely, the day book and sales ledger for the sales department, invoice book and purchase ledger for the purchase department, and a cash book for recording cash transactions. These books may all be specially adapted for the particular business to which they apply in order to save time in making up balance-sheets, etc., and for ease in reference when such is necessary.

In the works department the following are the principal books used:—the time and wages books, stores inwards and outwards books, works cost ledger, prime cost ledger, and private cost ledger.

Works Costing System.

The card system is adopted throughout the whole works. As soon as an order is received it is passed to the contract department, where it is pasted into an order guard book and duly indexed under the customer's name. A general order on a special form is then made out with duplicate, and full particulars given of the order guard book folio, the estimate book folio, date issued, customer's name, destination of goods and the route to be despatched, whether carriage paid or forward, customer's order number, date of the order, when delivery is required, and full details of the material ordered. On the back of this card is a space for full particulars of deliveries. At the same time a contract card is made out for the information of the invoice clerk and accountant, which gives full prices, discount and terms of payment. This order, after being signed by one of the principals, is sent over to the works manager's office, where a works order is made out for the same. Each department in the works which has to deal with this order receives a duplicate copy for reference. After this is done a prime cost card is made out by the chief cost clerk, and the works order and the prime cost card are then filed away in a filing cabinet in order of number. Whenever the works manager finds he has workmen ready to go on to the job, and also sufficient material in stores, the work is put in hand and the leading hands or under-foremen in each department issue to the workmen an order to the card office to do a certain piece of work. The workmen then hand in these orders to the card office, and are issued works job cards. On these cards there is a space for material received from stores and also materials returned to stores, and on the other side full details of the tally number, rate and time allowed, and time spent on the job. As soon as a workman has completed this order, he gets his card punched by his charge hand and foreman, which is taken as evidence that the entries are correct and the work satisfactorily performed. It is then returned to the card office, whence it goes to the costing office. To make certain that no cards are lost, every card has a number printed upon it, and as soon as that particular card is issued its number is entered in the card issue book. When the card is returned, it is marked off as such. The costing department then cost up the value of labour and material as shown on the card, and post the items to their respective accounts in the works cost ledger, after which the card is filed away in the filing cabinet under its particular works order number for future reference.

When the whole contract is completed, the totals of these job cards are transferred on to the prime cost card, which is then signed by the works manager and sent over to one of the principals for examination. If the card is passed as correct it is returned and filed in the cabinet for future reference. Whenever any material of any kind has to be despatched, a despatch order is issued and signed by a principal, bearing full particulars of the despatch. The general order card is withdrawn from the works manager's office by the despatch clerk, who enters on the back of it the date and full particulars of the despatch. After the despatch has been completed, the general order card is then returned to the works manager's office, and the despatch order goes to the day book or invoice clerk in the general office. The chief cost clerk then affixes a cost sheet to the general order card and returns it to the general office. As soon as this is done, an invoice is made out for the goods in question and the despatch order is stamped "invoiced." No materials of any description leave the works without despatch orders, which are eventually passed into the hands of the invoicing clerk, so that it is impossible that any materials can be sent away without being invoiced.

As regards articles made to stock, exactly the same process is carried on, with the exception that no general order is issued, general orders being used only for customers' orders. The despatches or deliveries to stores in the case of stock work are shown on the back of the works order card. Should, in the process of manufacture, it be found necessary to take material intended for another job due to urgency or some other cause, transfer cards are issued. These cards give the works order number to which the particular part which is being transferred has been made, and in this way the true cost of a completed article is arrived at. These transfer cards, after being made out and signed, are returned, when the job is completed, to the costing office and filed with the other cards.

The next, and one of the most important parts of the works system, is that applying to the stores department. Here, the books required are the stores inwards book and the stores outwards book, which simply record full particulars, etc., of goods received and despatched. It is not considered necessary or advisable to use, as many large firms do, a store stock ledger, which, although a very nice thing to have, entails an enormous amount of clerical work. In place of this, stores stock cards are used, which contain particulars of stores received into the bin from the suppliers, and also material given out and returned from the works. By balancing off these stock cards, the amount of material in stock can be ascertained immediately, and, as every entry on the card is initialed by the storekeeper, double check is held against him: firstly, by the stores stock card; secondly, by the entry on the job card, both of which eventually reach the costing department. On the stores stock card there is a column for the works order number, and it is a very easy matter indeed to run over these enteries and pick out the material used on any particular order number. By this means the costing clerk can see at once whether the material put upon the job, as shown on the job card, has been accounted for in the stores. In many engineering works the method of treating stores is different, every workman having first to receive a written order from his foreman to the stores, giving authority for the material to be given out. This system, although a very excellent check, is bad, because it is the cause of considerable loss of time, owing to the fact that a workman may have to go hunting about the shop for the foreman before he gets his order for the material. With the system described, the workman simply presents his job card and asks for what he requires, when it is immediately handed out to him without delay, the necessary check on the material being the examination of job cards by the charge hands and foreman, and also the costing department.

In the case of all standard articles the costing department have a complete list of the material required to produce the same, and by comparing the entries on the job cards with this list it can be seen at once whether a man has received duplicate material, possibly owing to the fact that he may have destroyed or broken some, and to get out of his difficulty has simply made away with it.

The balance of material in hand is shown periodically by the works cost ledger, which should tally absolutely with the amount at stock-taking time.

When this balancing system is carried out over an extended period, it is possible to tell to a nicety exactly what discrepancy to expect due to scrap unaccounted for, and it is therefore very easy indeed to check theft, which has always got to be watched.

In order that the costing department may be kept up to date as to the current prices at which materials are purchased all suppliers are required to send duplicate invoices, one copy of which, after being checked, goes to the costing office. The prices are then taken off and put on to an index card which is always ready for immediate reference. In this way it is never possible for a mistake to be made in the costing up of material on any particular job.

In the same way with wages: the wages clerk, whenever he is notified of any advance or alteration in the rates of any workman's wages, fills in an index card and sends it to the costing office, which is filed under the tally number in the index card cabinet.

Too much stress cannot be laid upon the necessity for having an accurate and easily worked costing system. Nowadays, when almost all work is obtained by tender, it is of the utmost importance that the firm tendering should know exactly the cost of production. It is possible to arrange a system which will balance absolutely to a penny, but such a system is not what should be looked for, as the clerical work entailed in keeping it right is enormous: simplicity and approximate accuracy are sufficient, and it is with a view to these two items that this system has been drawn up.

At any time when it is necessary to take stock for the purpose of valuation for an audit, a good costing system saves an enormous amount of labour in pricing the stock, and enables accuracy in this line to be obtained which would otherwise be practically impossible.

It is to be particularly noted that, although it costs a good deal in stationery and clerks' salaries, a properly-worked system is the means of saving a very large sum of money per annum by keeping proper checks on material and wages.

On Wireless Telegraphy. By Professor F. G. BAILY, M.A., F.R.S.E., M.I.E.E.* (With 2 Plates.)

The recent enormous extension of the distance to which wireless telegraphy, or telegraphy by electro-magnetic waves, has been found feasible, has stimulated the curiosity and interest of the public to a high pitch. To many the whole thing seems incomprehensible, and to most it appears very complex, while the accounts published are either too technical for the average mind, or consist in repetitions of messages successfully transmitted. It is proposed to give, if possible, a simple account of the various methods now in experimental or actual use, with explanations of the principles of the systems. The author will not dwell on matters of historical interest only, nor deal with the question of priority of patents.

Though wireless telegraphy, as we now understand the expression, is very new, it began with the divine command, "Let there be light, and there was light." Everything is radiating waves of heat, and if the body is sufficiently hot those waves become of a size which the eye can see. The hot body is the transmitter, the eye is the receiver, the brain the recording apparatus. These rays or waves, which

* Read and illustrated before the Society on 9th Febuary 1903.

travel through space at a speed of 300,000 kilometres per second, or 190,000 miles per second, are of an electro-magnetic nature, produced by some electrical disturbance in the particles of the body and transmitted through the ether with which all space is filled. The visible waves are very short, about 50,000 to the inch; there are others still shorter which, though invisible, can be detected by a photographic plate; while others, also invisible, are longer, and have been detected not very much smaller than one millimetre in length.

Clerk Maxwell first propounded the theory that these waves are electro-magnetic, and this theory has been abundantly verified. Dr Herz afterwards showed that much longer waves could be made, which nevertheless behaved in all respects like the shorter ones, being reflected and refracted, interfering, and so on, and travelling with the same velocity. They are produced by electrical disturbances in bodies, but as the whole body or a system of bodies may form the place of the disturbance instead of the individual particle, the wave is correspondingly larger, and may be miles long. The medium is the same—the ether—but the immensely increased size of the waves give them new properties. A mote of dust will interfere with and obstruct a light wave, while a house will be harmless to a wave half a mile long. Being so enormously greater than the molecules of bodies, the structure does not greatly affect the waves; and unless the bodies are conductors of electricity, even the shorter waves pass readily through them as of light waves through glass. All non-conductors of electricity are therefore transparent to these waves, however large the bodies may be; while small bodies of all kinds, conductors or non-conductors, are passed by the larger waves without appreciable effect on the wave.

To produce these waves we require a rapid to-and-fro current of electricity in a conductor. As the current surges backwards and forwards it produces magnetic effects, which spread out through space with the speed of light, and each reversal of directions of the current produces a reversal of the magnetic effect. Therefore a succession of opposite magnetic disturbances pass off into space, constituting a set of waves. If the conductor is a long straight one, the current collects at each end, at the end of each rush, charging up the end to a high pressure, much as a body of water rushing to and fro in a long vessel dashes up against each end alternately. Thus we have a system with powerfully charged ends between each current rush, and electric force is radiated out from the ends into space. The two effects unite, and the electro-static effect—the force from the charged ends—dies away very quickly if the ends are near together. But in certain methods of wireless telegraphy this charge at the ends probably produces a considerable effect.

The period of the wave, or the time that one wave takes in passing, must be very short if the wave is to be of reasonable length. If the waves are too long, there is a danger of our receiving apparatus not responding to them—not seeing them, in fact; and as the speed is so great—300,000 kilometres per second—a wave one kilometre in length would pass in $\frac{1}{300000}$ part of a second. Therefore our current rushes must be equally rapid.

It is well known that an electric spark is not a simple transference of electricity from one body to another, but that the electricity surges to and fro several or even many times, gradually quieting down as the energy is dissipated. Some systems radiate their energy very rapidly, and after one or two rushes of current the energy is practically all gone. In others the loss is more gradual, and the current continues oscillating many times. The first will be a very powerful radiator for a moment, the second will produce a milder but more continuous train of waves; and we may liken them to the crack of a whip, and the sound from a vibrating piano string. Additional losses, damping due to the resistance of the system, must be diminished as far as possible, since the energy is wasted without being radiated.

A mechanical system will go on vibrating a long time if little energy is given out, as in a large, heavy tuning-fork. The heavier the moving parts and the greater the movement, the greater is the energy we can put in, and the more it can give out. In the electrical vibrator we have an electromagnetic inertia corresponding to the mechanical inertia, which is small in straight wires, but very much increased if the wire is wound into a coil. The strength of current passing corresponds to the velocity of the body at the middle of its swing, and the quantity of electricity moving to and fro corresponds to the length of swing. We can get a large swing by using a strong force, and similarly we get a large quantity of electricity in motion by employing a powerful electrical force or pressure. But the extent of the swing also depends on the yielding of the system—the weakness of the restoring force—and this is represented by the capacity of the ends of the electrical system. By making them large, so as to hold easily a large quantity of electricity, we shall obtain a larger movement of electricity.

Lastly, the time of swing depends on the inertia and the yielding. It is proportional to

$$\sqrt{\text{moment of inertia} \times \text{yielding facility}},$$

and the time of that electrical swing depends similarly on the electro-magnetic inertia and the capacity, or is proportional to $\sqrt{LK}$.

Dr Herz, and everyone since his time, has used the spark discharge for setting up these oscillations. If long rods are joined to the spark balls, the current surges backwards and forwards, radiating waves which are of a length equal to twice the length of the pair of rods. If the rods are laid horizontally, the waves along the surface of the earth are interfered with by the difference of their velocity in air and in the earth, and the effect is modified by induced charges of electricity in the earth beneath, which rush to and fro in the opposite direction, thus partially neutralising the effort. But if the rods are set vertically, this is avoided. Moreover, it is not necessary to use two rods: the earth may be employed as one side of the system, and the spark-gap may therefore be at the base of the rod. In this case the wave length is four times the length of the air wire, if it consists of a straight wire with no addition at the top. This gives us the early form of radiator. It radiates very powerfully, but the oscillations die away very rapidly. The wave length may be increased by making part of it into a coil; further, by putting a cap on the top.

Leaving the transmitter for a time, let us look at the receiver. This is a similar rod. When electric waves pass such a rod, they induce in it electric surgings similar to those which produce the waves, although much weakened. If the original wave is of short duration, we shall get only a pulse of current in the receiver. But if the transmitter sends a long train of waves, there will be a succession of pulses in the receiver. These will run up and down the rod with a definite speed, depending only upon the rod itself. Hence if the time of arrival of fresh impulses corresponds with the time of swing of the previously produced pulses, the effects will be added and a greatly increased surging will result; whereas if the two times do not agree, the effects will partially neutralise each other. The effect is well known in the case of two tuning-forks, one of which is struck. If not exactly in tune, the second is but slightly affected; but if perfectly synchronous, it picks up a considerable portion of the energy of the transmitter.

It is obvious that a transmitter with a very short train of waves will set up a surging current in any receiver, for there are practically no succeeding waves to interfere. While it lasts it is very powerful, and hence such a transmitter is in many ways advantageous, as no particular tuning is required. But, as it happens, the methods adopted for increasing the power of the oscillator also increase the time of duration of the oscillations. Or to put it another way, there is a limit to the amount of energy that we can send per oscillation from an air wire, and the only way of increasing the total energy is to increase the number of oscillations. Therefore modern systems always use a tuned receiver; but the tuning need not be as exact as with the forks, a matter which will be returned to later. Still, the longer the oscillations keep on, the more needful is it to have the receiver tuned to the transmitter.

The indicating apparatus is something which will be affected by the passage of these rapid surgings of current. There are three distinct patterns in use.

The coherer, so called by Sir Oliver Lodge, is a bad electrical contact due to two or more metal surfaces lightly touching and generally more or less tarnished on the surface. It was first discovered by Hughes, for he found that his well-known microphone would respond to radiations from a spark discharge. But that was before the time of Herz, and his discovery was not understood or misunderstood. Afterwards Branly found that a tube of filings, which when at rest had an enormous resistance, became a good conductor when electric waves passed over it. This was much developed by Lodge and further improved by Marconi. Marconi's form is a small glass tube with silver rods pushed in from each end, until only separated by a couple of millimetres. This space is half filled with a mixture of silver and nickel filings. The tube is exhausted and sealed up. The air wire and the earth are connected to the ends, so that the oscillations pass through the tube, breaking down the thin coatings of oxide, and diminishing the resistance very greatly. If a battery and indicating instrument, such as a galvanometer or siphon recorder, or relay and Morse ink writer, or telephone, be joined to the ends of the tube, a current immediately flows round and indicates a mark. Tapping the tube breaks up the contact and the current ceases. An automatic tapper may be used, worked electrically by the same battery, or a mechanical clockwork tapper may be employed, by which means the circuit is immediately broken again. But if fresh trains of waves keep arriving, it is continually re-made, and the recording instrument marks a continuous line. Thus it is easy to make a set of Morse signals, by holding down the sending key for long or short intervals of time. If a telephone is used, a succession of cracks is heard, so long as the circuit is made and broken, ceasing when the sender stops. In the battery circuit are included small coils of wire to choke off the oscillations from passing round the coherer instead of through it. Sir Oliver Lodge prefers pointed needles instead of flat ended rods, as he finds the effects are more concentrated.

This necessity of tapping back the coherer prevents very rapid signalling, and therefore attempts have been made to invent a self-restoring coherer, but they have not been successful. The Italian pattern has a carbon and an iron rod, with a tiny drop of mercury just touching both. While it works perfectly as a coherer, it does not always decohere by itself, and the adjustment is more troublesome than with the simple filings tube.

Though a slightly tarnished surface is advisable, the layer of air on the surface of metals is sufficient to separate them, if the pressure is very slight; but though this pattern is extremely sensitive, it is apt to conduct without any waves, and is therefore more troublesome. In Marconi's tube the nickel is the tarnished metal, and prevents the free passage of the current.

Fessenden in America uses the heating effect of the surging currents. A silver wire with a very fine core of platinum is placed in the receiver circuit, and at one part the silver is dissolved away by nitric acid, thus leaving a short piece of very fine wire. The current, in passing down this, heats it and increases its resistance. The loop is put as a shunt or by-pass to a telephone and battery, so that more or less current passes through the telephone according as the shunt is cold or hot. Therefore each set of waves causes a crack in the telephone, and the message is buzzed out. The loop is put in a polished silver box, to prevent radiation of heat, thus increasing the effect, and this again in an exhausted glass vessel for the same purpose. Of course no tapper is required, since the tiny wire cools almost instantly, and fairly rapid working is therefore possible. A speed of forty words per minute has been accomplished, but it is not very sensitive.

The third method depends on the magnetic action of these very rapid oscillating currents. It is well known that a lightning flash will demagnetise the magnets of telegraph apparatus, and Mr Rutherford at Cambridge devised a detector on this principle, causing the currents to pass round a small coil in which was a magnetised needle. The strength of this was shown by a small compass needle or magnetometer, and the receipt of a train of waves immediately reduced the deflexion of the magnetometer. This was cumbrous, and Professor Wilson of King's College improved it by using a soft iron core, in which the magnetism was kept perpetually changing by an alternating current. When a train of waves comes, the rapid shaking up of the particles of iron renders them more sensitive to magnetic changes while it lasts, and a larger magnetic effect is produced by the alternating current. A third coil, connected to a telephone, is influenced by these changes, and a buzz is heard while the waves are passing. The normal action of the magnetic changes is compensated in the telephone, so that between arrivals of waves the telephone is silent.

Marconi has simplified this by using a long band of iron wires passing past a magnet. Fresh iron is perpetually coming forward and being magnetised. When surging electric currents pass round the strip, the magnetic friction or reluctance to being magnetised is diminished, and the sudden increase of magnetisation produces current in a second coil connected to a telephone. Thus each train of waves results in a crack in the telephone. With this instrument, which is exceedingly sensitive and also continuous in its action, greater speeds of signalling can be obtained than with his coherer, upwards of thirty words per minute being attained over short distances.

Air Wires.—These are often simple rods or wires like flagstaffs or lightning rods. But a greater capacity is obtained by placing wire cages on the top, by which means a greater quantity of electricity may be put in motion. Marconi used a great fan of wires on the ship "Carlo Alberto," stretched between the masts, for signalling between Cornwall and Russia; and at the Cornish and the Canadian stations a large inverted cone of wires is employed, stretched on a frame made of wooden towers. This has a large capacity and very great radiating power. The towers are 200 feet high and form a 200 feet square. The cone has 150 wires.

An ordinary induction coil would not supply enough power for these large radiators. At the Cornish stations an alternating current dynamo of 35 h.p. gives current at 2000 volts, and this produces discharges between spark balls. These are transformed up in a Tesla transformer to a very high pressure. For short distances a large capacity can be obtained by using two concentric cylinders, the inner one connected directly to earth, and the outer forming the other connection to the spark balls. Thus the two rods of the simple form are made of tube, and placed one inside of the other, instead of being put in line. When a coil is put in the circuit to increase the self-induction or inertia, this gives an oscillator which continues for a long time, while the radiations are feeble. It is intended for military work in the field, to communicate with beleaguered towns and camps, and can be made quite portable, since cylinders 6 feet long will send a good many miles. For the receiver a rod is better since the tubes are poor collectors.

Before going on to the methods of tuning, it will be as well to examine this matter more fully. Recent work has been all in the direction of accurate tuning, and each worker constantly declares that his system is perfectly secret, and that no interference need be feared between two different stations. On the other hand, we have reports from other people that they can receive all the messages sent out from Poldhu without any tuning at all. Probably the truth is as follows:—

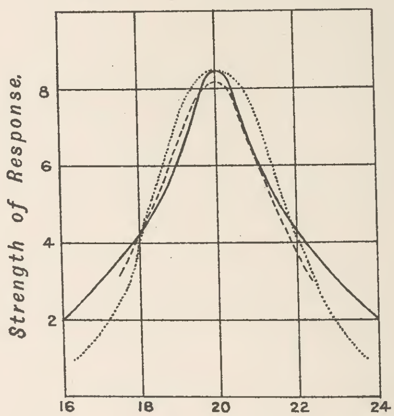
If two circuits are tuned, and one of them gradually altered, it is found that at one value the effect is a maximum, falling off as the time period is increased or diminished. But it does not cease abruptly. And this because the waves sent out are not all exactly identical. Changes in the nature and vigour of the spark, and hence in the resistance of the spark gap, will alter the period. Although the term is approximately proportional to $\sqrt{LK}$, more accurately it is proportional to

$$\sqrt{\frac{LK}{1-\frac{K}{4L}\cdot R^2}}$$

where R is the resistance, so that with a larger capacity even a small resistance will affect the period. As these variations will be quite accidental, they will follow the law of averages or variation from the mean. The law of variations from the mean is well known, and from it we find that the smaller the errors the more marked is the maximum.

FIG. 1.

EFFECT OF TUNING ON RESPONSE COMPARED TO CURVE OF ERROR.



1. *Length of Receiver, curve* ————
2. *Length of Vibrator, curve* -------
3. *Theoretical curve of Error* ....

If there is any variation, there will be some range of values, at which a fair proportion of actions take place. Therefore if the second circuit is tuned to respond to the average value of the waves in the first, the effect will be a maximum; but if not quite in tune, the effect will not cease: it will be diminished to the value corresponding to the error of tuning. In addition to this, there will be the effect produced in any case in imperfectly-tuned circuits, and also the effect due to the first wave or two. This last will be very small if the circuits are good vibrators, or if the sender is a poor radiator.

The curves in fig. 1 show the experimental determination of the vigour of response in the receiver, according as the time of the transmitter and receiver are varied, and it will be seen that the type of curve is just that of the law of probable error shown in the same diagram. When very much out of tune, the response in good oscillators is very small. Mr Marconi has found that while the s.s. "Philadelphia" received messages up to 1500 miles, the "Umbria," a day behind her, with untuned receiver, rapidly lost the ability to receive. On another occasion a receiver at 50 metres failed to respond, while a tuned one received up to 30 miles. But these are carefully chosen bad conditions. Approximate tuning will receive something, though not so much as perfect tuning.

Therefore the talk about complete isolation is idle. The number of stations that can be kept distinct is small, because a fair interval must be allowed between the periods of each to prevent overlapping, and when the octave is reached, or double the speed, the lower ones begin to respond again with the first harmonic, and the upper ones also respond to the lower. How many can be arranged depends on the probable variation of the waves; and if oscillators can be devised giving a pure tone like a tuning-fork, a great many might be used, provided that the stations are not very near together. But the sender can never prevent some one putting up a simple air wire near to the station, and picking up a small effect from the powerful discharges.

Systems.—There are many systems now being more or less tried, but four important and successful ones will be picked out—Marconi and Lodge, English; Slaby, German; and Fessenden, American. Their essential parts are shown in fig. 2.

Marconi uses a transformer for both sender and receiver. Sparks between the balls set up oscillations in the coil and condenser, which form an excellent oscillator.

The coil induces oscillating currents in the secondary coil at a high pressure, and these run up the air wire and down to earth.

Slaby and Lodge also use a coil and condenser oscillator, but Slaby puts his spark in the circuit, while Lodge connects his in parallel, as Marconi. The air wire in each of these is an extension or overflow, along which, and to earth, splashes of current flow. The additional coil in each is for accurate tuning, being made with a variable number of turns.

Fessenden uses the simple air wire with additional capacity and self-induction to increase the wave length and to permit of tuning.

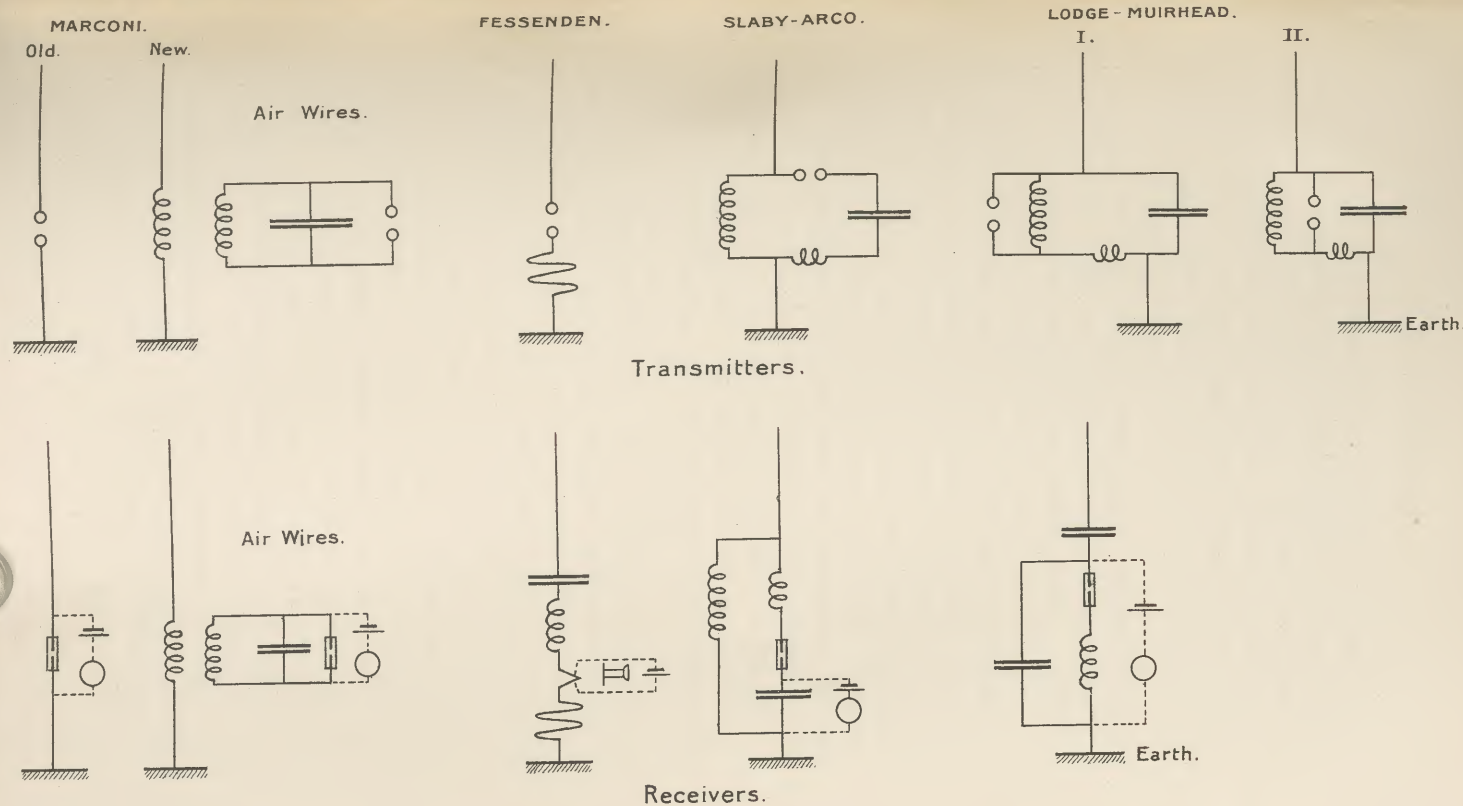
In receivers Marconi uses a coil in his air wire, which induces currents in a second coil. These oscillate between condenser and coil, and overflow into the coherer. The coherer and spark balls are similarly placed. Both air wire and second coil must be tuned to the transmitter.

Slaby collects the oscillations on the air wire, and these run into the oscillating circuit, stimulating oscillations in it. The coherer is in this circuit, which is not good, as its resistance is variable.

Lodge uses a condenser on his air wire for tuning by altering the capacity, and oscillations occur between condenser and coil, passing through the coherer. An additional condenser is shunted across coil and coherer, which he says does not enter into the main action, but protects the coherer from sudden current rushes from other causes, such as thunderstorms. Fessenden has a similar arrangement without the shunting condenser.

Stripped of non-essential parts and symmetrically arranged, it is seen that there is not great difference nor great complexity in the different systems.

Professor Braun of Strasburg reports that he can send



Professor BAILY on Wireless Telegraphy.

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any amount of energy into space and obtain perfect tuning and complete freedom from disturbance by other stations. Distance, therefore, is no difficulty. He can also direct the waves and send them as a beam along one path. All of these things have been confidently asserted before and still remain difficulties, so we may await further details, which at present he desires to keep unpublished.

Marconi, Slaby, and Lodge have shown the possibility of sending and receiving two or more messages at the same time from one station to another. Separate sending circuits of different pitch are all connected to one air wire, and the surging waves of each circuit run up and down independently. To the receiver air wire are connected the same number of receiving circuits correspondingly tuned. Each one picks up and absorbs the waves of its own pitch, discarding the others, and hence several messages can be sent at once. Hitherto only two messages at once have been thus sent and received over a few miles, but for short distances the method may be practically useful. The number of messages is limited by the overlapping, as was explained before.

This does not diminish the sensibility much, for the circuits out of tune will not allow the oscillating currents through their coils, whereas the self-induction of the proper circuit is lowered by the induced current, and the oscillations therefore pass through. The method may be compared to the response of piano wires, which take up and absorb the sounds with which they are in tune, while others pass over unaffected.

At the beginning of the paper it was stated that these radiations were the electro-magnetic waves discovered by Herz. But this is not strictly accurate, since the two stations are connected by the earth, which forms the one side of the oscillator. The charge in the air wire is stopped at the top, and gathers under pressure before running back. But in the earth there is no stop, and nothing to draw it back, and it will therefore continue to flow outwards in all directions in rings of alternately positive and negative electricity (not to enter into questions about the meaning of these terms), which, moving with the velocity of light, would constitute electric currents.

If they were started in a perfectly uniform medium, they would spread out in all directions uniformly in hemispherical waves, with possibly a slight tendency to additional strength at the surface of the earth; and they would run up any extension of the surface, such as an air wire. Being alternately positive and negative, they would produce oscillations in the wire, such as we have been considering, and if the time constant of the wire were correctly tuned, a considerable effect would be produced. As the rapidity of arrival of these waves is the same as the rapidity of emission of waves from the transmitter, the tuning will be the same for earth-borne waves and ether waves, so that the two may combine to produce an enlarged effect.

There will be a certain amount of damping of these waves, owing to the resistance of the earth; but when once beyond the immediate vicinity of the transmitter, the area of material becomes so vast that this resistance will probably not be of great importance. In fact it is in certain cases advantageous, for the sea has a very much lower resistance than the solid earth, and therefore the currents will tend to keep to the comparatively thin surface-layer of salt water, rather than penetrate into the depths of the earth. Radiating in all directions, their intensity will diminish as the square of the distance, neglecting the additional loss due to resistance; but if they keep entirely to the surface, the intensity will only fall off as the distance. The ether waves fall off as the square of the distance, with certain additional losses due to refraction and curvature of the earth. Therefore the surface waves would at great distances become more powerful than the ether waves, whatever they may be near at hand.

There are three observations which uphold this suggestion. One is, that while the earth is round and ether waves go in straight lines, still they will travel nearly a quarter round the globe, and hithero only the vaguest suggestions have been made to explain why they travel in circles, for the waves are small compared to the 3000 miles traversed. Also the signals are not obstructed by mountains and mountain chains, which should by reflexion and refraction make a mitigated shadow behind themselves.

The second is a more positive indication, viz., that while signalling over the sea is very good, signalling over land is not at all good, and signalling over fresh water is not good. Marconi's voyage to the Baltic seems to throw light on this. Signalling was good until they got right up to Cronstadt, where the water is almost fresh. But signals came freely over Norway, which is fairly mountainous. It is possible that they came principally round by the Baltic, the way the ship came, up the channel from Cornwall, across the North Sea and round the Baltic. It must be remembered they are travelling with the speed of light, and would be there in $\frac{1}{100}$ part of a second.

The third is that while over shortish distances the effects fall off as the square of the distances, this would scarcely permit of signalling to Canada. From 100 miles to 2000 means 400 times the power, which is not being used.

A certain element of difficulty arises from the possibility, and even probability, that interference would take place between the effects of the earth waves and those of the ether, if they did not travel with identically equal velocities, or did not travel over identically the same distance. Thus at certain points the effects would be added, and at other points midway between, the effects would be subtracted. Whether this is so or not, it is too early to say, since there are many other causes of imperfect response in long-distance working. But experiment on these lines should be capable of yielding information. Also the question how far the currents are confined to the sea might be tested by obtaining waves along the two different sea paths. Again interference should result, if there was any marked concentration of current at and near the surface. But these criticisms need not as yet be taken as objections to the theory, since the effect has not yet been looked for.

It may be that, if this is true, our sending and receiving apparatus should be modified; that height becomes of less importance compared with power, and that great capacity is the thing for long distance. Height is, however, important in getting the waves started, for a large flat plate over the earth would keep the opposite charge attracted to itself, whereas it must be free to travel off. We are reversing the order of things, and using the air wire as a convenient apparatus for sending off current waves through the earth. Marconi's inverted cone makes one suspect he has got the same idea himself, since that would be an excellent oscillator for discharging earth waves.

This suggestion must be looked upon only as an immature hypothesis, unsupported by any direct experiment, though some may be possible. Of course it is only a part of the action in any case, since ether waves undoubtedly do come into play, and with complete transmitters separate from the earth the ether wave is alone produced. It will be noted that the tuning will be the same in each case, since the earth waves will have the same time period.

Sir Oliver Lodge points out this effect, but suggests it is effective only at short distances. The author inclines to the belief that it is at long distances that its effect is chiefly noticed, though it is easy to show that it plays its part over very short distances.

It may be asked finally: What is the future of wireless telegraphy? Will it supplant land lines or submarine cables? With regard to land lines in populous countries no one will hesitate to say No. Babel would be nothing to the receiving office of a large telegraphic centre worked by wireless telegraphy. Ocean cables to isolated places may be supplanted; but allowing multiplex working over the Atlantic up to half a dozen messages, working at ten words per minute, which is very problematical, it would not do more than one Atlantic cable worked duplex. And it would interfere with all other applications over the British Isles and the Continent of Europe. Marconi's message to Canada is magnificent, but it is not business.

To ships and ports wireless telegraphy will be a priceless boon. And this surely offers a sufficient field for its application. We, as the greatest shippers in the world, should therefore take heed that this benefit be not lost for the sake of a petty competition for a tithe of the submarine cable work, which can be done much more surely by telegraphy with wires. When you can use a speaking-tube you do not need to shout; but if the tube is impossible, then shouting is the only means.

REPORT BY COMMITTEE.

Your Committee having carefully considered Professor Baily's theory as to the means whereby wireless telegraphic signals are conveyed, as contained in the communication made to the Society in February 1903, beg to report as follows:

Professor Baily suggests that the signals may perhaps be sometimes conveyed by the earth, and particularly by the sea, instead of solely by etheric electro-magnetic Hertzian waves; such currents liberated in the vicinity of the ocean would, owing to its comparatively great conductivity, largely pass along the salt water, and would not therefore diminish in intensity according to the square of the distance, but would only fall off as the distance; thus they would carry very much further than purely etheric disturbances. Professor Baily supports his suggestion by various observations, and in opposition to the views of Sir O. Lodge, who thinks this mode of transmission effective only for short distances. Professor Baily believes, and your Committee are inclined to agree with him, that it is effective chiefly for long distances.

Your Committee hope that Professor Baily may be able to put his suggestion to the test of some direct experiment, and they consider the Society is indebted to Professor Baily, not only for this hypothesis, but also for the lucid account he gave of wireless telegraphy, and which he illustrated with interesting experiments, and they beg to recommend the communication to the notice of the Publication and Prize Committees.

Archibald Wilson.
J. H. A. Macdonald.
Dawson Turner, *Convener.*

On High-Pressure Gas Lighting and the Scott Snell Lamp.
By C. Scott Snell, C.E.* (With Illustrations.)

Gas is delivered at present as a rich mixture of hydrocarbons and other elements incapable of combustion without the addition of air, and, but for practical drawbacks, could be changed, by the mere addition of air, into double its value for illuminating incandescent mantles. However, as long as gas is delivered in an unærated state, so long must supplementary means be used to add air at, or near the point of, combustion, and the present bunsen burner system is therefore in general service. In this, as is well known, the jet of issuing gas draws air, by its injector action, into the tube, and combustion ensues at the head of the burner.

It early became obvious that increased gas pressure would fulfil in a manner the requirements of large unit lighting; and the gas compressor system was installed. In this, the gas is delivered under pressure, and in consequence its injector action, or power to suck in more air, is increased. But such a system necessarily depends on the contour of the burner for its efficiency in sucking in air, hence there has followed a crop of patents for the shape of the burner bodies. With different shapes different pressures gave different results, and hence we see the existence to-day of compressor systems varying in their pressure from 9 inches of water column to 15 lbs. per square inch.

As the conditions of the struggle became better understood, they practically crystallised into the following:—The air delivered with the gas must bear such a proportion to the gas as to ensure perfect combustion. The velocity of the combined mixture must be such as to ensure a certain number of thermal units being brought into contact with a mantle of given size in a given period of time. The desirable velocity may have to be modified to suit the fragile nature of the mantle, in order to ensure reasonable life. Under these circumstances it appears to the author that the highest attainable efficiency can best be assured by arranging the

* Read and illustrated before the Society on 23rd February 1903.

two elements of combustion—gas and air—in separate circuits, each under separate control, so that (1) the correct proportion of air and gas can be obtained by adjustment, and (2) the correct volume of such mixture can be controlled and supplied to suit a particular size of mantle.

How this adjustability is effected in the Scott Snell system is readily understood from the adjustable burner illustrated in the diagram (fig. 1).

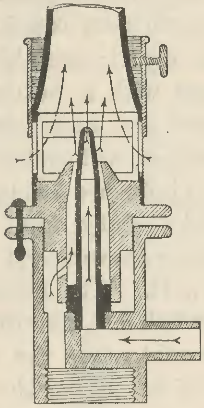


Fig. 1.

Fig. 2 shows the air-supplying part of the lamp, which may be described as involving a closed cylinder, or displacer (1), within a somewhat larger outer or containing cylinder (2), the latter being fitted with non-return inlet and outlet valves (5).

A spring at the head of the cylinder (2) takes the weight of the displacer (1), which nominally is thereby suspended at about mid-position. A diaphragm (4), or membrane, is attached at its periphery to the cylinder (2) or its appurtenances, and at its centre it is attached to the centre rod of the displacer (1).

This, with the addition of the necessary burner (20), and an air reservoir (3), to prevent violent fluctuation, completes the lamp; and as an engine or machine it is remarkable, inasmuch as the diaphragm (4) is the equivalent of, or, at any rate, admits the banishment of, any driving cylinder, crank-shaft, air-pump, fly-wheel, connecting-rod, or such-like accessories, which are usually involved in the attainment of compressed air from a heat-actuated motor.

When the apparatus is cold there is no resultant air delivery, even if the displacer (1) be moved by hand, but when the lower end of the cylinder (2) is heated, the lamp is self-actuating, and also delivers air under pressure to its reservoir (3).

Even those hitherto unacquainted with the action will readily grasp the principle upon examining the diagram, fig. 2, and remembering that any air assembling below the displacer (1) must be in contact with a heated metal surface, and, therefore, it will expand, and such heated air, if transferred to the cooler upper surface, will contract.

Expansion makes its influence felt upon the diaphragm (4), which it distends, and thereby lifts the displacer (1) yet higher, disturbing the air above it and transferring it to the increasing space below it. The hitherto cool air is in its turn heated and expanded, and, but for the existence of the outlet valve (5), it would cause the cylinder (2) to burst. However, it finds relief by lifting the outlet valve (5), and delivering the air into the reservoir (3), and thence to the burner nipple, where it applies forced draught to the burner (20).

The initial charge of air in the cylinder (2) is in due course exhausted, and the pressure lessens, allowing the displacer (1) to fall from the high level it had reached.

The fall is rapid and decided; the very first retrograde movement, in fact, caused some of the hitherto highly expanded air below the piston to assemble in the colder space above the displacer (1), where it was condensed, and so contributed to a further reduction in volume within the cylinder (2). A decided vacuum is thus set up, and the atmosphere presses down upon the diaphragm (4), thereby effectually depressing the displacer (1), and compressing its sustaining spring. If no further air could enter, this condition of vacuum would continue and produce a deadlock, but through the inlet valve (5) an inrush of air occurs, killing the vacuum and liberating the spring, which again recovers its normal position,

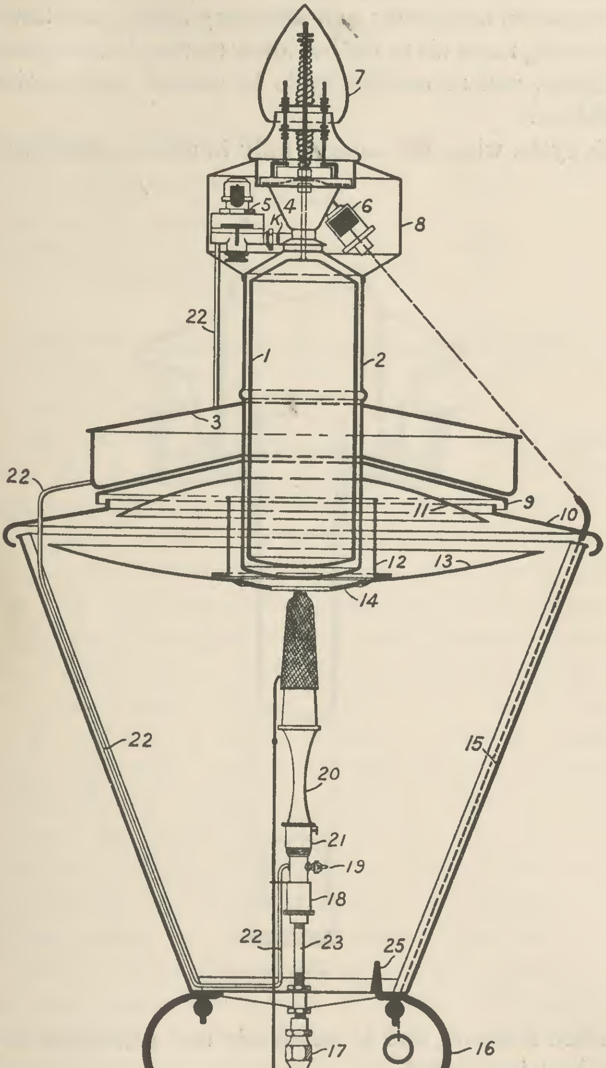


Fig. 2.

carrying the displacer (1) with it. In doing so, however, it has completed one cycle; and this very lifting movement, by transferring more air to the hot lower section, induces pressure once more, and so another cycle is started and motion is maintained.

This cycle, when the lamp is fully in action, takes place in

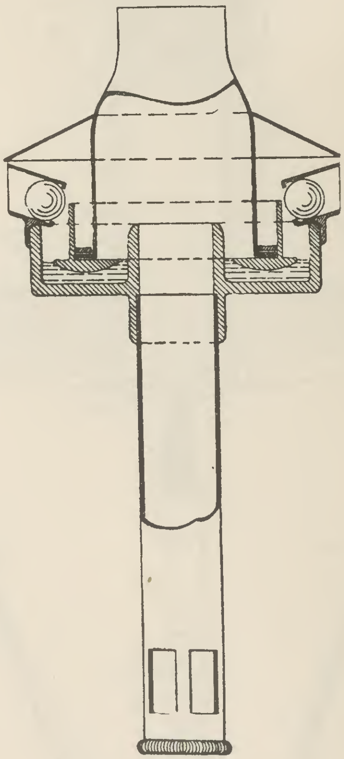


FIG. 3.

about half a second, and is automatic and continues as long as the heat is supplied.

A novel accessory is the anti-vibrator (fig. 3), by the use of which, in some situations where the life of a mantle was a day, the life has been prolonged to three weeks.

The results of trials with the Scott Snell lamp, made quite away from the author's control, are as follows:—

EXPERT PHOTOMETRICAL TESTS.

	Consumption of Gas per Hour.	Candle-Power.	Candle-Power per Cub. Ft. of Gas.
Consolidated Gas Co., New York, 19th March 1902	13½	572	42
People's Gas Light Co., Chicago, 23rd April 1902	13	548	42·1
Long Branch Co., Long Branch, N.J., 20th August 1902	13·06	562	43·1
New Amsterdam Gas Co., Ravenswood, L.I., 17th October 1902 .	12·9	544	42·1

The essential principle of the lamp being understood, its facility for lighting, under what may be considered a new system, will be readily seen.

This system consists in cutting down the lamp proper to a skeleton (fig. 4), just sufficient, in fact, to perform its functions, and arranging a single reservoir and a single relief, or pressure-governing, valve, to serve the series of lamps. This is convenient in connection with warehouses, drawing-offices, and such-like positions, and ensures the highest economy of gas, with the advantages of non-interference with existing system of gas supply or change in the normal gas pressure.

Let us assume that a row of lights of 500 to 600 candle-power is required to light counters, drawing-boards or benches. Each light consists of a burner similar in character to the No 4 Kern, for instance, but fitted with the combination air and gas nipple, whereby the gas consumption may be raised to 15 feet, and the light to 500 to 600 candles. These lights project from the wall, or are suspended from the ceiling, as may be desired, and have no connection whatever with the air-compressing section, except that each burner is fed with compressed air by a flexible air-supply pipe. Immediately over each burner, but in no wise in rigid mechanical connection therewith, is placed a "generator," or body of lamp, in order to utilise the heat in the escaping products of combustion to produce the necessary compressed air. This consists of only the cylinder and its accessories, *i.e.*, the valves, diaphragm and displacer. The motion which ensues from the application of heat, and the consequent delivery of compressed air, is used to supply air to a light-distributing tube attached to the wall, running along it, and fitted with suitable feeding nozzles to take the flexible connections for the burners. At the end of the tube may be fixed a small reservoir to check pulsation by "cushioning."

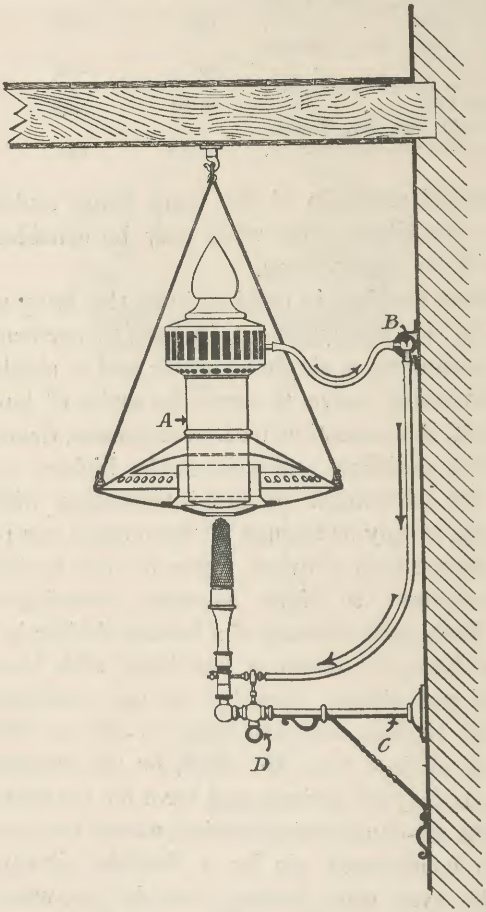


FIG. 4.

A relief valve prevents the generation of more than a pre-arranged air pressure in the circuit.

In this system the gas supply is in no wise affected, and no extra dangers are introduced; if desired, any burner can be arranged so that it can be cut out of circuit; that is, the air supply turned off and the gas reduced in volume until it forms merely the usual small unit unintensified light. This admits of economy where a few hands only are working late and where just a few "police" lights are to be kept going in an establishment all night. Each lamp as lighted supplies the necessary extra power to operate itself, and the cost for air is nil, whilst the economy of gas steps up from, say, 20 to 40 candles per cubic foot; in other words, it halves the gas bill for an equal light for low-pressure lighting.

The writer takes this opportunity of pointing out that gas lighting by incandescence has, in his opinion, not by any means reached finality. The advantages of permeation of air by gas, in contradistinction to mechanical mixtures, will become recognised, and the competition of gas with electricity will become considerably more formidable.

REPORT BY COMMITTEE.

Your Committee have examined this lamp, and beg to report as follows:—The lamp appears to possess the following advantages:—

1. It can replace the ordinary lantern without any modification of the standard or source of supply or complication in the method of use, while the efficiency is at least twice that of ordinary mantle burners, so that the extra cost of the lamp (about £4) will be more than repaid in one year's working in Street Lighting.

2. The novel part of the lamp lies essentially in the pump, which is particularly simple and inexpensive. The working parts are very durable, since there is a complete absence of friction. The diaphragm—the only part requiring renewal—is cheaply and easily replaced. Your Committee have no personal experience of the life of these diaphragms, but do not see any difficulty in obtaining a reasonable durability. The cost of upkeep, therefore, is not much greater than that of an ordinary lantern with mantles.

As a working heat engine the design is extremely ingenious and novel, and an important improvement on other similar apparatus. It may indeed be found very useful as a simple source of compressed air for small purposes in the arts.

3. The device for regulating the supply of air to the burner, both high pressure and atmospheric, is simple and most effective, and, when the gas pressure is governed, as is usual, the adjustment is made once and for all. The floating mercurial anti-vibrator deserves special mention, and your Committee gave this a severe test with satisfactory results.

4. Compared with other high-pressure systems, this has the great advantage of being self-contained, doing away with extra pipes in the case of high-pressure air, and avoiding the difficulties of leakage and cost of special service in the case of high-pressure gas.

Therefore for street lighting and other instances where the lamps are widely spaced, the Scott Snell self-contained compressor has decided advantages.

At the same time your Committee considered that the lighting of factories, etc., where a small amount of power can be readily obtained, the cost of compressor and special service either of compressed air or gas would not be greater than the extra cost of the Scott Snell lamp if a large number were required.

In conclusion, your Committee consider this invention of considerable value, and desire to recommend it to the favourable notice of the Prize and Publication Committee.

Francis G. Baily.
Henry O'Connor.
W. Carmichael Peebles, *Convener*.

ADDENDUM.

Your Committee notice a small difficulty in the lighting of these lamps in that there is a chance of the pump not starting automatically. The inventor has added a starting valve, to be operated by hand, in order to deal with this, but this entails that the lamplighter must stay by the lamp until it is seen to start, thus rendering the lighting of a large number of lamps a more lengthy process. It is, however, probable that this can be remedied, and in any case involves only a small extra expense in the cost of the lamplighter.

F. G. B.
H. O'C.

On the Measurement of Light and a new Photometer.

By Henry O'Connor, Assoc.M.Inst.C.E.* (With a Plate.)

(Abstract.)

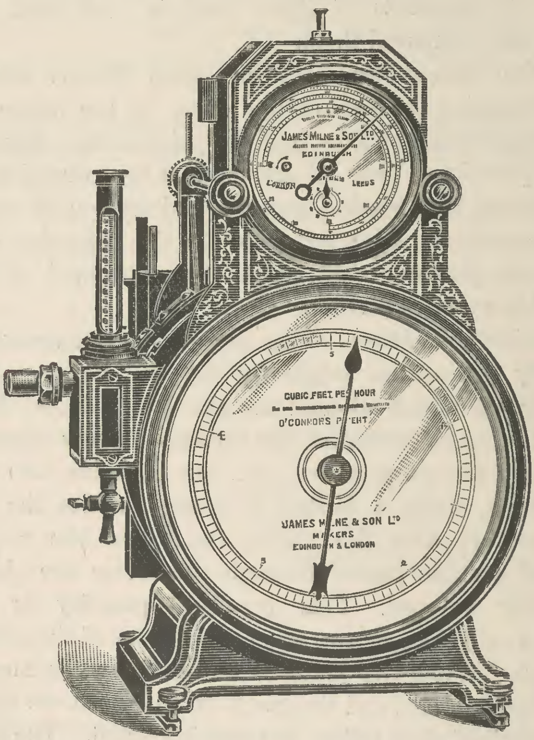
The author described the principle upon which the various pieces of apparatus for measuring light were constructed, and showed a number of photometers of different types. He then detailed the standards of light used in this and other countries, and compared them.

The author then showed his own patent *Plunger meter*, in which, by altering the level of the water in the meter, it is made to register fast or slow, and the pointer then shows the corrected quantity. Thus all calculations for corrections due to temperature, barometrical pressure and tension of aqueous vapour are avoided. This was a step in the reduction of the difficulties of photometrical work. (The method of using same was then described.)

Automatic Clock Meter.—This is a further improvement designed by the author originally for the Referees Table Photometer, and since adopted for the Extra Rapid Photometer. This meter contains the means already described for correcting for temperature, etc., but contains also other gearing which, when a button is pressed, starts the clock and connects it with the meter, and when the required quantity of gas has passed through the meter the clock is automatically stopped. This required quantity is two-twelfths of a cubic foot, or two exact revolutions of the cylinder of the meter. When this meter is in use a test is made as follows. The standard and the gas to be measured are lighted for the prescribed time before the test is started. The gas is turned down and then gradually raised until the two beams of light are considered equal, and a mark made on the scale of the quadrant cock where the pointer is found to be. The gas is then turned up too high and gradually reduced until the beams of light are again considered equal, and a second mark made on the scale. It will be found that these marks rarely coincide. Then the two operations are repeated and the

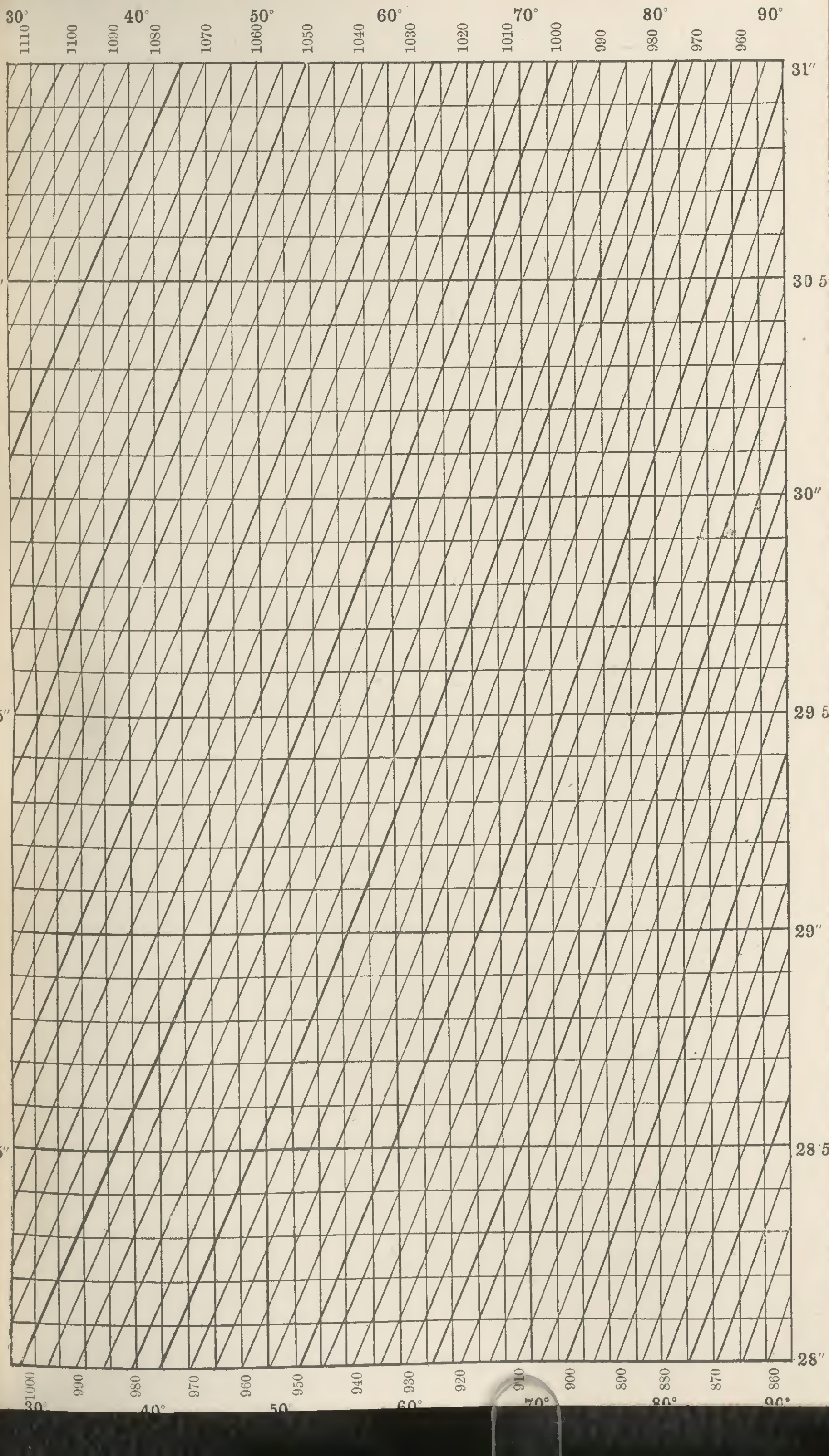
* Read and illustrated before the Society on 9th March 1903.

pointer set to the mean of the four marks. The button to start the clock is pressed, and after a period of about two minutes the clock will automatically stop. This occurs when exactly the two-twelfths of a cubic foot of gas has passed through the meter. As no further corrections are required, and the time taken to consume the gas indicates the illuminating power, the author has a second scale graduated in candle-



Automatic Clock Meter.

power, around the ordinary circle, showing seconds, and each period of $7\frac{1}{2}$ seconds equals 1 candle power with 16 candle power gas, and 4·8 seconds equals 1 candle power with 25 candle-power gas. The position where the clock hand stops thus indicates the exact candle power without any calculation, and the operation can be performed by any man with an eye capable of adjusting the two beams of light.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1110 1100 1090 1080 1070 1060 1050 1040 1030 1020 1010 1000 990 980 970 960
31″
30 5
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29 5
29″
28 5
28″
1000 990 980 970 960 950 940 930 920 910 900 890 880 870 860

The author has also adapted the same principle for the durability test, but in this case the time taken to pass one-twelfth cubic ft. is the measure of the illuminating power.

The testing of gas is thus reduced to an operation which any workman may perform, and for which no technical training or knowledge of mathematics is required.

In the testing of gas, corrections have to be made for variations in temperature, barometrical pressure and tension of aqueous vapour from the normal, which is 60° and 30°. Tables to simplify this have been made, and the Plate is a diagram constructed by the author for graphic use in this connection.

REPORT BY COMMITTEE.

Your Committee, having examined Mr O'Connor's paper on the measurement of light and a new photometer, and the apparatus therein described, beg to report as follows:—

We are of the opinion that the invention of the plunger meter for making simple corrections for the effects of variations of temperature and pressure of the gas from standard values is of distinct merit and ingenuity, and will be found of great ultility in gas-works, where frequent photometric readings are required. As the usual range of variation in working is not great, the corrections produced by the setting of the plungers should be of quite sufficient accuracy for the purposes of photometry.

We wish also to express our appreciation of the Automatic Clock Meter, as a further simplification of the process of taking readings. The operation is, in fact, reduced to the lowest limit of difficulty, and all calculations are eliminated, while there is nothing in the apparatus which entails expense or complexity of mechanism.

We have therefore pleasure in recommending these inventions to the favourable consideration of the Prize Committee.

With regard to the paper itself, a considerable portion is devoted to a description of well-known photometric appliances and methods, and we suggest that this part might be abbreviated, but that the tables of corrections for temperature and pressure shown by Mr O'Connor would be a convenient and valuable addition to the Proceedings, and we recommend their publication with the description of the inventions above mentioned.

R. M. Ferguson.
Alexander Frazer.
Francis G. Baily, *Convener.*

On the Application of Electricity to Coal Mining. By Alexander Ogilvie, B.Sc., Electrical Engineer.* (With Plates.)

In these times when one hears almost daily of some further special application of Electricity, or of improvement to existing forms in one or other of our national industries, it occurred to the author that it might be interesting to the members of the Society to have brought to their notice what has been and is being done in the application of electricity in the coal mines of this country.

In a general manner everyone is conscious that electricity has been utilised in coal mining, as in other large industries, but, beyond those directly interested—the mine owner and the manufacturing electrical engineer—it is probable that few are aware of the extent to which electricity has been used in this work. This is largely due, in the opinion of the author, to the fact that the region of work is underground, where access can only be gained with sometimes no small amount of personal discomfort.

It was not until the year 1870, the date of the original Gramme Patent, that what may be considered the first commercial continuous current dynamo was produced. The Siemens machine followed a few years later, so that the early seventies, one may say, were devoted to the establishing of simple continuous current machines. During this period the discovery was made that if current was conveyed from a dynamo to another similar machine, that machine would run

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* Read and illustrated before the Society on 23rd March 1903.

as a motor and give out mechanical energy. The application of electricity to all industries has therefore practically been confined to the last thirty years, and during this period rapid strides have been made in every direction.

Until comparatively recent years most installations in this country for generating electric energy for transmission of power have been of the continuous current type, shunt, series or compound machines being used according to the class of work to be performed. It is, in fact, only within the last few years that polyphase alternating currents—usually either two or three phase—have been adopted in this country for the transmission of electric energy, although they have been used very largely for some years on the Continent and in the Colonies. The consideration of their advantages and the large possibilities of their use is, however, far too extensive a subject to enter into in this paper, and, moreover, very few collieries in this country are as yet using multiphase transmission. The author proposes, therefore, to confine his remarks almost entirely to the applications of continuous current in the coal pit, as, after all, the applications in both systems are alike, differing only in details more or less of an electrical nature.

The first possibility which appealed to the coal owner was the introduction of electric light to the pit bottom and main roads, as well as to the pit banks, sidings, yards and offices. As in the earlier stages the introduction of electric light was largely experimental, we find that it was usual then for coal owners, with a view to economy, to purchase a continuous current dynamo and drive it by belt from some of the auxiliary engines on the surface, or if a suitable engine was already working at the pit bottom it was arranged to drive the dynamo from it and thus do away with any electric cables leading down the main shaft. As the reliability of the dynamo increased, we find the coal owner arranging to drive the dynamo from a slow-speed, often second-hand horizontal engine housed in a separate shed adjacent to the main shaft. As the demand for electric power in the pit arose, with the various applications for driving machines, it came to be essential, where electric power was to be adopted, to provide a suitable engine-room for the engines and dynamos near the pithead. The dynamos nowadays are driven either by belt or rope from slow-speed economic high-class horizontal engines, or are coupled direct to the shafts of high-speed vertical engines, termed "*Combined Sets*" (fig. 1). Where floor space is a consideration the "Combined Set" has the advantage, as the space occupied by it is a minimum, and also a spare or 'Standby' set, an essential to guard against breakdowns, does not occupy much space.

If lighting, hauling, pumping and coal-cutting are to be performed, then the dynamos are usually arranged for parallel working. If, however, only *large* motors are required, each working separate machines, such as pumps, then it is better, probably, to have a separate series-wound generator on surface, working through separate connecting mains to *each series-wound* motor at the pump in the pit.

The mains from the terminals of the several dynamos or generators are led to the engine-room switch board, on which is mounted a double pole switch, double pole fuses, an ammeter, and a voltmeter for each dynamo or unit. On this board is also arranged coupling bus bars, so that any of the dynamos, including the "spare" or "standby" dynamo, can be thrown on to any one of the pit circuits as desired.

The various pairs of main cables are then led to the pit shaft. If the distance is considerable, then bare ærial conductors on insulators fixed to poles in the usual manner are used, but as the engine-room is almost always quite near to the pithead, the cables are usually of the insulated class and protected in wood casings or iron pipes. There are practically two classes of insulation adopted in these main cables—(1) Vulcanised Rubber, or (2) Bituminous Compounds with paper or jute covering.

The former is more expensive, and therefore suitable for smaller class of cables.

The latter (Bituminous) class is cheaper, and is usually adopted for the heavy mains leading down the pit.

These mains are commonly of the concentric type—lead covered and protected mechanically by wrappings of either steel tape or galvanised iron wires. They are conveyed down the pit shaft in one of the following four methods, in all cases being kept as far as possible out of the region of damage from falling coal, etc.:—

1. *Fixed to insulators* securely fastened to the side of the shaft at intervals near enough one another to take up the weight of the cables.

2. If heavily armoured, then *cleated at intervals* to the wall of the shaft by stout iron cleats, which grip the cables and so take up their weight.

3. *Run in wood casings,* say run down the sides of the guides for the cage.

4. *Run in iron pipes* securely fastened to the wall of the shaft. Inserted every fifty yards or so in these pipes is a cast-iron junction box with watertight connections to the pipes and with watertight lid. These boxes contain a junction board with mechanical connections, so that the weight of the cable is taken up and any fault can be easily localised and repaired.

The question of how best to convey the power and lighting cables to the pit bottom is a most important one, and should be carefully considered for each particular case. In this connection one should bear in mind that the two most common sources of trouble are: (1) *water* breaking down the insulation, setting up chemical action with the copper conductor, and eventually causing it to break, and (2) *falling coal* from the loaded hutches breaking the cable or its supports.

The mains on reaching the pit bottom are usually terminated in some form of distributing switchboard, well protected and fixed in as dry a place as possible. From this board sub-main cables are led to the various sections of the pit to be supplied with electrical energy. Each section should have one or more pairs of mains, led through fuses and double pole switch, so as to reduce to a minimum the risk of total failure of power in any one section. These branch mains leading through the workings are carried on the sides, or roof, hung loosely on insulators. In the main roads, where movement of the strata has ceased, the cables are sometimes buried 6 inches to 12 inches below the surface in iron pipes or in wood troughs filled in solid with bitumen.

In pits where the workings are one, two, three, or more miles from the pithead the loss due to transmission has to be carefully considered. The question comes to be what power is to be lost in overcoming the resistance of the cable, and this is determined by the size of the cable adopted. It becomes largely a commercial consideration, as the smaller the cable the more power is wasted, while the larger the cable the less power is wasted, but the initial cost is increased. In practice the percentage loss of pressure allowed in the mains in pit work varies from 5 per cent. to 20 per cent. or sometimes even more.

One can easily understand, then, how in long distances the initial cost of the large copper conductors required to keep the loss of voltage down to economic limits becomes very considerable.

As the distance increases from the generating station to the furthest motor or lamp in the workings, the voltage at the station must be increased. The limit to this increase, however, in continuous current working is from 500 to 600 volts, as it is not desirable to have a higher voltage than about 500 volts on any machine in the pit which men have to operate.

It is in dealing with transmissions of, say, three miles and over that the undoubted efficiency and economy of multiphase currents comes in.

Having now briefly considered some of the chief points which appear in conveying electrical energy to the pit bottom, let us pass on to its various uses and applications there.

I. *The lighting of the pit* was one of the first of these, and generally the methods adopted are similar to those with which everyone is nowadays more or less familiar.

For the pithead, banks, sidings, etc., *arc* lamps were greatly used at first, but owing to the amount of attendance required in trimming them and the liability of the ever-present finely divided coal dust clogging the mechanism and moving parts, one now often finds clusters of incandescent lamps taking the place of the arc lamps. The lamps, whether arcs or incandescents, are suspended from poles in the usual manner, these poles carrying the cross-tree with insulators for supporting the ærial wire. When incandescent lamps are used they are enclosed in the type of fitting largely used on board ship—either a short square-kneed stout brass guarded bracket or a pendant—and, indeed, this class of fitting is used throughout the main roads at the pit bottom as being strong, simple and fairly cheap.

At the workings the fitting is usually dispensed with, and the simple lamp and holder tapped on to, and hung from, the branch wires.

Generally the lights in the pit are tapped off the nearest power circuit, in which case they are arranged in groups of three, four, five, or even six lamps in series, according to the voltage used, each group being arranged to switch in and out together. The disadvantages of such an arrangement are that if one lamp gives way all the lamps in its group go out, and again with the stopping and starting of large motors on the same circuit the lamps are submitted to sudden increase in voltage which shortens their life. To reduce the effect of this the author has sometimes seen an extra lamp put in the series, so that the lamps are "underrun." The light is accordingly reduced somewhat, but the life of the lamp is much increased. Sometimes the lighting throughout the pit is of sufficient magnitude to warrant a separate generator being used for this, in which case separate lighting mains are led from the generator to the switchboard and on to the pit bottom and workings. The lamps can then be safely worked up to their full candle power, and worked independently of the power circuits. There is no doubt that with well-lit main roads and workings the work is carried on both more quickly and safely and the coal output increased accordingly.

Portable electric hand safety lamps are also used by the miners for lighting at the coal face, but one disadvantage to this form of lamp is that it will not indicate the presence of gas, as the oil lamp does.

II. Let us now consider the most important application of electricity in coal mining, namely, the driving by means of electric motor the various plants or machines employed for *pumping, hauling, coal cutting and ventilating.*

The electric motor, by which power is transmitted to these machines, is now almost universally of the protected or enclosed type, as illustrated, and often so thoroughly enclosed as to be gas-tight (fig. 2). The windings of the continuous current motors are either series, shunt, or compound, according to the work to be performed.

In the *series motor* the "Torque" or moment of the force causing rotation is greatest at starting, and the speed varies with the load. Where a large turning movement is required at the start, and a fairly uniform load obtained afterwards, the series motor is used. Such is the case usually in pumps where at start the friction of the bearings, gearings, etc., of the pump and of setting the long column of water in motion has to be overcome.

In the *shunt motor* the speed remains fairly constant with varying loads, but it is not so well suited as a series motor for starting under a heavy torque. A starting resistance is required by which the field circuit is first closed and the armature brought up to its speed gradually.

In the *compound wound motor* a combination of the starting power of the series winding with the speed regulation of the shunt winding is obtained.

Pumping.—For the conveying of the water, which collects throughout the mine, to the surface, various types of pumps are employed, and the driving of such *pumps* in the mine by means of electric motors is one of the most common applications of electricity.

The pumps are usually either of the *ram* or *centrifugal type.* Double ram pumps are sometimes used, but the three-throw ram pumps are by far the most common. In them the rams are worked from three cranks set at angles of 120° on the shaft, thus securing a more uniform delivery and a more equal strain on the gear.

The piston speed of the three-throw pump varies from 50 to 100 feet per minute, so that even using a slow-speed motor, which is most desirable although more costly, a considerable reduction in speed has to be arranged.

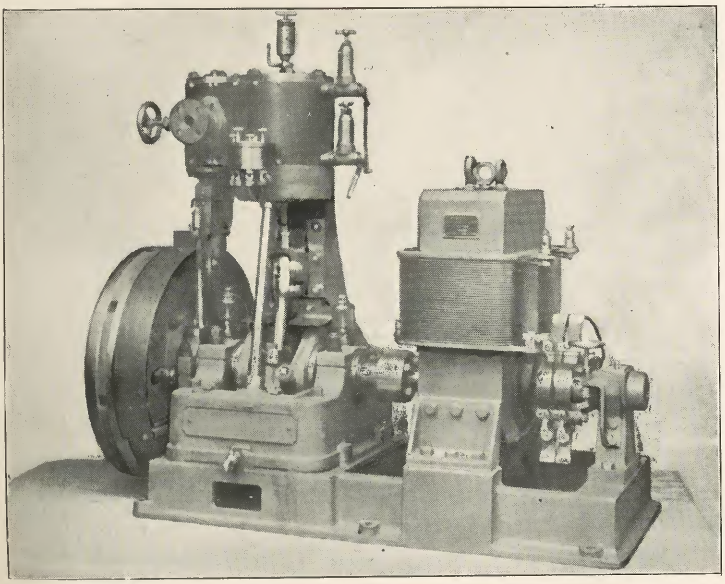

Fig. 1.—Combined set.

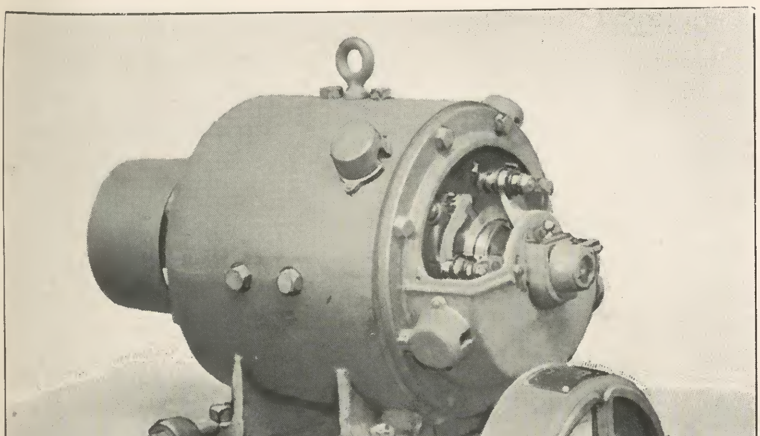

Fig. 2.—Electric Motor (enclosed type).

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This is obtained in one of three usual ways:—

1. *Rope and belt drive.*
2. *By spur gearing.*
3. *By worm and worm wheel.*

If space is not limited, then rope or belt drive is often used, which also gives an elastic drive and tends largely to reduce the shock on the armature and pump on starting. The motor and pump are fixed to foundations in a pump chamber at such a distance apart as to give a good drive, and they are then coupled by means of a belt or ropes in the usual manner.

In some cases, however, the atmospheric conditions do not permit of the satisfactory driving by belt or rope, and then either spur or worm gearing has to be adopted.

In cases where the space is limited then spur gearing is used, the speed of the motor being reduced by driving through two sets of spur wheels and pinions, or what is commonly called a "double reduction." The motor gearing and three-throw ram pump are mounted on one bedplate, and a compact pumping set, as illustrated (fig. 3), is thus obtained. One of the sets of spur wheels and pinions may be dispensed with and the latter part of the reduction of speed obtained by a belt drive, when an elastic drive is again obtained.

In large sizes of pumps driven by spur gearing helical teeth are usually employed, and sometimes a drive to each end of the crank shaft is arranged so as to give a more uniform drive. The teeth of the gear wheels are often machine-cut, and raw-hide pinions with steel shrouds have been used on the motor shafts to reduce the noise.

Where it is desired to reduce the space occupied by the pump and motor still further, then worm gearing, in a bath of oil, is sometimes adopted, but this arrangement is not so efficient as spur gearing.

Pumps driven in some of the foregoing manners are fixed in pump chambers throughout the pit, from whence the water is removed in cast-iron pipes to the surface. Sometimes these pump chambers are built off the main shaft some distance from the pit bottom, so as to catch the water before it silts through to the workings and thus save power in reducing the vertical height to be raised. For removing water from the advancing face of the workings the electrically-driven pump is most suitable, as pump and motor can be mounted on a small bogie and run out quite near the water. A flexible length of hose leads the water to the pump, and a flexible cable conveys the current from the nearest junction box to the motor. The portability of such an arrangement renders it specially useful in such work, and this is also very marked in driving sinking pumps, where the motor is usually fitted on the upper part of a framing and drives down by means of double reduction spur gear to the three-throw ram pump below.

For pumping against low heads and dealing with muddy and gritty water *centrifugal pumps* are largely used, and these have the further advantage in that they can be coupled direct to the armature shaft (fig. 4). When working against low heads the efficiency of a centrifugal pump compares quite favourably with that of a ram pump, but they are not used for heads of more than 40 to 50 feet. If a higher head is required, then sometimes two or more centrifugal pumps are worked in series so as to build up the pressure, as it were. The quadruple centrifugal pump and motor illustrated was made by Messrs Scott & Mountain for Messrs The Lothian Coal Company.

The efficiency of transmission in electrically-driven pumps *i.e.*, the H.P. in water lifted compared with E.H.P. at the dynamo terminals, usually varies from 60 per cent. to 70 per cent., and sometimes higher.

Haulage plants.—The success which attended the use of electricity for driving pumps was such as to warrant the extension of the employment of electric motors to the driving of the various forms of haulage plants. For bringing the coal from the working face to the pit bottom either rope or horse haulage is used, and we find electricity now largely employed for both of these.

In the case of the rope haulage electric motors are employed to drive the winding drums by either belt or gearing, as in the case of pumps, while under certain conditions the horse is replaced by electric mine locomotives.

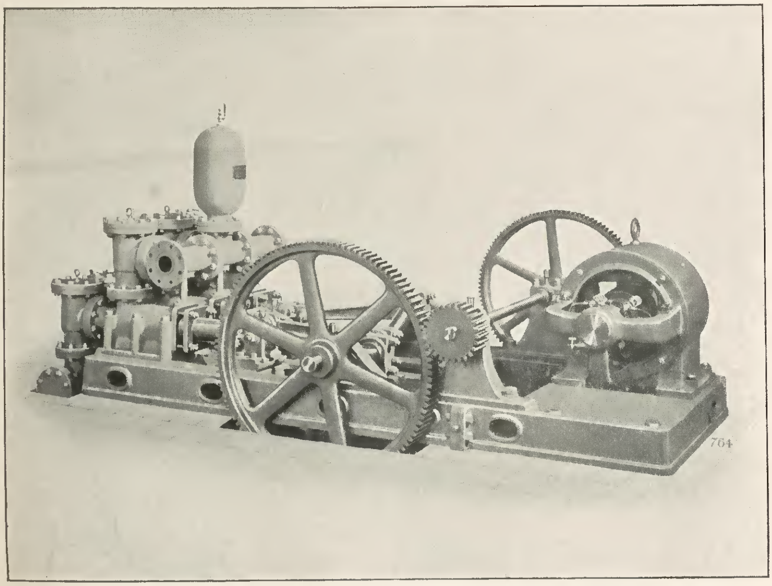


Fig. 3.—Three-throw Ram Pump and Electric Motor.

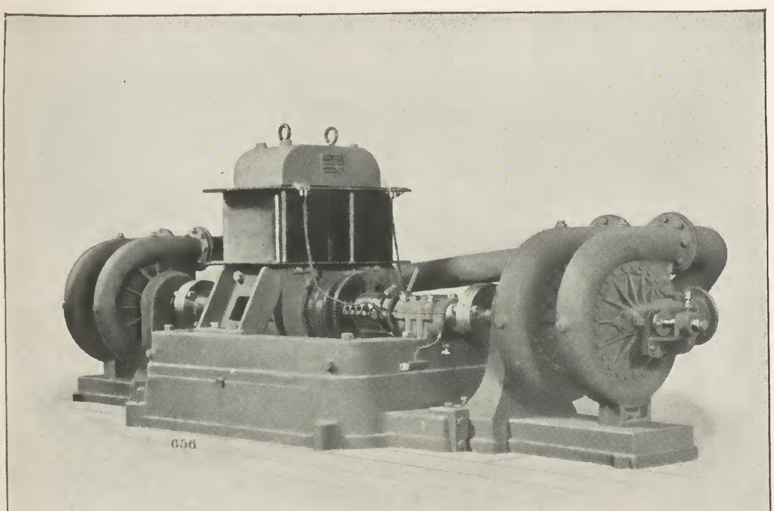


Fig. 4.—Centrifugal Pump and Motor.

Mr Alexander Ogilvie, B.Sc.

The various forms of rope haulage are :—

1. *Single rope haulage,*
2. *Main and tail rope haulage,*
3. *Endless rope haulage,*

each of which is specially suitable for the various conditions usually met with in pit work.

1. *Single rope.*—Where the coal face lies to the dip of the shaft, then the empty hutches are allowed to run down by gravity, and after being filled with coal they are pulled up the incline by the winding drum. The electric motor, as in the case of the pumps, drives on to the winding drum by means of worm gearing, spur gearing, belt, or rope. A large reduction in speed being required between the motor and the drum, a combination of spur gearing and belt drive is often adopted, so that the elasticity of the belt may tend to reduce shock to the motor on starting. With spur gearing alone a double reduction is required, but with worm gearing the reduction in speed is obtained with one reduction. Here also the noise is diminished, but, as stated before, the efficiency is usually less than with spur gearing. In either arrangement the drum is mounted loose on the shaft, and is thrown into gear by a friction clutch after the motor and gearing have got up to their speed. A powerful band brake is fitted to the drum, and this is actuated by foot or hand by the attendant in rear of the gear. This brake must be powerful enough to hold the train of loaded hutches on any part of the gradient—in case of any breakdown to motor or gearing during haulage. Where the gradient varies, then the coal hutches have to be pulled both in and out from the face, for which two drums are required. This is what is called (2) *a main and tail rope haulage* (fig. 5). The main rope from one of the drums passes down the dook and is attached to the train of hutches to be brought out from the face. The tail rope is attached to the end of the train of hutches. and after passing round a pulley at the end of the dook it returns to the other drum.. Each drum is provided with a friction clutch, so that after the motor has attained its speed the clutch is thrown in on either the main or the tail rope drum, according

as to whether the full hutches are to be pulled out or the empty ones pulled in. Both drums are fitted with powerful band brakes, as before, operated either by foot or hand. The illustration shows such a gear in position, where the motor drives by rope and spur gear on to the drum shaft. Where it is not possible to arrange for a belt drive, a combination of worm and spur gearing is sometimes used. The main and tail rope haulage are usually worked where single lines of rails only can be arranged for, and the speed may be anything from four or five miles per hour up to ten if the roads are good and the lines well laid.

3. *Endless rope haulage* is used on roads which are fairly straight and on which a double line of rails can be fixed (fig. 6). The rails are laid side by side, and an endless rope passes down the centre of one set and up the centre of the other, motion to the rope being derived from a large rope wheel round which the rope passes. This rope wheel is driven from the motor through the various types of gears already mentioned, but as the speed of the rope does not usually exceed two miles per hour, a high ratio of reduction is necessary. With spur gearing three reductions are usually required, but one of these can be replaced by using a belt or rope drive as before. The strain on the motor, however, is in this case much more uniform, so that the necessity for a rope drive is perhaps not so great. By worm and worm wheel the reduction can be obtained in one step, and a more compact gear obtained. The rope wheel, of a good large diameter, is usually fitted with renewable chilled cast-iron segments, securely fastened to the wheel, so that they can be easily renewed as required. Such gears are arranged on one bedplate for working one, two or even three roads, each rope-wheel being complete in itself with its own rope, friction clutch and friction brake. The gear illustrated is for two roads, the motor driving by rope and spur gear on to the rope-wheel shaft; both this and the immediately preceding illustration being of Messrs Scott & Mountain's machines.

In the case of an endless rope system there is a continuous delivery of coal to the pit bottom. The full hutches are attached one after another to the moving rope, conveyed to

Fig. 5.—Main- and Tail-Rope Haulage.

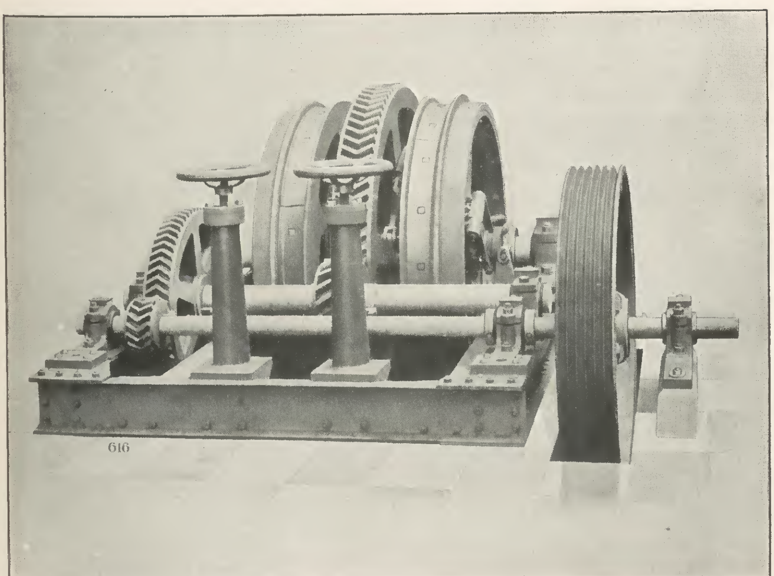


Fig. 6.—Endless-rope Haulage Gear.

the pit bottom, emptied, and returned to the working face. In the main and tail rope system a train of full hutches has to be made up, then pulled out and the empties pulled back, so that intervals of idleness of the haulage gear occur.

Electric locomotives have been used to a small extent for mine haulage in this country and to a considerable and increasing extent in America. There it is computed that some 600 or 700 mine locos are in use now, and the present rate of increase is put down at over 100 per annum. They are particularly applicable for dealing with the mining of American bituminous coal, which, the author is given to understand, occurs in thin and nearly horizontal seams extending over large areas usually near the surface.

One of the earliest American electric mine locos appears to have been built in the year 1889, and it is interesting to note that the following year there was made in this city an electric loco which was fitted, and worked for some time, in a coal pit in Midlothian.

During the 90's the electric loco for mine use evolved, until we have now arrived at the compact machine, as illustrated, where a Westinghouse mining locomotive is shown hauling its train of coal hutches (fig. 7).

In the earlier designs one motor was used, and this geared through an intermediate shaft on to one or both of the two wheel axles. Now, however, two motors are almost always fitted, supported separately on springs and one geared to each of the two axles. The gearing is a single reduction one, enclosed in tight metal casings fixed to the motor. The motors are of the enclosed type, usually four pole with slotted core armature, and generally of the approved railway design. The frame usually consists of heavy cast-iron sides bolted together by end pieces. The motors obtain their current from bare hard drawn overhead copper wires supported from insulators at suitable distances apart. The well-known trolley pole, as in tramcars, is used for conveying current from the overhead wire to the motor, and the rails usually form the return conductor.

The controller has starting and reversing handles; it is provided with speed regulating resistances, and is mounted on the end of the loco. Alongside of this is the brake wheel, which actuates powerful brakes usually on all four wheels. An electric light in a guarded oyster or bulkhead fitting fixed to the front of the loco completes the machine.

The weight of these locos runs from 2 to 15 tons, 8 to 10 tons being a common size. This weight entails the making of good solid roads on which the rails and sleepers are laid. The gauge is usually 30 inches or 36 inches, and the speed of the loco and loaded train of hutches runs from six to ten miles per hour. Continuous current is always adopted, and the pressure should not exceed 500 volts, although 250 volts seem to be preferable as diminishing risk of shocks where the conductors are bare and within easy reach.

In thin seams lying between hard rock the low head room required by such a loco is greatly in its favour, as every additional inch required for the roadways involves increased expense in rock cutting. This is one of the points where electric mine locos have the pull over the compressed air loco, which, carrying its own energy in large tanks of compressed air, is a cumbrous machine requiring large head and side room. Where again, however, there is any risk of gas in a pit, then electric locos are out of the question owing to the occasional sparking at the trolley wheel, and compressed air locos are then the only safe form which can be adopted.

The height of electric mine locos varies from 30 ins. to 36 ins., length from 10 ft. to 12 ft., and width from 42 ins. to 56 ins.

As an example of the use of electric mine locos in America, the author understands that at the Eureka Mines there are in regular service thirty-two locos, weighing each 13 tons. They can haul forty-five loaded cars up a 2½ per cent. grade, each car weighing 1½ tons gross. Each loco hauls 500 tons of coal per day, making eleven trips on a regular time schedule Each train has one driver and one trainsman.

Cost of haulage with mule, 10 cents. per ton.

Do. do. el. loco, one cent. per ton.

This, however, seems exceptional, as the admitted saving is usually stated at from 4 to 5 cents., or 2d. to 2½d. per ton, or just about half of that claimed in the Eureka Mines.

Coal cutting.—We come now to the next, and probably the most important, application of electricity to mining, namely, the driving of machines for "getting" the coal.

During the past 140 years or so mining engineers have been working at the production of a machine which will "hole" under or in the coal mechanically, and thus do away with the ordinary method of holing by hand, and the numbers and types of machines patented for this purpose are legion. The application of electricity to driving some of the best of these is, of course, recent, and dates back only some fifteen years or so.

The earliest attempt at getting coal by mechanical means was made by a Mr Michael Menzies of Newcastle-on-Tyne in the year 1761. The power was to be either steam or "fire" engine, water or windmill, and the method was to carry heavy chains down the pit by which motion was given to heavy iron picks or chains carrying cutting tools. During the next 100 years a large number of patents were taken out by numerous inventors, many being most interesting and novel. In 1861 Mr Wm. Firth, West Ardsley Colliery, Yorkshire, brought out what might be called the first successful coal-cutter from a practical point of view. This machine was called "The Iron Man," and in it the to-and-fro motion of the piston rod of a 7-inch cylinder with a 15-inch stroke, was transmitted by a connecting rod to the pick arm, which carried two picks at its far end. It holed to a depth of from 2 ft. 6 ins. to 4 ft. at an average rate of 4 to 5 yards along the face per hour.

Swinging pick machines continued to be used and improved upon until a rotary form was introduced. In 1869 Mr Hurd, sen., father of the patentee of the *bar* coal-cutter, brought out the first practical chain coal-cutting machine, although various forms of chains had been tried as early as 1853. In Mr Hurd's machine the cutters were attached to an endless chain carried round a projecting arm or jib which cut into and under the coal seam. This machine appears not to have come into practical use, and it fell to Baird & Co. of Glasgow to bring out the first practical chain coal-cutter in the year 1872.

These machines were made at Baird's Gartsherry Iron Works, Coatbridge, and were used for a number of years in their own coal pits and elsewhere. Compressed air was used to drive a two cylinder engine 6 ins. diam. and 9 ins. stroke—motion being transmitted to the chain wheel by spur and bevel gearing. The machine also drew itself along the pavement by a chain on a drum driven by toothed wheel and ratchet. The depth of the cut was 3 feet, and the cost of getting the coal was stated at 3s. 1¾d. per ton. The machine was withdrawn eventually, principally owing to the attitude of the miners.

About this period (1872) Messrs Gillot & Copley further improved their first 1868 patent, in which the cutters were carried on the periphery of a disc wheel revolving on a vertical axis. This machine was driven by compressed air and cut in under the coal seam, its action being, in fact, like a circular saw working on a horizontal plane.

Then came the Rigg & Meiklejohn, and the Yorkshire Engine Co.'s machines, both similar disc machines driven by compressed air. By this time the electric motor was in its early stages, and in 1887, at Bowers Colliery, near Leeds, a machine was designed, the motive power being electricity. The electric motor, etc., of this coal-cutter was arranged by Messrs Goolden & Trotter, and from then onwards the electric motor has been largely used in place of compressed air for driving coal-cutting machines. The efficiency of compressed air machines, including transmission, works out at anything from 30 per cent. to 50 per cent., whereas with the electric motor the efficiency, including transmission, is of the 60 per cent. to 70 per cent. order. This is therefore a very great consideration in favour of electric driving, but, again, if there is any liability to gas being given off in a pit, the compressed air drive is, the author thinks, the only safe method, although some engineers claim that absolute safety can be secured by using gas-tight electric motors. Advantage can be taken of the higher efficiency of electric transmission over the compressed air, by conveying the power electrically to the foot of such a pit, and as far in-bye as is safely possible, where it would be converted by means of an electric motor driving an air compressor. From this compressor the air is led to the compressed air coal-cutting machine at the face, thus removing all risk of firing the gas. With the compressed air drive also the air at the face is improved by the exhaust of the engine.

In this country there are two methods of working the coal, viz.:—

1. Pillar and stall. | 2. Longwall.

In the *pillar and stall method*, or, as it is called in Scotland, *stoop and room*, a series of parallel cuttings are driven into the coal face at intervals, so as to leave ribs or pillars between them to support the roof. These stalls are usually 4 to 5 yards wide, the width of the pillars being controlled by the condition of the roof. One disadvantage of this method of working is that a considerable quantity of the coal seam is lost owing to the pillars having to be left.

In the *longwall* method of working, as the name implies, the coal is removed at once from a long, straight face several hundred yards in length, if possible. This system is most suited for coal-cutting by machine, the machine travelling along the face, and either *under-cutting* or *over-cutting* the coal along the bottom or the top of the seam respectively. The cut is made either in the coal dirt or shale above and below the seam, or in the coal itself, according to the conditions of the seam (fig. 8).

The coal is then pulled down, broken up, filled into hutches, and removed to the pit bottom and thence to the pithead.

A cubic yard of coal when in the seam weighs 2133 lbs., or almost a ton, and the depth of the cut varies from 3 to 5, or sometimes 6, feet. A free space of 6 feet or so is required along the face, and the roof above this space is usually held up by a double row of props. This arrangement gives the maximum quantity of coal, and, further, the coal is not so much broken up. Gates and roads at right angles to the face are left at intervals of, say, 50 yards, and along these the coal is removed. The branch cables are joined to the main cables at these gates and led down the roads to the working face, where they terminate in a double-poled switch and fuse contained in an iron box fixed to the side of the road. Suitable plug connections are arranged in this box, and from these the cables to the motors are led—either two single cables or a concentric cable, which is sometimes also armoured. As the coal-cutter progresses along the face, the flexible connections to the motor are removed from one connection box to the next, and so on. Before considering the types of coal-cutting machines to which electric driving has been successfully applied, the author desires to briefly state the main advantages claimed for coal-cutting by machinery over "holing" by hand.

1. The rate of under-cutting is much increased—a good workman in a ten hours' shift will hole 4 to 5 yards of face to a depth of 3 feet, whereas a longwall coal-cutter employing three men will undercut 80 to 100 yards in that time.

2. The back of the cut by hand is irregular, but by machine it is straight, thus maintaining a straight face. Also, according to some authorities, the coal is more easily pulled down when "machine undercut."

3. The saving in amount of the waste or "slack" is great, as can be seen by reference to the illustration, which shows under-cutting in a 30-inch seam to a depth of 5 feet: (1) by hand, and (2) by machine (fig. 9).

Here the amount of slack by "hand" holing is $3\frac{1}{2}$ times that by the "machine," and for every yard of face this represents 1260 lbs., or over $\frac{1}{2}$ ton of coal, taking 80 lbs. as being the weight of a cubic foot of coal. The smaller the width of the seam the greater is the percentage loss of coal, so that in narrow seams of from 20 to 30 inches the loss by hand holing is such as to make the seams unworkable at a profit save by machines. In the seam shown (30-inch) the wastage is 42 per cent. by "hand" holing but only $11\frac{1}{2}$ per cent. by machine cutter.

4. Owing to the increased rate of cutting by machine, a larger amount of coal is obtained on a shorter length of face. This concentrates the working and reduces the length of roads to keep open and the distance over which the coal hutches have to be hauled.

5. The machine can be arranged to cut at any height from the pavement to suit the position of the good coal seam.

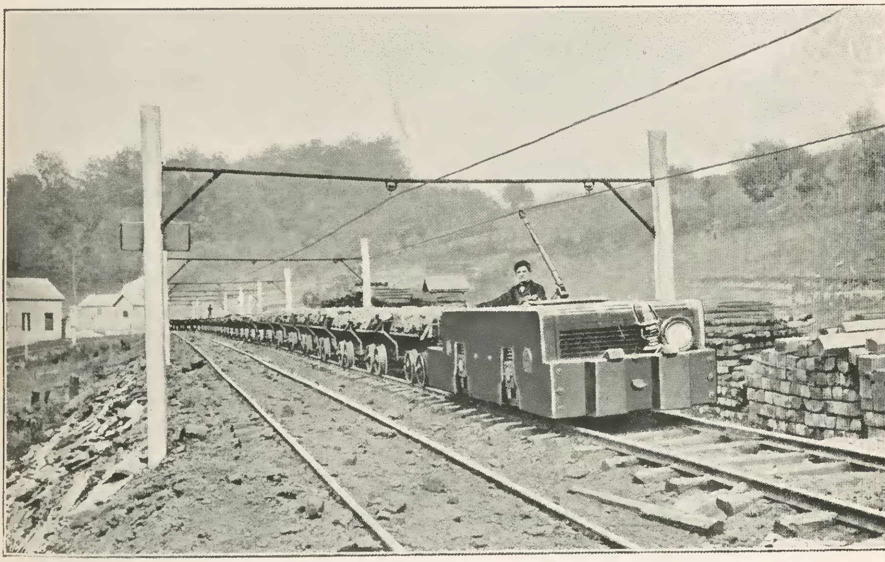
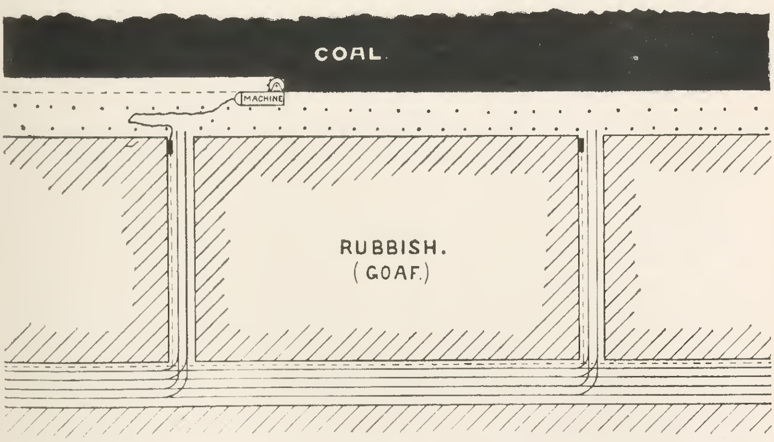


Fig. 7.—Westinghouse Mining Locomotive.



Longwall Working.

Fig. 8.

6. Owing to the comparative rapidity of the cut, tender roofs are not kept so long unsupported, and this in itself tends to diminish the risk to the workmen.

Electrical coal-cutters can be classified into four different types, as follows :—

1. Pick machines.
2. Disc machines.
3. Chain machines.
4. Bar machines.

1. *Pick machines.*—These are used either for under-cutting or for shearing the coal in a direction at right angles to the face, but they are mostly driven by compressed air at a pressure of 70 to 80 lbs. per square inch. There are only one or two kinds of pick machines successfully driven by electricity, the best known one being the *Morgan-Gardner machine.*

In it a cam is driven by an electric motor, which draws the piston back and compresses a strong spring. The spring is then released and strikes the blow, when the cam again compresses the spring, draws back the piston, and so on. The stroke of the piston is usually 8 inches, and from 170 to 200 strokes are delivered per minute. The machine is mounted on two small wheels, its length over all being about 7 feet and the width over the wheels about 21 inches. It is much used in America for "Pillar and stall" working, and it makes about 30 per cent. less slack than hand holing, the speed of under-cutting being from four to six times that by hand. The machine is mounted on a board 6 feet × 3 feet wide, raised at the back end so as to incline the machine down to the face. The operator sits behind and guides the machine by the two handles at the rear end, the recoil being taken up by the inclined plane and also by an air cushion at the end of the cylinder.

2. *Disc machines.*—This is probably the most popular type of machine in this country, and in it the cut is made by a large cutter wheel revolving in a horizontal plane and carrying on its periphery a series of picks. The illustration (fig. 10) shows the type of machine of this class which the author's firm, Messrs King & Co., have now made for several years. The cast steel frame has axle boxes at the

ends in which are fitted trunions adjustable as to height. In these run the shafts with the wheels on which the machine travels. By the adjusting screws the cutting disc can be made to follow within limits any inequalities of the pavement. The motor is mounted on the back end and is of the enclosed pattern of 20 to 25 H.P. It is series wound, and if more than one motor is driven from one generator at the pit-head a special controller with the necessary resistance for starting is fitted to each coal-cutter. The armature is of the slotted ring type, carbon brushes being used so as to allow the machine to be run in either direction. Starting and stopping and reversing of the machine is carried out by means of a controlling switch behind the motor, to which the flexible cables conveying the power are attached. The motor drives on to a countershaft by a gun-metal or malleable cast pinion working into a cast steel bevel wheel, and from there by a cast steel double helical pinion to a cast steel double helical wheel on the main shaft. This shaft drives direct to the cutter disc by steel bevel pinion. The cutter disc is of cast steel, carried on a steel bracket with an extra large bearing with gun-metal bush so as to give ample support to the disc. The forward feed of the machine is obtained by worm gearing working on to a drum, which can be thrown in or out by a clutch for stopping the feed independently of the motor. The worms are of cast steel and the worm wheels of gun-metal. Over the drum is passed a chain or wire rope fastened to trees in front and behind the machine. By having the motor reversible the machine can be worked backwards. If it is desired to *cut* backwards then the picks have to be reversed, and this can be done in a much shorter time than that taken to flit the machine back to the other end of the face at the completion of each cut. The machine has an overall length of 8 feet 6 inches. It is specially designed for low seams and cuts in a 21-inch seam. It can cut on the level of the pavement with a $3\frac{1}{2}$-inch to 4-inch width of cut. The cutter wheel is 4 feet 6 inches in diameter, allowing a 3 feet 6 inches to 3 feet 8 inches under-cut, and it revolves at a speed of about 40 revolutions per minute. The machine runs on rails laid parallel and near to

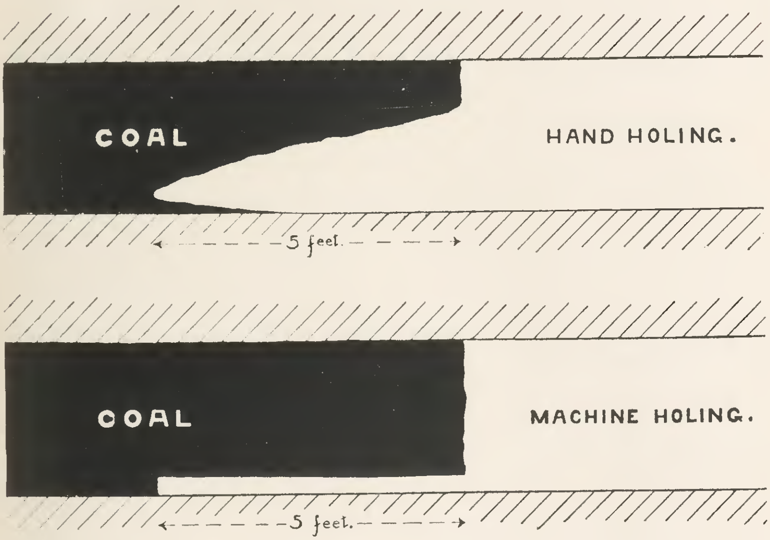


Fig. 9.

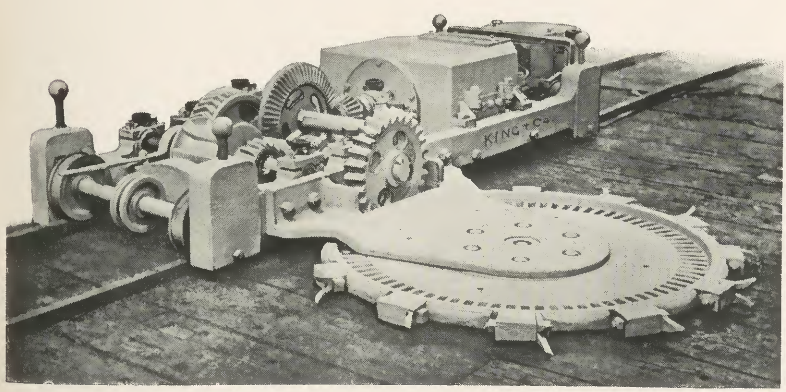


Fig. 10.—" Disc " Coalcutter.

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the working face, while the disc projects under the face. Usually three men are required to operate such a machine, one in rear working the machine while two prepare the road and lay the rails ahead. The gearing is protected by a sheet-iron covering, and over this the rails, upon which the machine has travelled, are passed by the man in rear to one of the two men in front of the machine. It cuts at the rate of from 1 to 3 feet per minute, and in an eight hours' shift undercuts from 80 to 120 yards of the face. If the seam is 30 inches thick, this means about 70 to 110 tons of coal per shift per machine.

In several designs of disc coal-cutters the feed is obtainable by means of a connecting rod driven from the intermediate shaft, which drives by pawl and ratchet another shaft from which the winding drum is driven by spur gearing. The rope is attached to the machine, led round a pulley block fixed some distance ahead, the drum winding up the rope, and so the machine pulls itself forward.

3. *Chain machines.*—In these machines the cutting is performed by cutters or picks attached at intervals to an endless chain, which is carried under the face by a steel jib. As a typical machine of this class the author takes *Messrs Mather & Platt's Electrical Coal-cutter* (fig. 11). The gearing runs in an oil bath and consists of a pair of planed steel mitre wheels and a four-threaded steel worm working on a cut phosphor bronze wheel.

The feed gear is driven from a worm on the commutator end of the armature shaft, on to a worm wheel, and thence by pawl and ratchet to the winding drum. The jib can be slewed through 180°, so the machine works its own way into the coal at the start. It is made in two sizes, the smaller being 2 feet high and undercutting 4 feet, the larger being 2 feet 6 inches high and under-cutting 6 feet. In the larger machine thirty-five picks are used. One feature claimed in machines of this class is that owing to the narrowness of the chain carrying jib the coal can be wedged up within about 2 feet of the cut and thus prevent the coal behind settling down and binding the jib. The machine pulls itself along the front of the face just as described for the disc machine. A special form of chain machine is largely used in America for pillar and stall working, in which the motor and jib with chain and picks cuts into the coal in a direction at right angles to the face. It works on a stationary frame racked by screw jacks to the roof and pavement, and feeds forward through spur wheels, driven by worm gearing, and engaging on racks fixed on the underside of the stationary frame. The motor drives through spur and bevel wheels on to a sprocket wheel, on which works the chain carrying the picks.

4. *Bar machines.*—In these the cutters or picks are carried on a tapered bar, which rotates by means of various forms of gearing driven by a motor. The illustration (fig. 12) shows the "*Hurd*" *Bar Coal-cutter*, as manufactured by Messrs Mavor & Coulson. In this machine the motor, which is of the enclosed pattern, drives, through its pinion, a double bevel wheel, which in turn drives the pinion on the cutter bar with a speed reduction of 2 to 1. The cutter bar can be slewed in a horizontal plane by a rack and pinion in the lower part of the gear case, and the bar can be tilted in a vertical plane by a worm and worm wheel. The cutter bar is of mild steel tapered towards the point.

Taper holes for the cutters are drilled on and also between the threads, so that two widths of holing can be obtained. The spiral thread on the bar acts as a worm conveyor, bringing the cuttings out to the face, and a reciprocating motion is given to the bar by means of a worm which drives two small wheels, each of which drives a toggle by means of an eccentric pin. This combined reciprocating and rotary motion gives a shearing action to the coal and is said to prevent the bar from clogging.

The starting switch and resistance is fitted in a case in front of the motor, and in front of that again is the winding drum actuated by pawl and ratchet wheel as already described.

The machine is made in three sizes, under-cutting to a depth of 3 feet 6 inches, 4 feet 6 inches, and 6 feet respectively, and, if required for over-cutting, the cutter bar is mounted on the top of the gear case. In machines of this type the coal can be wedged up within 18 inches of the bar and thus prevent the coal settling down and binding the cutter bar.

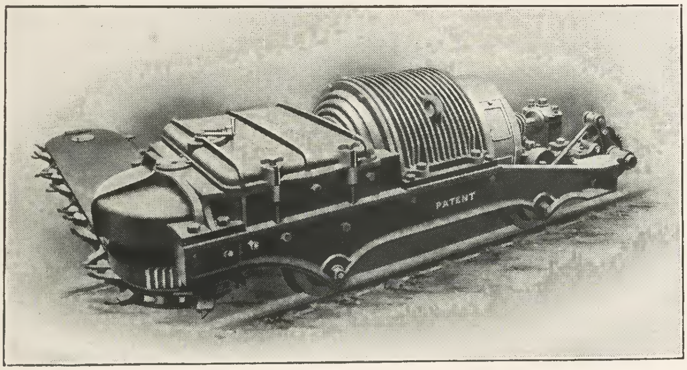

Fig. 11.—"Chain" Coalcutter.

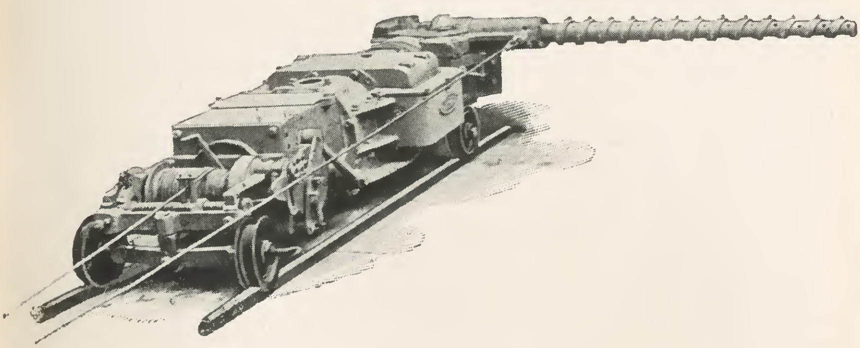

Fig. 12.—"Bar" Coalcutter.

Mr Alexander Ogilvie, B.Sc.

It is interesting to note the relative number and output of coal-cutting machines in America and in this country. From Government returns on this subject there were 316 coal-cutters in use in this country at the end of 1900, and they had mined during that year over 3¼ million tons, or about 1¾ per cent. of the total British output of coal. In America at the same date there were practically 4000 coal-cutters in use, and they had mined during the year 1900 almost 48 million tons, or practically 20 per cent. of the total output.

The large majority of the coal-cutting machines in this country are driven by compressed air, but owing to the increased efficiency, and the readiness with which power can be transferred from place to place, the electric drive is steadily replacing the compressed air method, unless, of course, in the case of very damp or fiery mines, where, as already remarked, compressed air is, in the author's opinion, the only safe drive.

Ventilation.—Another application of electricity to mining work is the driving of the large ventilating fans by means of motors. In the early part of last century ventilation of coal mines was effected by having a large fire at the bottom of the *upcast* shaft. This heated the air in the shaft, caused expansion to take place, and induced a current of fresh air to descend the *downcast* shaft, traverse through the workings and ascend to the atmosphere by the upcast shaft. This method answered the purpose for many a day, but the maintaining of a furnace at the foot of the pit was both dangerous and inconvenient, so that mechanical ventilation quickly followed. Air pumps were first tried, but these were soon replaced by the centrifugal fan, which is now almost universally used. The fan is usually connected to the opening of the upcast shaft, from which it draws the air out of the pit and discharges it to the atmosphere, fresh air to take the place of the foul air descending to the pit by the downcast shaft. There are various forms of fans and methods of discharging the air to the atmosphere, but the consideration of these is outside the subject before us. The early fans were of large diameters, 45 feet to 50 feet, and ran at a slow speed, so that the engine was connected direct to the fan. Nowadays, however, the fans are made smaller in diameter and the speed increased, necessitating a drive either by gearing or ropes, the latter being the most common. Such engines are sometimes replaced by electric motors, in mines where electric driving has been adopted, the motors being similar to those already considered, coupled direct to the fan spindle or driving by ropes, according to the speed of the fan.

Electricity is also largely used for driving light drills, which are used for drilling holes in the coal when it is necessary to shoot it down after it has been undercut by the coal cutter.

There are two classes of drills—

1. Rotary.	2. Percussive.

In the *rotary drills* the drill is carried on an upright with adjusting screws at the end for jamming the upright between the floor and the roof. The motor is small and light; it is fixed to the upright, and drives the drill through a single reduction gear of about 5 to 1. The drill revolves at a high speed, and holes of from 5 to 6 feet in depth can be drilled in a minute.

The *percussive drill* is usually employed for harder material, and one of the best known electric drills of this class is the *Marvin* drill, as made by the Sandycroft Foundry Co.

In it two coils, wound on a steel tube, receive alternately the half waves of an alternating current, thus imparting a reciprocating motion to the steel plunger in the tube. This plunger is of soft steel, and carries the chuck for holding the drill at one end, while to the other end is fixed a rifled rod running in a rifled nut with ratchet wheel and pawl. A twist is thus imparted to the plunger on the back stroke. A strong helical spring checks the back stroke and returns the energy so stored to the forward stroke. The generator for driving this drill is a two-pole machine, with drum armature containing a loop winding, in which a single phase alternating current is generated. One end of the loop winding terminates in a solid collector ring, and the other in a half ring which alternately passes the current into the two

GEO. STEWART & CO. EDINBURGH

THE ASSUAN RESERVOIR DAM FROM THE SOUTH-WEST

SKETCH BY H. M. CADELL, SHEWING THE RESERVOIR NEARLY FULL, DECEMBER 1902 coils of the drill. The machine is separately excited, and gives 135 volts uniform pressure at the drill. Its speed is usually 380 R.P.M., which means 380 complete strokes of the drill per minute. A 5-inch drill will drill a $1\frac{1}{8}$-inch hole a depth of 3 feet with about 4 H.P.

No coal mine is complete without an arrangement of *electric signalling apparatus* for the stopping and starting of the various winding and hauling gears, etc. For these single stroke electric bells are used, with the usual primary battery, pushes, and bare copper connecting wires. These wires are run along the roads fixed near to one another on the props, so that the bell at the pithead can be rung from any point by bringing the wires together.

The use of *telephones* throughout the mine largely facilitates the regulation and progress of the work, and such an installation is found in almost every mine.

Then, again, the *firing of shots* by electricity, either by the magneto generator or from the lighting mains, has so many advantages that it is universally adopted.

From the outline of the various uses of electricity in the coal mine, which the author has had the pleasure of laying before the Society, he thinks it is clear that much has been, and is being, done to utilise electric energy in this great national industry, coal-mining.

On the Watering of Egypt. By Henry M. Cadell of Grange, B.Sc., F.R.S.E.* (With 7 Plates.)

The portals of the twentieth century open on a new chapter in Egyptian history, a happy time when the conquests of the pick and shovel fall to be recorded rather than those of the sword and gun, a time of rest and prosperity such as the land has seldom for long enjoyed before. The new century re-opens the age of great monuments, not monuments for

* Read and illustrated before the Society on 13th April 1903.

the dead, but works of permanent benefit to the living, comparable in size with those of the pyramid builders of 6000 years ago, but enormously greater than any of these prodigies of the ancients in the solidity of the benefit they will confer on the people of Egypt for many generations to come.

Geographical Outlines.—The modern land of Egypt is bounded politically by the Red Sea and the Gulf of Akaba on the east, and on the west by an undefined and hazy line running southward from the Mediterranean through the Libyan desert, in the neighbourhood of the 23rd degree of E. longitude. It extends southwards into the tropics as far as the 22nd parallel of N. lat., which crosses the Nile a short distance below Wady Halfa, a station at the northern edge of the Anglo-Egyptian state of the Sudan.

As thus defined, the geographical extent of Egypt reaches the respectable figure of some 390,000 square miles, nearly that of France and Germany combined, but for all practical purposes the deserts included in this area are no more a part of Egypt than the sea at the mouth of the delta. They feed no tributary and contribute almost no merchandise, and are only useful to the country as impassable barriers to protect an immense line of frontier.

The real land of Egypt, famous in history, is that small part which is watered by the great river, the thin green streak in the hot tawny desert, which is capable of cultivation and does not cover so much as 9000 square miles altogether,* a smaller area than that of Belgium.

Flood Irrigation.—The method of watering the Egyptian plain by the system of basin irrigation, which had been in vogue for more than 6000 years, was to wait till the Nile rose and overflowed his banks at the end of summer. The water was retained in enormous basins between dykes or embankments running from the river to the desert, where it remained till most of the mud in suspension had time to settle, and the ground thus fertilised and watered, as soon as it was sown down, brought forth and produced abundantly. These basins in some instances covered an area of from 50,000 to 75,400

* Sir Wm. Willcock's *Egyptian Irrigation*, 2nd ed., 1899, p. 16.

acres, but on the average their size was about 9000 acres, and the shortest time they remained under water was about forty days—from the 12th of August to the 22nd of September.

After the flood had subsided, the water was run off by means of canals entering the river further down the valley; and if a further supply was required before next flood, it had to be lifted by various appliances from the river direct, or from canals so constructed as to flow at all times except when the river fell to an abnormally low level. In favourable circumstances it used to be possible, at a few places only, to employ perennial irrigation, and the great object of the irrigation department now is to enable the country to be so watered that it can be cropped practically all the year round, and not, as in the remote past, at one season only. Egypt has only three seasons—summer, flood, and winter; its soil is unsurpassed for fertility by that of any other land, and its first requirement, in the almost total absence of rain, is a sufficient supply of Nile water to enable it to produce a series of crops following one another in regular succession during the year. The land needs primarily a supply of the red muddy water which is the most valuable part of the flood, and this must be so distributed as to fertilise every part of the area under irrigation. Hence it becomes a matter of prime importance for the irrigation department to arrange that the water is distributed with a view to equality of quality as well as equality of quantity. As every new system of water supply to a district necessitates an accompanying system of drainage to carry off the spent fluid, so in Egypt the problem of irrigation includes that of adequate drainage canals and works connected with them, and unless these three primary considerations are kept in view, the full productiveness of the land cannot ever be reached. The Nile water, however, although essential, is not entirely sufficient for all the agricultural needs of the land. It is rich in potash, which constitutes the principal food of leguminous plants, but is very poor in nitrates on which cereals depend, and therefore manure must be supplied to prevent exhaustion by constant cropping. This is provided by the cattle, by soil from ancient dwellings, and by fertilising salts obtained in some parts of the desert.

Perennial Irrigation.—At present Egypt is in a state of transition, and the ancient system of basin irrigation is being replaced as rapidly as circumstances will permit by perennial irrigation, while large tracts of country that have either never been cultivated at all, or have been allowed to deteriorate and go out of cultivation under centuries of war and misgovernment before the British occupation, are now being steadily reclaimed on scientific principles, to the great advantage of the country and its industrious population.

According to Sir William Willcocks, the land under cultivation and paying full taxes is at present	4,690,000	acres.
Land under reclamation and paying diminished taxes	1,060,000	„
Together .	5,750,000	„
Of which there are in Upper Egypt .	2,320,000	„
And in Lower Egypt (or the delta) .	3,430,000	„
Besides this, there are in Lower Egypt .	500,000	„

of salted marshy land on which no reclamation has been attempted, but which was probably cultivated in Roman times before the Arab conquest, when Egypt had an immense population. The whole area that might therefore be cultivated is 6,250,000 acres, or say 9800 square miles, and the land of Egypt will not arrive at the zenith of its capacity until all this ground is brought to its full state of agricultural productiveness.

In order to understand clearly what is required from the Nile, it is necessary to consider the crops and the seasons in which they can be grown. As has been already mentioned, there are in Egypt only three seasons—summer, flood, and winter. In summer, which lasts from 1st April to 1st August, the semi-tropical crops grown are cotton, sugar cane, rice, millet and garden vegetables. This is followed by the flood or Nile season, from 1st August to 1st December, when the river rises and covers the land with rich alluvium and then subsides, leaving the ground ready for cultivation. The flood crops are principally dates, millet and rice, and in the winter season, from 1st December to 1st April, the main crops are wheat, beans, barley and clover.

It is thus clear that the summer and winter crops are more valuable than the flood crop, and at present cotton, the most lucrative crop of all, is grown in summer, when the sun is hottest—before the flood comes on.

The whole area of 5,750,000 acres in 1898 yielded crops to the value of £39,060,500, or £7 per acre on the average over Upper and Lower Egypt, and this large figure could not have been reached unless a great part of the country had been perennially irrigated. There were still at that time 1,730,000 acres under flood irrigation alone, which might be irrigated perennially and made to increase their gross yield by £2,700,000. The rent of the land is from 54 to 57 per cent. of the gross yield, and at present in Lower Egypt the agricultural rent of the best land under perennial irrigation is as much as £10, and the value of the crop on it from £17 to £20 per acre. The land tax is assessed at about one-third of the rent, so that if the land increases in value, the State benefits by the improvement, and is therefore directly interested in promoting the agricultural welfare of the country districts.

Perennial irrigation in Lower Egypt was introduced by Mohammed Ali, the great Pasha of Egypt, who ruled the country with much energy and intelligence, but in a somewhat fickle and entirely autocratic style, from 1805 till his death in 1848. In the ancient Pharaonic days the delta was laid out in flat terraces, surrounded by dykes to retain the flood water, and under the old basin system the land was so fruitful as to support a population of 12,000,000—some 2,000,000 larger than it is at the present day. After the Arabs conquered the country in the seventh century and massacred the Christian and Pagan inhabitants in thousands, or converted them by force to the faith of Islam, the ancient civilisation was thrown back, and the population continued to shrink till, in 1800, it was not more than 2,000,000 persons. Countless ruins of ancient towns now standing in the midst of vast desolation tell their own sad story, and part of the tale includes the abandonment of irrigation over a great part of the delta. Under Mohammed Ali cotton was first introduced about 1820, and as cotton is a summer crop, perennial canals had to be cut so as to convey the low-level summer supply of the Nile to the ground capable of producing this crop. At the same time the embankments of the old basins were broken up, and the dykes of the Nile banks strengthened to prevent inundation, so that the delta was deprived of much of the mud that used anciently to be deposited wherever the flood irrigation had full play.

Summer Crops.—With cotton cultivation the modern chapter of Egyptian irrigation opens. Under the old system, only winter crops, such as wheat, barley, beans and clover, were grown on the moist muddy land, which had been lately inundated. Cotton requires to be protected from inundation, and to be planted and irrigated before the Nile begins to rise. As the river level is low when this water is wanted, a great deal of labour is involved in raising it from the canals to the surface of the land under crop, and therefore it is of the first importance to keep the water in the canals as high as possible when irrigation is going on. If the river falls very low, as it has done in recent years during summer, no water may be able to enter the canals, and the summer crop may be lost; but if the level of the water can be maintained so that it will never fall below a certain minimum height, and can be lifted on to the land by ordinary appliances, or, still better, run over it by gravitation, the situation will be saved and the crop reaped in security.

The Barrages.—Although perennial irrigation is now employed over by far the greater part of Egypt, the supply is not nearly adequate for the needs of the country, and Sir William Willcocks has estimated that practically one-third of Egypt is totally undeveloped * on account of the insufficiency of the summer supply. The Nile cannot be trusted implicitly, and in order to regulate its flow over the delta, the idea of raising its level by means of temporary dams, or impediments, called by the French *barrages*, was originated long ago, so far back indeed as 1799, and by so notable a personage as Napoleon Bonaparte. It was not,

* *Egyptian Irrigation*, 2nd ed., p. 426.

however, till 1833 that any practical steps were taken to carry this idea into practice. Mohammed Ali in that year actually began to make a dam across the Rosetta or western branch of the Nile, so as to throw the water into the Damietta, or eastern branch, and of course injure to a corresponding extent the supply of Alexandria and other places on the Rosetta side. On the advice of his engineer Linant Bey, however, who pointed out the disastrous consequences that would follow this course, Mohammed Ali at once resolved to make two dams, one on each branch, and for this purpose to utilise the limestone blocks of the great Pyramids of Gizeh, the granite coating of which had already been stripped off long ago by builders in search of handy material. Linant was, however, a clever diplomatist as well as an engineer, and all credit is due to his memory for the tact with which he averted such an act of vandalism on the part of the despot. He pointed out that the stone could be obtained more cheaply from the quarries than from the pyramids, and his arguments proving successful, the excavation for the work was begun in the end of 1833 by means of Corvée labour. The men were sent by the Viceroy in such numbers as to cause considerable embarrassment to those in charge, but the work went on steadily until 1835, when plague broke out among the workers. After the visit of the pest, the work itself seemed to be stricken, and the Viceroy lost interest and appointed a Commission, to whom he intimated that he no longer considered barrages a necessity. The Commission, however, stuck to their guns and declared strongly in favor of M. Linant's scheme, but their master was immovable, and said although they were no doubt quite right he did not want barrages. The works were stopped and the workshops dismantled, for the sake of the wood of which they were constructed.*

Such was the fate of the first attempt to bar the Nile, and it must have been extremely galling to Linant when, seven years afterwards, another French engineer, M. Mougel, appeared on the scene and persuaded Mohammed Ali to carry out the idea that Linant had originated, but on a different

* Major Sir R. H. Brown, *The Delta Barrages*, 1902, p. 8.

plan. Mougel considered, and rightly, as it has proved, that *all* the low Nile water was required for irrigation. He laid his plans before the Conseil des Ponts et Chausées, but that body reported against what they considered an impossible proposal. Mohammed Ali, however, was again of a different mind from his advisers, and returned with renewed zeal to the execution of the project in spite of them. He gave orders for the immediate construction of the barrages under M. Mougel's direction, at a new place, fourteen miles below Cairo and close to the fork of the river, and the present barrage is the completion of what M. Mougel began in 1843 (fig. 1).

The history of these works; the alternations of good design and bad execution, under an able and strong but fitful Oriental despot; the partial failure and subsequent repair of the old works under a constitutional government, and the final triumph of the undertaking, leading to a succession of works of still greater magnitude all over the Nile valley—this record is in itself one of the most fascinating chapters in the history of civil engineering and applied science that has yet been written.

The barrages as designed by M. Mougel are close together, with merely a tongue of land between, so that they really constitute one work. The works on the Damietta or eastern branch were begun first in 1843, and in 1847 those on the Rosetta branch were started. The progress seemed too slow for the Viceroy, who in that year peremptorily ordered that 1000 cubic metres of concrete were to be laid every day, whether possible or not. There were many objections to such a course, which subsequent events proved only too well founded, but in went the concrete as commanded, and as the water was running at some parts, the mortar in it was all washed away and nothing but the loose stone left for the foundations.

Failure of the Barrage.—The great Viceroy died in the following year, 1848, and was succeeded by Abbas Pasha, who in 1853, not being satisfied with the progress of the work, dismissed M. Mougel, and put Mazhar Bey in charge of the barrage. The defects in the foundations were not remedied, but the superstructure was completed in 1861. The labour

FIG. 1A.—Old Cairo Barrage, Damietta Branch, upstream side.

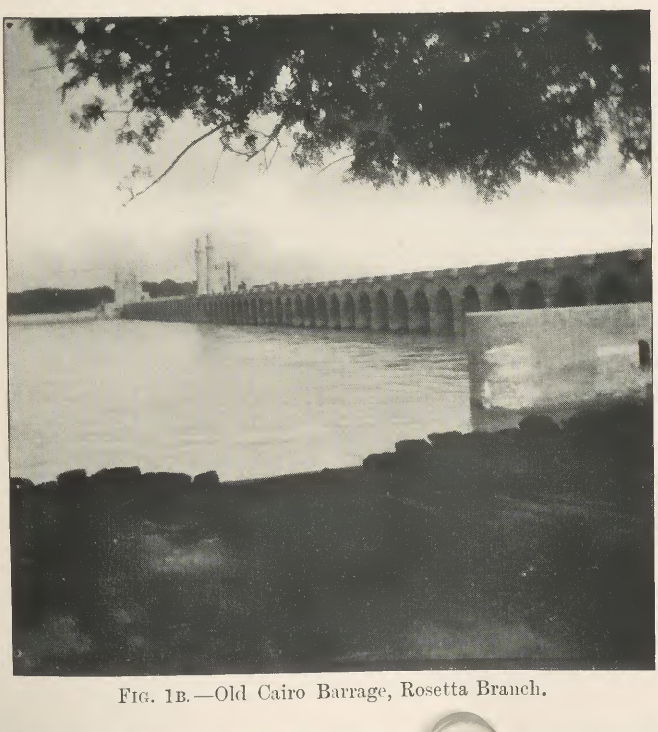

FIG. 1B.—Old Cairo Barrage, Rosetta Branch.

was principally by the Corvée, but in spite of this the cost is said to have been £1,800,000. After the completion of the barrage some cracks appeared in the superstructure, and springs burst through at the foundations. In 1863 nothing had been done to remedy these defects, but as the river was very low and the want of water was becoming seriously felt, the gates of the Rosetta barrage were closed, so as to raise the water level about five feet and feed the canals above. The result was that the sand below the floor was forced out, and the cracks increased in number. But worse happened in 1867, when another attempt was made to hold up the water —*part of the Rosetta barrage separated from the rest and began to move bodily down stream.* Ten of the arches gave way thus, and the amount of displacement, equal to about eight inches, can still be seen on the up-stream face of the building, but the parapet—the displacement of which was visible till 1897—has recently been straightened to its old line, during the course of other improvements. In Major Sir R. H. Brown's interesting volume on the history of the delta barrages, a good photograph is given of the parapet in its crooked condition.

After such a notable failure it was no longer safe to use the barrage for anything but a bridge, as more pressure of water might have pushed it aside and entirely ruined it for all purposes. It remained a monument of bad work and a subject for numerous engineers' reports and recommendations for seventeen years, till Sir Colin Scott Moncrieff, who had a large experience of Indian irrigation methods, appeared on the scene, and opened a new chapter in its history.

First Repairs of the Barrage.—Sir Colin was solemnly warned to have nothing to do with the doctoring of such a bad patient, but with the support of the Government and his own good sense to guide him he set hopefully to work and stationed Mr (afterwards Sir William) Willcocks at the barrage to apply his gigantic intellect to the problem of restoring the shaky structure. The disease was deep-seated, and its cure was not a matter of months. As operations progressed, it was discovered that the foundations were in a far worse condition than had been suspected, so that it took no less time than thirteen years to make the original structure thoroughly sound and serviceable. Even then it was found possible to greatly increase the capacity of the barrage by the construction of weirs in the river below, and these were only completed in the summer of 1901, fifty-eight years after the foundations of M. Mougel's great work were first commenced. The old French engineer was still alive in 1884, but he had been thrown aside and forgotten, as many worthy public servants were under the fickle system of government that dominated Egypt before the British occupation. The design of the beautiful structure was his, and perhaps it might have served its purpose better if he had been allowed to work out his own plans without interference from outside. But be that as it may, he lived to see others working on his plans, repairing his mistakes, and earning the reward of ultimate success. To the everlasting credit of Sir Colin Scott Moncrieff be it recorded that he never rested till he had rescued M. Mougel from the state of destitution and distress in which he found him living in Cairo, and obtained from Government a pension by which the poor old engineer was enabled to spend his declining years in some degree of comfort and respectability.

The prime difficulty in making a tight dam in the Nile valley is the deep mud and sand in which the foundations must be laid. This difficulty had also to be faced in making the barrage at Assiut, but did not exist at Assuan, where the river flows over solid rock. The first repairs that were attempted at the Cairo barrage in 1884 consisted in completing the stone pitching below the barrages and providing gates for the Damietta barrage, which had never been closed at all. This comparatively small piece of work, which cost less than £26,000, was found so effectual that in June it was possible to hold up the water 7 feet on the Rosetta and 3 feet on the Damietta branch, and provide a large summer supply of water for the delta canals, to the great advantage of Lower Egypt. Next year the water was raised nearly 10 feet in the Rosetta branch, but the pressure was more than the weak structure could stand, and the old cracks began to open ominously, and other signs of insecurity appeared, warning the engineers that more must be done if the work was to be of permanent use.

The limited experiment that had, however, been made proved the enormous advantage of the barrage, and Government were satisfied that if only it could be permanently repaired, the outlay would be amply justified. As the engineers were confident this could be accomplished, a liberal grant was made, and a thorough renovation and extension of the foundations was at once initiated. The first large piece of work was the widening and strengthening of the platform of concrete on which the piers were built, and the construction of an impermeable bar across the river through which springs could not pass. This work was spread over four seasons, and each part to be repaired was surrounded by a ring bank of earth, from the interior of which the water was pumped out at low Nile. When the flood came on these banks were washed away and all work suspended for four months, from the end of June till the first of November. Only eight months were thus available every year, and out of that period two months were required to form the ring banks and two more to pump out the water enclosed by them, leaving only four months for the actual work of construction. The height of water held up by the banks was at one time as much as 40 ft., and the work was carried on without interfering with the water impounded by the other parts of the barrage, so that at all times the operation was full of anxiety to the engineers in charge.

Operations were begun in 1887 at the western part of the Rosetta barrage and carried on day and night from 24th March till the 1st of July, when the last piece of machinery was removed, and before next morning the rising flood had overflowed the banks and covered up all the season's work. This was the part of the barrage that had moved twenty years before, and when the foundations were laid bare the workmanship was found to be deplorably bad. At each end of the barrage there is a lock for the passage of boats, and the western lock walls were found resting on foundations 8 ft. higher than the floor of the barrage itself, and when these were laid bare it was difficult to prevent the lock walls from falling over bodily. The masonry and foundations of the barrage were found badly fractured, and in one place showed a fissure 4 inches wide. These defects were, however, made good by Mr A. G. W. Reid, who had come from India to take special charge of the work and showed great ingenuity and resource in overcoming the numerous difficulties that cropped up from time to time.

Barrage Gardens.—The barrage, externally a beautiful structure such as French engineers are accustomed to design, was further embellished in 1895, when the waste ground between the branches of the river was laid out and planted with a large selection of beautiful trees and shrubs. The delightful garden which has now grown up, with its shady walks and well-watered undulating lawns, is one of the finest public parks in Egypt, and the barrage has become a favourite pleasure-ground for the crowds who care nothing for the triumphs of modern engineering, and think less of the vast brain power and physical energy which generations of engineers have expended in bringing the Cairo barrage to its present happy condition.

The Cairo barrage as thus completed consists of three parts: (1) the Damietta barrage, 535 metres in length, with sixty-one arches and two locks (fig. 1A); (2) the Rosetta barrage, also with sixty-one arches and two locks, but only 465 metres in length (fig. 1B); and (3) a handsome road 1000 metres long joining these structures and running through the barrage garden between lines of shady lebbek trees. Three large canals carry the impounded water to the three sections of the delta separated by the two branches of the river. The Rayah Behera, which feeds the canals of the Behera province on the western side of the delta, has its mouth on the left bank just above the Rosetta barrage. The Rayah Menufia, in the middle of the barrage gardens, feeds the canals in the province of Menufia and Garbieh between the Nile branches. The Rayah Tewfiki, which has its head on the right bank of the Damietta branch, irrigates some of the eastern provinces of Lower Egypt. These canals, with others already in existence, are intended to complete the summer irrigation of the whole delta.

The Barrage Weirs.—But the rectification of the original barrage was not the only means adopted to keep the canals running in summer. While the last-mentioned improvements were in progress two most important pieces of work were begun, which have enormously increased the capacity of the original structures. Sir William Garstin in 1896 suggested that to assist the barrage to hold up more water, supplementary dams or weirs should be built across the stream some distance below each section, the effect of which would be to reduce the difference of water-level between the sides of the structure and diminish the risk of future accidents. Even when repaired, the barrage was not at all times able to supply enough water for the growing demands of Lower Egypt in summer, and the construction of weirs, which would allow the level at the canal mouths to be raised without increasing the head on the barrage gates, was clearly the proper way of answering the question. It was decided to limit the maximum head of water on the barrage to 3 metres, or 10 ft., beyond which the level might not be raised with safety.

Government decided to adopt Sir William Garstin's excellent plan and construct a weir below each barrage to give the additional height of water above, and granted a sum of £E530,000 for the work. This was begun in March 1898, and practically finished in July 1900, before the flood came on, and the cost was only £E434,000 or £E96,000, under the allotment.

The length of the Rosetta weir is 500 metres and that of the Damietta weir 418 metres, and each is provided with a lock for the passage of boats. The effect of the weirs is to raise the level of the water below the barrage 10 feet, and as the barrage gates can raise the level other 10 feet, the total result is that, when the gates are down, the water above the barrage can be held up 20 feet altogether. This height could never have been attained by the original structure alone, and the addition of the weirs has therefore enormously increased the value of the barrage to the farmers of Lower Egypt.

Benefits of the Barrage.—The agricultural returns prove that the expenditure on this great work was more than justified. In 1901, a year in which the summer supply of water was unusually low, the production of cotton had risen to 6,250,000 kantars (or hundredweights), as against 3,186,000 kantars, the highest figure for any year previous to 1884, when the repairs were started. Another advantage of the barrage is the saving to Government of the large annual outlay for pumping. Had the water been raised by this means quarter of a million would have been needed every year, as against £10,000 required for the annual upkeep and working of the barrage at present. The Government actually paid between £80,000 and £90,000 a year previous to 1889 for pumping, an outlay that is no longer required.

The increase in the height of the water in the canals has also saved an enormous quantity of labour in clearing out the silt that accumulated in them every year. This work used to be done by the Corvée system of forced labour, the speed of the work being kept up by the liberal application of the kourbash to the naked backs of the unwilling workers. In 1883 the number of unpaid labourers who were turned out for this purpose was over 106,000, working for one hundred days. In 1884 it was reduced to 88,299, and in 1885, when Lord Cromer's humanity led to the abolition of the lash, the men refused to turn out, the only inducement to do so having just been removed. It was thus necessary to employ paid labour, and now £200,000 a year is spent in Lower Egypt on the work formerly done by the Corvée. The results are said to be more satisfactory under the new system, and the abolition of slavery is therefore by no means the least of the benefits the barrage has conferred on the people of Egypt.

Zifta Barrage.—The success of the barrage paved the way for other works of the same kind, and before the repairs were well finished three other projects were set on foot. The smallest of these is the Zifta barrage, half-way between the Damietta barrage and the sea It is designed to hold up about 13 feet of water, and was completed and opened on 7th March 1903 by the Khedive and Lord Cromer. It has fifty openings, 5 metres, or 16½ feet, in width, and with the subsidiary works, was estimated to cost £E500,000, but was completed for £50,000 less than this estimate. With the other barrages it will so use up the main stream that when the river is low the natural mouths will be practically dry, every available drop being turned into the summer irrigation canals.

Works in Upper Egypt.—The great dam at Assuan is so big an object in the popular imagination as to dwarf the importance of every other piece of recent Egyptian engineering, and people at home are apt to forget that it is the success achieved in Lower Egypt and the experience gained there that have both shown the need for a new reservoir and indicated how the scheme might be successfully carried out. Had the delta barrage proved the permanent failure that many people expected, and some hoped it would, after British engineers took in hand to repair it, this method of improving the irrigation of Egypt might have been relegated to the limbo of Utopian impossibilities, and the idea of controlling the waters of such a large river given up perhaps for a generation to come. But when it was found physically possible to execute such works, and still further, when it was clearly demonstrated that important financial results were certain to follow, neither the ways nor the means were very difficult to find.

The delta barrage was clearly of no direct benefit to Upper Egypt—the long and valuable portion of the Nile valley above Cairo—and it was felt to be most desirable to improve the irrigation there, as well as in Lower Egypt. Even with the delta barrage the danger of a very low Nile in Lower Egypt could not be quite got rid of. While practically the whole of the low Nile is used in summer for irrigation, so that very little water escapes to sea by the natural mouths at Rossetta and Damietta, the river when in flood goes largely to waste for want of a regulating dam or reservoir to store it up at times when the supply is good. There are no lakes below the junction of the Nile and the Atbara, and the rise and fall of the river is to a great extent subject to the floods that come down from the Abyssinian Highlands, and to the variation in rainfall in the part of its basin above Khartoum. The White Nile, which rises in Lake Victoria Nyanza and Lake Albert, has at its head a regulator of enormous size, and it is principally this vast reservoir which provides the summer supply when the Blue Nile is very low and the Atbara totally dry.

A Nile Reservoir.—How to make an artificial reservoir lower down so as to equalise the flow and fill the summer canals of Egypt, was for a good many years a matter of serious consideration, and various places were pointed out where this might be attempted. In the end, and very wisely, the author thinks, the site of the first cataract, 740 miles from the sea and about three above the small town of Assuan, was chosen for this purpose in preference to all others. Both the geological and topographical character of the ground are favourable for a reservoir dam here. At the same time, the configuration of the Nile valley would doubtless have suited still better had the upper part been wider, so as to allow the impounded water to spread out and cover a larger area than is at present possible between the steep cliffs that line both banks nearly all the way up (see fig. 3). Had there been no steep banks there might, however, have been no granite bottom, and the world-renowned granite of Assuan provided both a sound foundation at the place and plenty of the best building stone for the whole great edifice.

The Nature of the Nile Valley.—The Nile valley has not, like the famous Colorado cañon, and most other river-beds, been produced by the erosive action of the muddy stream so much as by movements of this part of the earth's surface, which have given rise to enormous faults or rifts along which the water has found its way to the sea. The Valley of the Jordan and the gulfs of Akaba and Suez, and the huge straight trough of the Red Sea itself, are due to earth fractures of this kind, which affected this region at a comparatively recent geological period. The lower part of the Nile Valley appears to have at one time been a deep fiord or narrow tongue of the sea produced in this way and extending southwards as far as Esna 485 miles above Cairo. The river has in course of time filled it up with gravel and mud, and spread out its remaining alluvium as a delta in the sea. It is therefore impossible to find a solid foundation for any structure such as a dam or bridge below that point.

Fig. 2a.—Assiut Barrage, downstream side.

Fig. 2b.—Assiut Barrage, upstream side.

But even far above Esna the bottom appears to be alluvial material like that at the Cairo barrage, and it is only where the granite crops up and forms cataracts or rapids that any rock of a solid nature is to be found in the river-bed. The skill of the engineer is evidently far more taxed when he has to work on a soft mud foundation than on a platform of solid granite, and the new barrage at Assiut, only 250 miles above Cairo, was in this respect perhaps even a greater achievement than the dam at Assuan, which was built at the same time and by the same engineers.

The Assiut Barrage.—The Assiut barrage (fig. 2) is part of the same scheme as the great dam, and its main object is to raise the level of the river in summer and increase the flow of the Ibrahimia Canal which waters all the west side of the Nile valley and flows northwards into the fertile province of the Fayûm, a distance of about 200 miles. Before this barrage was built the summer supply was too low, and a great deal of good land could not be fully cultivated in Upper Egypt. If the barrage had been built without the dam, too large a proportion of the summer supply might have been given to Upper Egypt and the delta would have suffered in consequence. With the dam, however, the summer supply will be increased for Upper Egypt, while the quantity left for Lower Egypt will not be diminished, and may perhaps even be augmented considerably. To what extent the dam will fulfil the high expectations of its makers remains of course to be found out by experience. Should there be a continuance of the low Niles of the last three years, it will prove at once an enormous boon, and even now the effect of the Assiut barrage has been excellent. In the summer of 1902, when the Nile was again very low, the work was in consequence happily so far advanced that the gates could be shut in time to raise the canal level and save the cotton crop in Upper Egypt, just as the Cairo barrage had been the means of saving the crop in Lower Egypt in 1901. The value of the cotton crop of Upper Egypt is over £1,000,000, and if even half of this sum were saved by the barrage, the whole of its original estimated cost would be repaid to the country in the first season.

The Assiut barrage is 833 metres, or a little over 900 yards, long, and has 111 arches, each 5 meters or 16¼ feet wide. The piers are 6½ feet thick, and at every ninth opening there is an abutment pier 13 feet thick. The roadway is 14½ feet wide, and about 41 feet above the floor of the waterway. The floor on which the structure rests is a bed of concrete 10 feet thick and about 86 feet wide, laid between two lines of cast-iron sheet piles driven 13 feet below the bottom of the concrete into the soft river bed and faced with a bed of stone at each side. As in the other barrages and canal regulators, the piers are provided with square vertical grooves into which the massive gates are lowered by travelling cranes, so that the water can fall over the upper edge. When the gates are closed the barrage can hold the water up 10 feet.

During the course of the work, which was begun in 1898 and finished in the spring of 1902, great difficulty was experienced by water bursting through the foundations in springs, no less than 974 of which had to be stopped from time to time. This was managed by the system of boring holes and injecting cement grout under the foundations, that Major Brown had employed with such success at the old Cairo barrage.

Utility versus Beauty.—The Assiut barrage has a lock at the west end, and is a plain substantial building without any ornamentation or turreted superstructure to break the dead level of its parapet, such as poor M. Mougel placed on his picturesque and historic edifice at Cairo It does not necessarily follow, as many British engineers seem to think, that because a structure is useful it should be ugly, and it is not always impossible to combine beauty with utility even in works of this class.

The great dam at Assuan, for example, is a most impressive object, no doubt, but by no stretch of imagination can it be called beautiful, as a more plain and bald-looking structure it would be difficult to think of.

The only plea in favour of ugliness in buildings is that of cheapness or want of imagination on the part of the designer; but in the case of the Egyptian Government, with its annual increasing surplus and its unparalleled financial prosperity, due principally to irrigation works like these, such a plea can

Fig. 3.—Bab-el-Kalabsha, 30 miles above the Dam, where river is 108 feet deep

surely not be urged at this time of day. It is only reasonable to expect a little attention to be paid to the external adornment of the springs from which such a fountain of wealth will flow, particularly in a "show place" like Egypt; and when the dam comes to be raised to its full height it is to be fervently hoped that an architect will be consulted with an eye for beauty as well as strength, instead of a plain engineer who wants nothing but substance, to put the last light touches on that monumental building. Something more than a good cornice, such as Sir William Willcocks designed originally, is wanted to break the grim dead line that runs like the loopholed front of a fortress for a mile and more across the rocky glen. An obelisk or a sphinx, for example, set at every buttress on the top of Sir William Willcocks' pylon cornice would be a vast improvement; and if granite figures were too costly, the economical engineers of the P. W. D. might, with their great experience of this material, contrive to use concrete, which would look like granite and would be about as durable in that rainless climate. Plenty of clean desert sand and stones exist close by, and an imposing concrete sphinx consisting of, say, four cubic yards of material, might be cast in a mould and finished off after it had set, for, say £5, and as there are only some twenty buttresses altogether, £100 would probably suffice, and nobody could complain of the expense.

The Assuan Dam.—The dam at Assuan is, properly speaking, a reservoir to regulate the flow and not a barrage for raising the level of the water above it. No irrigation canals exist above Assuan, and for a long distance up the river there is almost no land to irrigate, as the river course is a narrow glen in the dry desert, with steep rocky sides and a very small margin of flat ground even when the water is low (fig. 3). The narrow strips of alluvium at the base of the cliffs are entirely submerged when the reservoir is full, and only the tops and upper parts of the tree stems remain uncovered by the impounded waters. When the river is in flood the whole of the sluices will be left open, so that it can run through with as little interruption as possible and carry all its sediment down to the lower reaches. It will resemble an open barrage then for a short time, but will play the rôle of a reservoir during the rest of the season. It differs, however, from an ordinary reservoir in having no overflow, and the water will never be allowed to rise above a certain line known as R.L. 106, or 106 metres above the river-level datum at Cairo. The sluices in the dam, 180 in number, are 23 feet high by $6\frac{1}{2}$ feet wide, and are capable of venting the greatest flood the Nile is ever likely to send down. If by any chance, however, their capacity should be overtaxed by an unprecedented flood, the lock gates at the west end of the dam might be opened rather than run the risk of letting the water flow over the parapet. Such a contingency is, however, extremely improbable, as the discharge of the river has been carefully measured over a period of several thousand years, and its maximum volume is quite well known. Nilometers have been erected up the river on both its branches above Khartoum, the readings of which are regularly recorded, so that the approach of the flood is expected at Assuan and all necessary precautions can be taken long before the rise of the stream is felt at the dam. When full, this new Egyptian lake runs 130 miles up the valley to Dirr, a village above Korosko, historically interesting as the site of a small rock temple dating from the time of Rameses II.

The quantity of water impounded is over 1,000,000,000 tons, and on 8th January 1903, when the author last saw it, the reservoir was almost full, so that the effect of the inundation of its borders was clearly displayed.

The dam is constructed entirely of granite from the immediate vicinity, and the whole weight of stone used exceeds 1,000,000 tons. The face is of heavy blocks of granite ashlar set in strong mortar, consisting of 2 of sand to 1 of Portland cement, and the hearting is of rubble granite in 4 to 1 cement mortar. The mason work was executed principally by Italians, who did all the stone dressing and quarrying, and earned from 10s. to 12s. a day of wages. The native labourers who did the unskilled work were paid 5 piastres, or 1s. a day, on the average, a much higher figure than they were accustomed to get before. Work was carried on without a stop while the river was low, and as many as 12,000 men,

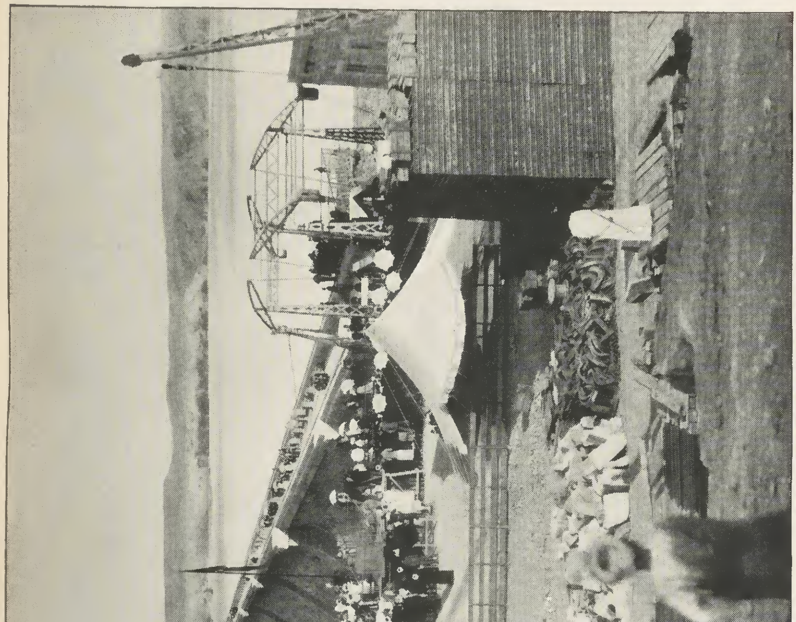

Fig. 4.—Opening of Assuan Dam, 10th December 1902.

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including 1000 Europeans, was the maximum number employed at one time. The greatest day's work was when the Bab-el-Kebir—the great door—was being closed in June 1900. On that occasion no less than 3600 tons of stone were laid in ten hours. The bedrock proved to be unequal in strength, and it was found necessary to go much deeper at some places than had been expected, in order to reach a thoroughly solid bottom. At low Nile the river on the line of the dam flowed in five main channels of varying size known as the Bab-el-Kebir, Bab-el-Harun, the Bab-el-Sughaiyar, the central and the west channels respectively. These channels, along which the river has worn down its bed more than elsewhere, are due to lines of weakness or decomposition, and when the rock was laid bare the bed of each of these channels was found to consist of soft decomposed stone, quite unsuitable for a tight foundation. The Bab-el-Kebir was on the softest of these lines, and the excavation had to be carried down 11½ metres, or about 39 feet lower than the contract specified. This deep hole had to be excavated and filled up with building to a height of 24 metres in two and a half months, before the flood came on. During June 1900, 45,000 cubic metres were built in by two shifts working continuously under the blazing sun by day, and under the cold electric light during the hours of darkness.

Where these operations were in progress, the river was kept back by "sudds," or embankments, such as had been used at the barrages, and the force of the current was so great that the closing of the sudds was sometimes a matter of much difficulty. Heavy embankments of stone were made on the north or down-stream side to arrest the current at each channel in succession, and in the still water above a dyke of sandbags was laid down, the open stone dykes being afterwards made watertight in the same way below. There were three such barrièrs across the deepest channels, and the last of these, that on the Bab-el-Sughaiyar, was the most difficult to close owing to the additional volume of water the closing of the others threw into it. Large blocks three or four tons in weight were carried away like pebbles, and the current was not arrested till two large railway waggons loaded with wire nets full of stone, tied on by wire ropes and weighing 25 tons each, were tipped bodily into the cataract. These were found heavy enough to withstand the current, and form a toe against which the stone bank and sandbags could be laid satisfactorily. When the sudds were finished, the water was pumped out of the interior, and the sandbags were found to make such a watertight bank that after the water was once removed, very little more pumping was required to keep the enclosure dry. The unprecedentedly low Nile of 1900 greatly favoured this most difficult part of the work, and when once the lower part of the building was finished, and the river could be run through the sluice apertures, the rest of the work was comparatively easy.

The greatest height of building from the foundation to the parapet at the Bab-el-Kebir is 130 feet, and the maximum breadth at the base 100 feet, the top width being 22 feet from face to face. A massive flat-topped parapet with a heavy dressed ashlar cope carrying a bridge rail runs along each side. A travelling overhead gantry moves along this when it is necessary to lift any part of the heavy sluices. A narrow-gauge line for small trollies runs along the centre: and as the length of this railway is a mile and a quarter, and the walk rather fatiguing in the sun, the pushing of visitors across affords the natives one of those opportunities of demanding bakshîsh that no true Egyptian ever neglects to take advantage of.

The sluice gates, 180 in number, are raised and lowered by very powerfully geared hand winches. They are of steel, and mostly work on free rollers suspended in frames on the system designed by the late Mr F. G. Stoney and manufactured by Messrs Ransomes & Rapier.

At the west end of the dam is the navigation channel, a mile and a quarter long, which is nearly all cut out of the solid rock, and is provided with four locks, each 260 feet long and 32 feet wide. The locks increase in depth towards the top, and the maximum height of the gates is 62 feet. The gates are not hinged, but slide on rollers into recesses in the walls. The motive power is a turbine placed in the interior of the masonry of the dam, which compresses a column of

Fig. 5a.—Front of Assuan Dam, from above.

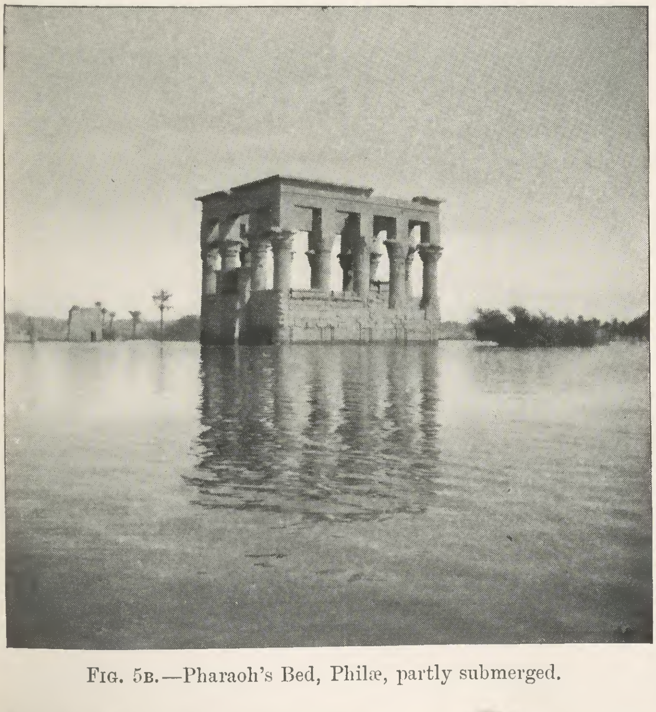


Fig. 5b.—Pharaoh's Bed, Philæ, partly submerged.

Fig. 6.—Submerged Temple of Philæ, dam in distance.

water to actuate the hydraulic machinery for moving these huge pieces of mechanism.

The dam was designed by Sir William Willcocks, whose plans were slightly modified in some parts by Sir Benjamin Baker. The actual work was carried out by Sir John Aird & Co., whose general manager, Mr John Blue, deserves great credit for seeing the structure so well and quickly built. Willcocks' original plan was to have raised the water-level 26 feet higher than it is at present when the dam is full, and this would have given 85 instead of the 35 milliards of cubic feet that the new reservoir is calculated to hold. But such an outcry was raised about the vandalism of submerging for a few months every year part of the Philæ temples (figs. 5B and 6), situated on an island a mile above the dam, that the Egyptian Government gave way to the clamour, and reduced the height to its present level. So strongly, however, has the foundation been laid, and there is so much weight in the existing body of masonry, that the superstructure can still be raised 6 metres, or about 20 feet, with perfect safety This will, it is calculated, exactly double the capacity of the reservoir, and no doubt after its utility has been established in perhaps a very few years' time, the comparatively small sum that is needed to complete it will be quickly forthcoming. By that time the supposed importance of Philæ will have greatly shrunk in the public imagination as compared with that infinitely more valuable monument—the great dam itself.

Looking Back and Forwards.—The Nile has been extremely low during the last three summers, and doubts have been raised as to the permanence of the full supply from the equatorial regions. But we have it on the best authority that there were lean years—sometimes seven of them at a time—so far back as the days of Joseph, who preceded Lord Cromer as public administrator of Egypt by some 4000 years. Joseph and Pharaoh provided against the lean years by building granaries, but Lord Cromer and the Khedive have provided against future lean years by making a storehouse for the water that makes the grain, which is just a more roundabout way of making a granary.

There is, however, one difference of importance. In the case of Joseph's storehouses the supply was stored to be spread over seven years of famine, but in the Assuan dam each year stands on its own base, and the water that would go to waste in flood is stored for the dry months of the same year only. The reservoir will be filled with the superfluous water in the river between December and March after the flood has passed, and will be discharged during May, June and July. To imitate Joseph more closely, a far larger storehouse is required—a reservoir that can provide for more than one year's possible deficiency.

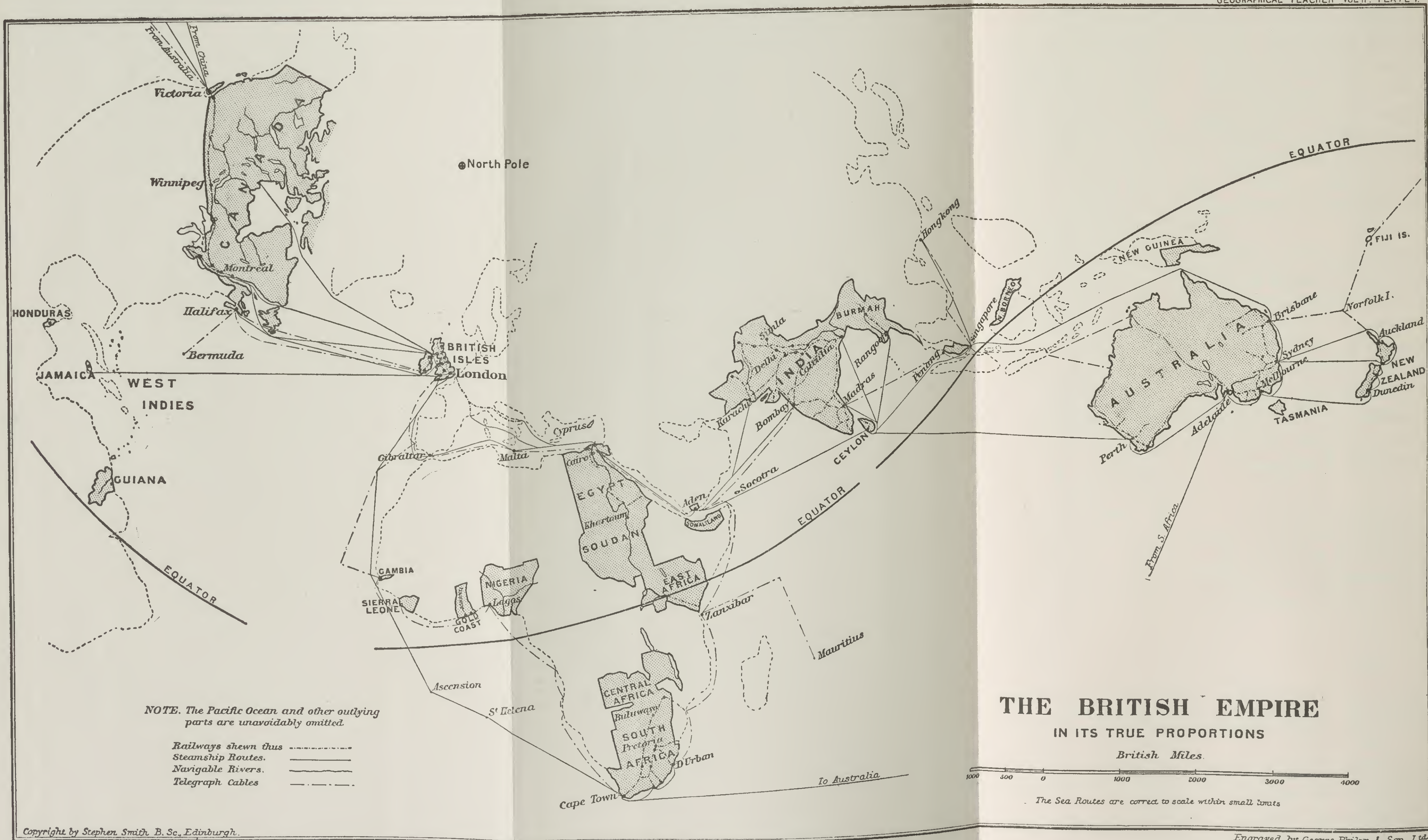
Such a reservoir already exists in the great equatorial lakes Victoria and Albert, and by making a dam across their outlets, only a few feet high, or a tunnel and sluice at the falls below, an enormous regulator might be constructed at the head of the White Nile. This territory, in the colony of Uganda, is entirely under the British flag and beyond Egyptian influence. Encouraged by the successes of the past, our empire-building engineers are now discussing great schemes for the extension of irrigation works into the Sudan, and the construction of dams, barrages and canals to water the plain beyond Khartoum.

These comprehensive proposals are, however, at present too nebulous and remote to be taken up in this paper, but in the course of a few years the development and irrigation of the Sudan will perhaps come to be as interesting a matter to engineers as the watering of Egypt has been in the past decade.

On a New Map of the British Empire. By Stephen Smith, B.Sc.* (With Plate.)

The geography of the British Empire as a whole has hitherto been made known to us mainly by the use of a map of the world on Mercator's projection, with British possessions coloured red. Mercator's is a projection of the sphere

* Read and illustrated before the Society on 27th April 1903.



Engraved by George Philip & Son, Ltd.

on its circumscribing cylinder, which is then unrolled into a plane. The equator is represented by a straight line, and the meridians by straight lines at right angles to it, and all at equal distances from each other. The parallels of latitude are also straight lines. But, on the sphere, the length of a degree of longitude diminishes from the equator to the poles, varying as the cosine of the latitude. As, in Mercator's projection, the degrees of longitude are represented of the same length in all latitudes, they are exaggerated as they recede from the equator in the proportion of the secant of the latitude, varying from zero at the equator to infinity at the poles. And in order to preserve the proper proportion, the degrees of latitude are, on the map, increased in the same ratio. The result is that the scale of the map in both directions east and west, north and south, is increased gradually from the equator to the poles. In the latitude of 25° the increase is only 10 per cent., but at 50° it is 55 per cent., at 60° 100 per cent., at 70° 200 per cent. Now two-thirds of the British Empire lies between the parallels of 40° north and 40° south, while the United Kingdom lies between 50° and 60° north, and Canada between 45° and 70° north. Relative to the British Isles, therefore, Canada is shown on the ordinary map exaggerated by about 33 per cent., and India, Australia and Africa diminished by 60 per cent. And, as a general result, the whole area of the Empire compared with the United Kingdom is decreased by about one-third, while the frozen regions of Northern Canada are shown four times the size of the fertile districts of Australia.

It is obvious that such a map gives a very incorrect conception of the proportions of our Colonies and Dependencies, and has, for educational purposes, many disadvantages. To overcome these the map now described and illustrated has been designed. It does not pretend to mathematical exactness, but it is an attempt to show, as far as possible, every part of the Empire on the same scale and in its correct relationship to the United Kingdom. The method adopted has been—in popular language—to pare strips from the surface of the globe and lay them out flat. One such strip includes India, Australia and New Zealand, which lie nearly in a "great circle," another, East and South Africa, a third, West Africa, and others the West Indies and Canada. It is clear, of course, that the distances between the extreme points of these strips, when laid out flat, are enormously exaggerated, and for this reason intermediate points at a long radius cannot be shown with any pretence of correctness, and the smaller islands in the Indian and Pacific Oceans have been omitted. But, for ordinary purposes, the general "lie" of the various parts is shown with comparative accuracy, and the shortest sea routes from the British Isles can be scaled with approximate truth. The curious position of Canada will be noted, turned, as it is, at right angles to the position in which it is usually recognised. It is, however, correctly placed, and illustrates the fact that the shortest route to Western Canada is through Hudson Bay, on the well-known principle of "great circle sailing" in high latitudes.

The information embodied in the map is an indication of the uses to which it may be put in the teaching of the commercial geography of the Empire. It could be completed in much greater detail, in such a way as to show clearly the chief products and the state of development of various parts, and to illustrate the problems of naval and military defence.

It is not suggested that this map should replace the ordinary Mercator one, which is constructed on strictly mathematical principles, but it is hoped that it will be found widely useful, if placed alongside a Mercator map, in the instruction of advanced pupils on the resources of that vast Empire for the maintenance and development of which we have all to bear a share of responsibility.

(The Society is indebted to the *Geographical Teacher* for the illustration.)

REPORT BY COMMITTEE.

Mr Smith has drawn a map of the British Empire with great care and ingenuity, which aims at giving at a glance and with fair accuracy the outlines and areas of the different territories and their distances from London. The present routes of intercommunication by sea and land are clearly depicted and true to distance. By itself the map does not show the extent of the British Empire relatively to that of the whole earth. But Mr Smith means his map to be interpreted along with a map of the world on the usual projections, or with a globe. Some idea of its magnitude, however, is given by marginal maps of the Russian Empire and of the territories of the United States drawn to the same scale. As Mr Smith treats the distant portions of the Empire as small surfaces of a globe approximately flat, his map cannot be drawn consistently with any projection. The object Mr Smith has in view is novel and interesting, and may prove useful educationally and otherwise. Your Committee consider that the best thanks of the Society are due to Mr Smith for his communication.

E. M. Horsburgh.
Alex. Thomson.
R. M. Ferguson, *Convener.*

A Feed-Gear for Coal-Cutting Machines. By Archibald Wilson, A.M.I.E.E.* (With Plate.)

In a paper read recently before this Society † a detailed account was given of the various types of machines used in the mechanical cutting of coal, and the methods employed in their operation were described at some length. It will be remembered that the chief characteristic of the most common types of coal-cutting machines consists of a disc, bar or chain provided with cutting tools which act after the manner of a saw in cutting a slot or opening in or below the coal seam, thereby allowing the coal to be easily dislodged from its position. The machines are almost universally arranged to cut continuously along the face by winding a rope or chain fixed at a point in advance, whereby the machine is drawn along, cutting as it goes.

* Read and illustrated before the Society on 27th April 1903.

† *Vide* page 90.

It will be readily understood that the rate at which the machine has to be propelled along the face will depend on the hardness of the material to be cut. There is great variety to be found in this respect amongst the many kinds of coal and clay which are met with in actual practice. Even in a single seam varying degrees of resistance to cutting are found, as at one time the machine may be working in comparatively soft coal, at another in hard clay. Consequently a feed-gear which can be easily varied in speed and which will automatically adjust itself to the working conditions should contribute to most efficient working and to a high output. The feed-gear which the author describes has been designed by him to meet these requirements.

Before describing it in detail, it may be well to refer to other methods employed for the same purpose.

A form of disc machine is sometimes used, in which the feed drum is mounted on a shaft which is driven from the main shaft of the machine by means of worms and worm wheels. The drum is provided with a claw clutch, and the feed can be started or stopped independently of the motor by engaging or withdrawing the clutch. The efficiency of the gear is not very high, and there is this disadvantage that, with a given set of gears, the feed is fixed at one rate only and cannot be varied.

Another method of feed, which appears to be almost universally employed in coal-cutting machines, is to drive the drum shaft by means of a ratchet wheel actuated by a pawl mounted on a rocking lever. This lever obtains its reciprocating motion from a connecting rod attached to a variable stroke crank fitted on the main shaft of the machine. This arrangement allows of a variation in the rate of feed, but to make the alteration the machine has to be stopped and the position of the crank pin altered. It does not, however, adjust itself automatically to varying hardness of materials.

The illustration shows in section the feed-gear which the author has designed, with the object of providing a feed which can be easily varied in rate from nothing up to the maximum rate at which the machine is intended to cut, and which will automatically adjust the rate of cut to the quality of the material met with, and to the power of the motor to overcome the resistance offered to it.

On the drum shaft are mounted two wheel castings provided with annular teeth, and to one of these is attached the winding drum. All of these run loose on the shaft. In the space between the two wheels there is keyed on the shaft an eccentric, on the outside of which is mounted a pinion wheel whose teeth engage with the annular teeth on the two outer wheels. The number of the annular teeth on these two wheels differ by one, or more. The wheel which is *not* attached to the drum is provided with a flat turned rim, on which is fixed a band brake, whose tightness is adjusted by a screw and lever mounted on the frame of the machine, the pressure of the screw on the lever being transmitted through a spiral spring, which gives a certain amount of flexibility to the action of the brake. The action of the gear is as follows:—

The shaft is geared by means of spur wheels to the motor which drives the machine, so that when the motor is started the shaft is made to revolve, and with it the eccentric with its pinion. The effect of the two annular wheels having a different number of teeth is that they tend to rotate, but in opposite directions to one another. If the movement of one of them be retarded, the other is accelerated in proportion. If one of them be held stationary, the other will take up the whole motion, and for each revolution of the shaft the wheel will rotate through a distance equal to the pitch of one tooth.

Under working conditions the wheel attached to the drum is retarded by the strain of the winding rope which passes over the drum, and if no strain be applied to the brake the brake wheel will revolve freely and the machine will not travel. By tightening up the brake the brake wheel will be retarded, and the drum wheel will be made to rotate and so cause the machine to move, while the amount of slip of the brake wheel under the brake will determine the rate of the feed. The brake should be so adjusted that when cutting at its ordinary rate and power the brake wheel is held stationary and the machine is fed at full speed. If the machine meets with any excessive resistance, the strain on the rope will overbalance that on the brake, the wheel of which will accordingly slip and the rate of feed will be reduced slightly, or in an extreme case the machine will stop feeding altogether.

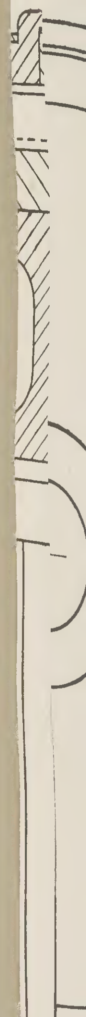
The points which have been aimed at in producing this feed-gear may be summed up as follows :—

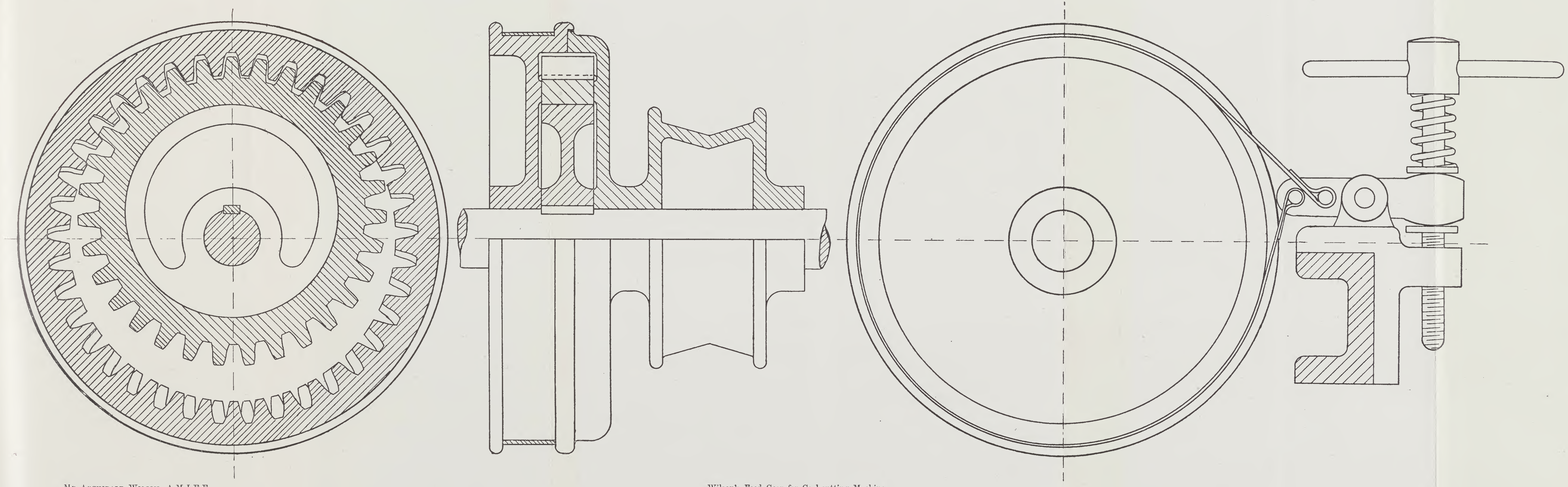
(1) That the feed of the machine can be stopped, started or varied easily by hand as required to suit various qualities of materials. (2) That that can be done without interrupting the working of the machine. (3) That the feed will automatically adjust itself to suit varying conditions and obstructions, and allow of more regular working and less risk of excessive strain to the motor and gearing.

REPORT BY COMMITTEE.

We have read this paper and seen the machine in motion, and we consider Mr Archibald Wilson's feed-gear a very ingenious and important improvement in coal-cutting machines. Such an improvement has been much needed in machines of this class, and Mr Wilson seems to have been quite successful in producing a feed-gear that can be relied on to automatically adjust itself to the varying conditions of working met with in most seams. We cordially recommend this paper to the favourable consideration of the Prize Committee.

H. M. Cadell, *Convener.*
C. D. Geddes.
John Ritchie.





Mr Archibald Wilson, A.M.I.E.E.

Wilson's Feed Gear for Coal-cutting Machine.

Address by Dawson Turner, M.D., Vice-President of the Society, *delivered at the Annual General Meeting of the Society, held on 9th November* 1903.

Fellows and Associates of the Royal Scottish Society of Arts,—It is customary at our annual general meeting to make some reference to the state of the membership of the Society. There were on the roll of last session 216 members; four of these have resigned and eight have passed away, being a decrease of twelve, but five new members joined, so that there are now on the roll 209 members, or a net decrease of seven. Two years ago our roll stood at 233, and seven years ago at 311, so that within this brief period our numbers have diminished by almost one-third. My first reference has thus been a sad one; the chief causes, I think, of our decrease in membership are to be found in the numerous and more recently instituted kindred societies and in the excellent scientific periodicals and reports which we can peruse at our fireside. I do not know whether it would be a heresy to refer to our hour of meeting, but I should like, with your permission, to suggest, for consideration, as to whether it might not be more convenient for some of our members to attend at an earlier hour, say, at five o'clock instead of at eight. It requires some fortitude to come out, perhaps, some distance on a winter night, and brave the sort of weather that we are now almost accustomed to, and which, we are told, being associated with sun-spot activity, may continue for another four years; were one of our meetings, as an experiment, to be occasionally held at five, and were a little light refreshment, in the form of tea, to be provided, members might attend our meetings on their way home from their work.

During the last session, seventeen papers were brought before the Society; their titles were as follows:—

On the Position and Material of Soil and Waste-pipes in Houses . .	By T. R. Proctor.
On a Ball Valve Flushing Cistern .	By T. R. Proctor.
On a Direct Reducing Levelling Staff	By G. W. Herdman.
On a Hinged Joint for Levelling Staves	By G. W. Herdman.
On a Patent Window . . .	By Arch. M'Kinnon.
On the Evolution of the Japanese Clock	By J. G. Goodchild.
On an Improved Form of Cyclograph	By J. G. Goodchild.
On a Patent Window . . .	By D. G. Ednie.
On British Manufactures and Foreign Competition	By M. T. Pickstone.
On Wireless Telegraphy . . .	By F. G. Baily.
On High-Pressure Gas Lighting and the Scott Snell Lamp . . .	By C. Scott Snell.
On the Measurement of Light and a New Photometer	By Henry O'Connor.
On the Application of Electricity to Coal Mining.	By Alex. Ogilvie.
On the Watering of Egypt . .	By Henry M. Cadell.
On a New Safety Hook . . .	By Stephen Smith.
On a New Map of the British Empire	By S. Smith.
On a New Feed for a Coal-cutting Machine	By A. Wilson.

Of all the scientific discoveries of the last year one stands out pre-eminent, not only from its scientific importance, but also from the great public interest it has excited. I refer to the discovery, by Monsieur and Madame Curie, of radium. This discovery was not, like that of the Röntgen rays, made suddenly, but had been led up to by the researches of Becquerel and of Röntgen, and was ultimately due to the painstaking and laborious analytical work of the Curies. Röntgen's great discovery of a radiation that would render the human body transparent was made in 1895; and Becquerel followed this, in 1896, by finding that uranium and some of its compounds emitted a radiation akin to that of the Röntgen rays, but in very feeble amount; lastly, the Curies, after examining almost every known element, found that thorium, and certain ores of thorium and uranium, viz., the pitch blendes, were also radio-active, and that the latter were even more energetic than the element uranium itself. The next step they took was to separate pitch blende into its constituents, each of which was carefully tested for radio-activity; by proceeding slowly and laboriously by this method they gradually separated the chief source of the radio-activity of pitch blende, viz., the elements polonium and radium.

As my interest in this subject is chiefly medical, I will commence by referring to the forms of radiation which have been more or less recently made use of in practical medicine and surgery.

They can be divided into five groups, as follows:—

1. Radiant heat rays.
2. Ordinary light.
3. Ultra-violet light.
4. Röntgen rays.
5. Radium emanations and rays.

The effluve or brush discharge produced by high-frequency currents and by static electricity has some of the properties of the last two.

About three of these forms of radiation a good deal is known. Thus, below the ordinary spectrum of white light, we have the long radiant heat waves, while above are the short ultra-violet rays; the latter, together with the blue indigo and violet, are called after the great Swedish doctor who first used them in the treatment of disease, the *Finsen* light.

The chief properties of ultra-violet light are that—

(*a*) They are powerfully actinic.

(*b*) They can excite fluorescence.

(*c*) They can discharge an electrified body, particularly if it be negatively electrified.

(*d*) They have clinical and bactericidal effects.

(*c*) They can produce nuclei for cloud condensation in moist air.

Coming next to the Röntgen rays, we find that their nature is still unknown, though evidence has been accumulating in favour of Sir George Stokes's theory that they are due to irregular impulses in the ether comparable acoustically to a noise. Thus it has been shown by Blondlot that they travel with the velocity of light, and that the rays are polarised, but they differ from ordinary light in not being capable of regular reflection or refraction; they can, however, excite fluorescence, affect a photographic plate and discharge an electrified body. The latter properties are shared by ultra-violet light, so that the Röntgen rays more closely resemble ultra-violet light than ordinary visible light. They differ chiefly in their powers of penetration; ultra-violet rays have but little penetrative power as regards our tissues, and are absorbed by the thinnest film of blood; while the Röntgen rays pass through our skin, and soft structures, with great facility, but throw shadows of the bones. Transparency to Röntgen rays is a question of density, but transparency to ultra-violet light is selective; thus, rock-salt and ice are transparent, while glass, mica, and gelatine are opaque.

Further, the Röntgen rays appear to have no bactericidal effect, while ultra-violet light has marked bactericidal effects. A very important clinical difference is this, that while the Röntgen rays will produce, if pushed, a severe inflammation and destruction of the skin and nails, the Finsen light never produces such untoward effects.

Whether the clinical effects of the Röntgen rays are due entirely and purely to the rays, or whether the electro-static field and ionisation round the tube also play a part, is an unsolved and difficult problem; there are, for instance, certain diseases, principally of the skin, in which the Röntgen rays always produce a curative effect. I have, to test this question, treated three such cases with the static negative breeze, and have produced the same beneficial results; and, in fact, in one case where the Röntgen rays utterly failed, the negative breeze was successful. These results favour the view that the curative action produced by exposing a patient to an X-rays tube is not due wholly to the Röntgen rays.

Turning now to radium, of which you will see a specimen in the centre chamber, producing perpetual fluorescence, its distinguishing radio-active properties, according to Professor Rutherford, are that it gives off a radio-active emanation and three kinds of rays, viz.:

α rays,
β rays,
γ rays.

It also maintains itself constantly at a higher temperature than its surroundings, and it continually emits heat at an estimated rate of about 100 calories per gramme per hour. It is thus in its behaviour in outstanding antagonism to some of our fundamental physical laws.

The emanation is of the nature of a luminous gas, which can be condensed by intense cold, and which imparts radio-activity to objects in its path. More than two-thirds of the heating effect of radium is due to this self-produced emanation, and one cubic centimetre of it would probably instantly melt down the glass tube which contained it.

The α rays consist of a stream of positively-charged particles of mass, about twice that of the hydrogen atom, and projected with a velocity of about 20,000 miles a second. These rays have but little penetrative power.

The β rays appear to resemble the cathode rays of a Crooke's tube; they are negatively charged, more penetrative than the α rays, and consist of particles of about the one-thousandth of the mass of a hydrogen atom.

The γ rays are the most penetrative of all, and evidently resemble the Röntgen rays from a hard tube.

Not content with manufacturing this extraordinary emanation, and with emitting three kinds of rays, radium appears to have a hand in the genesis of the but recently-discovered gas helium, so that we have the antithesis of a gas of absolutely negative properties being produced by a substance of altogether extraordinary properties.

Madame Curie has measured the atomic weight of radium, which is 225 ; that of thorium is 232. It would be placed in Mendelejeff's table in the group of the alkaline earths.

Attempts have already been made by various observers to use the wonderful properties of radium in practical medicine. It has been suggested that consumptive patients should inhale the emanation, so as to bring the powerful agent into as close contact as possible with the diseased lung. A few milligrammes of radium bromide might be placed in water, in a suitable inhaler, and the emanation drawn into the lungs with a deep breath ; what effect, if any, this treatment might produce is not yet known, but a strong word of warning to patients not to attempt such a remedy, without previous medical sanction, may not be out of place.

Owing to the property the emanation has of imparting radio-activity, the effect of the inhalation would probably continue for a considerable time, for the walls of the air passages would for the time become radio-active themselves.

Experiments have been made by Pfeiffer and Friedberger on the bactericidal action of radium rays. The micro-organisms of cholera, of typhoid fever, and of woolsorters' disease were destroyed by a three days' exposure to twenty-five milligrammes of radium bromide, placed in close proximity ; this result is not very encouraging ; still it must be remembered that the Röntgen rays have no bactericidal effect, though their beneficial effects in certain diseases cannot be doubted.

Though the micro-organisms of certain diseases are not very susceptible to radium rays, the human tissues are. It is unsafe to carry radium about in one's pocket. Several cases are on record of an inflammation and ulceration of the skin following such a procedure; even the carrying of it in a glass tube from one patient to another may set up an inflammation similar to that induced by an improper use of the Röntgen rays, and any ulcer formed is highly intractable, and may last for weeks or months.

E. S. London tested the effects of the rays on mice; reddening of the ears and blinking of the eyes appeared on the third day; general torpor and paralysis followed, with death on the fourth or fifth day; the skin and brain were the parts most affected. London has also discovered that persons who are almost blind can perceive light when radium is brought near, and that people with perception of light, but not of form, can detect the shape of objects which are in the neighbourhood of the screen; he thinks that there may be in this a possibility of teaching such blind people to write or draw. Persons who are totally blind are unaffected by radium. The position of the radium can, he reports, be detected with covered eyes, and even when the box is held behind the head. I regret I have not been successful in repeating the latter experiment, possibly because the fragment of radium that I possess is too minute.

The chief physiological effects of radium, so far as at present investigated, can be arranged in three groups:—

1. Effects on the skin, producing inflammations and ulcers.

2. Effects on the nervous system, producing paralysis and death.

3. Luminous effects produced in the partially blind.

The radiations of radium have been tried in various diseases, principally those in which the Röntgen rays and Finsen light have been found useful, and in many cases distinct benefit has resulted. The effects produced appear to be similar to those produced by the Röntgen rays. At present the prohibitive cost of radium precludes its more frequent trial. Should it become possible to obtain it in larger quantities, we may speculate on the uses to which it may be put. In practical medicine it would do away with our bulky and costly X-ray installations. Patients would instead be provided with a fragment of radium, sealed in a tube, which they would themselves apply, as directed, to the affected part. A few grammes of radium would light up an X-ray screen brilliantly through an inch or more of lead, and this it would continue to do for perhaps a thousand years; thus we should have a perpetual source of light and heat. An objection to its use would be that the lead would have to be enclosed in running water, to prevent it from fusing. Another objection would be that it would be quite unsafe to go near it, unless one were completely clothed in leaden armour, otherwise one would run the risk of having one's skin destroyed and one's nervous system paralysed. Could this slight difficulty be overcome, the reign of coal and smoke would be over. A small receptacle of radium in a house would both warm it by day and light it with a soft diffused light by night. A sufficient block placed in the furnace chamber of an Atlantic Liner would drive it backwards and forwards for generations across the ocean. Our knowledge of nature's secrets is ever advancing; and for those who wish to join, and there cannot be too many of them, in the investigation of such enthralling subjects as these new elements, much help and encouragement is afforded by this our Royal Scottish Society of Arts.

TRANSACTIONS

OF THE

ROYAL SCOTTISH SOCIETY OF ARTS.

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*Carburetted Air, and some Improved Methods of Employing It.**
By Hugh Marshall, D.Sc., F.R.S., F.R.S.E. (With Illustrations.)

The process of carburetting a gas consists in adding to it hydrocarbon vapours or gases so as to increase the value of the gas as a fuel or an illuminant; the name 'carburet' was formerly applied to compounds of carbon with one other element, and therefore included the compounds of carbon and hydrogen now known as hydrocarbons. The carburation of gas is now carried out on a large scale, in connection with the manufacture of coal gas and water gas, for illuminating purposes. In these cases the original uncarburetted gas is itself combustible, the carburation being for the purpose of enrichment of the illuminating power when the gas is burned at an ordinary jet. It is possible, however, to carburet an inert gas, such as nitrogen, so as to obtain a combustible mixture, provided the proportion of hydrocarbon vapour added is sufficiently large; working at ordinary temperature this necessitates a fairly volatile hydrocarbon. In such cases the original gas serves merely as a medium or carrier for the combustible vapour; they are not of practical importance.

The carburation of air differs in one very important detail from each of the preceding cases; air is neither a combustible gas, in the ordinary sense, nor inert, but acts as a supporter of combustion towards the carburetting material. Consequently certain proportions of air and hydrocarbon

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* Condensed from the Paper read and illustrated before the Society on 23rd November 1903.

vapour give rise to explosive mixtures; to avoid these, either air or vapour must be present in considerable excess above the proportion which would yield the most perfect explosive mixture. As admixture with excess of air would cause loss of combustibility, the only method of obtaining a product which is combustible, and at the same time safe, is to have a decided excess of the combustible vapour present. For carburetting air it is therefore necessary to employ a much more volatile liquid than would be necessary with a combustible gas, or even with an inert gas.

Air which has been carburetted by means of the vapour of a suitable liquid can be used for practically all the purposes to which coal gas is applied, and numerous methods of utilising it where coal gas is not available have from time to time been devised. On a small scale, the principle can be easily illustrated by simply blowing a current of air through a suitable liquid and conducting the resulting gas to a jet, where, on application of a light, it will burn with a flame similar to that of coal gas.

The liquids almost invariably employed for carburation are the lightest kinds of petroleum spirit (gasoline), now commonly known by the name of 'motor-car spirit.' These are mixtures of different hydrocarbons, which vary considerably as regards volatility, and this variation has an important bearing on the composition of the resulting carburetted gas. If air is blown through a quantity of gasoline, the most volatile constituents are carried off most rapidly, and the residue becomes less and less volatile as evaporation proceeds; consequently the gaseous mixture first produced is much richer than that subsequently obtained. This reduction in the quality of the gas, due to 'fractionation,' is intensified if the current of air is rapid, owing to the lowering of the temperature due to the evaporation of the liquid.

The vapours of all these hydrocarbons are much denser than air, so that carburetted air is also denser than air itself; consequently, if carburetted air escapes into a room it does not rise towards the ceiling, as coal gas does, but falls to the floor. On this account it does not accumulate in the room to any great extent, making its exit easily below doors, etc.

In virtue of its higher density it can be poured from one vessel to another, like a liquid; although it is invisible, its presence in the second vessel can easily be shown, as it becomes ignited on applying a light. Also on account of its high density larger pipes are required for its conveyance than those necessary for coal gas.

For domestic and similar purposes carburetted air may be employed, broadly speaking, in two distinct ways: 1st, It may be led all over a building by a system of pipes, being produced in a suitable central apparatus situated conveniently in or near the house; or, 2nd, It may be produced in a separate small apparatus, portable or fixed, at any point where it is required, each apparatus being more or less of the nature of a complete and self-contained lamp.

Carburetted-air Lamps.—Owing to the danger which would attend the use of lamps containing 'spillable' liquid so volatile and combustible as gasoline, it is practically necessary in all such lamps to soak up the liquid in such a way that it cannot escape from the lamp except in the form of vapour. Several types of lamp founded on this principle have from time to time been devised, but hitherto they have not come into vogue. The first of these with which the author became acquainted was that devised and patented by M. Notkin of Moscow. It consisted of a metal box or case, 7–8 inches square and 15–18 inches high, and provided with a central opening in top and bottom. The upper opening served for the admission of air, and was fitted with an adjustable plug; the lower opening was provided with a screw connection, to which was fitted a long brass tube which was bent at its lower extremity and carried an argand burner with chimney. The tube was also provided with an ordinary gas tap. The case itself was packed with sheets of paper pulp, placed on edge, to serve as absorbent. The lamp was charged by filling the case with gasoline and then pouring off all that remained unabsorbed. Placed thereafter on a suitable stand or bracket, the lamp could be started at any time by opening first the upper plug, then the bottom stopcock, and applying a light at the burner. The carburetted air in the case as it flowed out through the tube was replaced by a steady stream of fresh air through the upper opening, and this air in its turn also became carburetted; so the process continued as long as a sufficiency of gasoline remained in the container, after which recharging became necessary.

These lamps were very clumsy, and it was found that the paper pulp when wet became clogged into a mass through which the air could not readily pass. The author was asked to search for some better absorbent material, which might also lend itself to modification in the shape of the carburetter. After numerous experiments, it was found that a very satisfactory material could be produced by preparing a paste composed of about

1 part of Kieselguhr (infusorial earth),
2 parts of plaster of Paris,
and 5 parts of water,

casting this in suitable moulds, and, after it had set, allowing it to dry slowly by exposure to the air.

Blocks obtained in this way, although very porous, are fairly hard; in addition to being highly absorbent, and durable, they have the additional advantage of being composed entirely of mineral matter. The first idea was to employ plates or tiles of this material, these being packed into the carburetting vessel with narrow spaces between them; this was abandoned in favour of a single block pierced with numerous parallel channels of small bore running vertically through the block, so as to admit the air freely to all parts of the mass, and so ensure proper carburation. A special machine was devised to produce these channels at the time of casting, as it was hardly practicable to drill them out of the dried block.

Speaking roughly, these blocks will absorb about half of their own volume of liquid, and, once the liquid has been taken up, it can be abstracted only in the form of vapour. If an unenclosed block is saturated with gasoline, and then a light applied, there is, of course, a large flame produced, but combustion proceeds quite quietly; the blazing mass can be quite safely lifted by means of a shovel or tongs, or the flame can be immediately extinguished with the aid of a wet towel. The body of the block does not become very hot, as the material is a poor conductor, and even if the gasoline is allowed to burn away completely, the block remains intact, although it becomes somewhat powdery on the surface.

Greatly improved lamps were produced, fitted with these blocks, and they were also much neater in appearance, cylindrical cases being used. At first they were only provided with argand burners, but subsequently a special atmospheric burner was fitted to them, which adapted them for use with incandescent mantles.

Attempts to use lamps of this type for outside lighting were at first unsuccessful, as the flame flickered too much on account of draughts even when enclosed in a good lantern. This difficulty was ultimately surmounted by enclosing the carburetting vessel (which, in this earlier type of lamp, had to be higher than and outside of the lantern) in a special casing which communicated with the body of the lantern by means of a duct; in this way the air supply for the carburetter was drawn from a point near the burner, so that both the inlet and the outlet of the carburetter were equally affected by gusts, and the flame remained steady. Several English railway stations were satisfactorily lighted by lamps of this kind.

In actual use the lamps were quite safe, and the only stage at which there was any risk from the use of such highly inflammable liquid was during the *charging* of the lamp, which, of course, could not be performed near any naked light. In order to avoid even this risk the following system of charging the carburetters was devised :—The storage vessel for the gasoline (unless very small) was fitted into a pivoted frame, so that it could be easily inverted, and was provided with a screw connecting-piece, fitting the screw on one of the carburetter openings. Its second opening being securely closed, the carburetter was screwed on to the storage vessel and the whole inverted. Liquid flowed from the vessel to the carburetter and displaced the air, which could be heard bubbling up through the liquid in the vessel. When this ceased the apparatus was re-inverted, whereupon

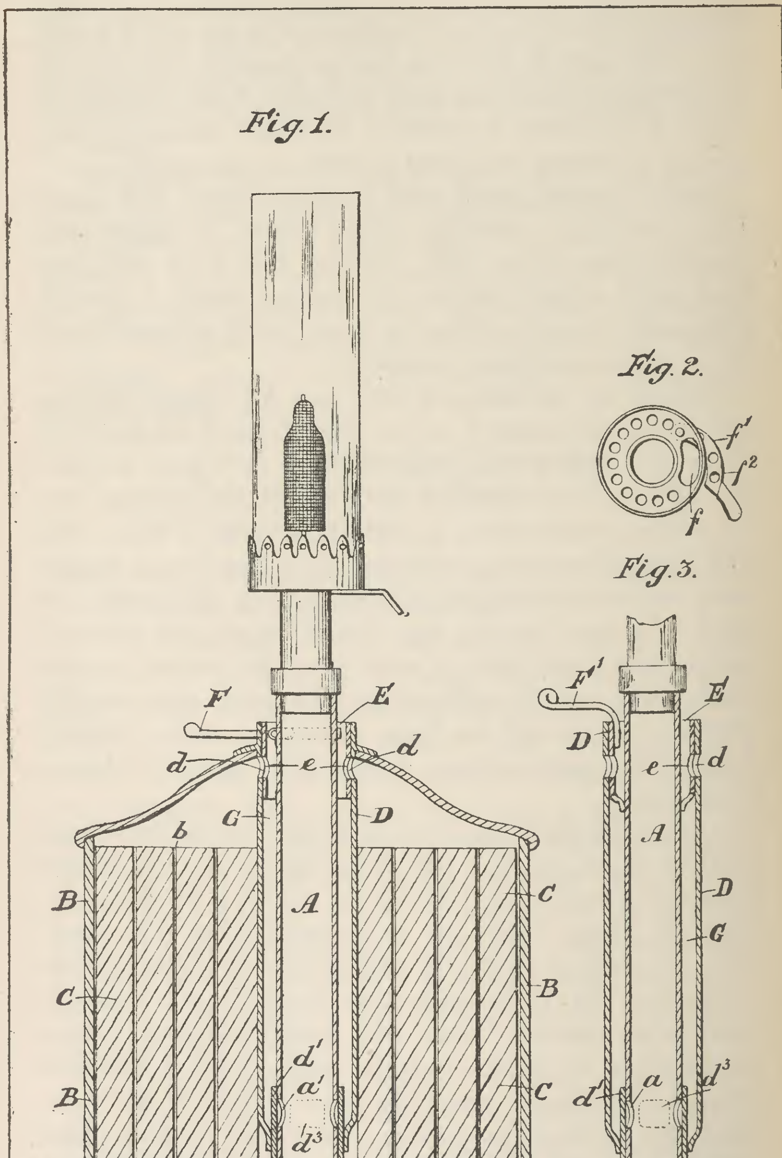
Fig. 1.
Fig. 2.
Fig. 3.
F
E
d
e
G
D
b
A
B
C
d'
a'
d3
d2
a
f'
f2
f
F'

EXPLANATION OF FIGURES.

A Burner tube, free to turn within lower sleeve d^1.
B Carburetter.
C Perforated absorbent block.
D Metal tube, fixed to, and depending from, cover of carburetter.
E Upper metal sleeve, fixed to A and turning within D.
d^1 Lower metal sleeve, fixed to D and surrounding A.
F Lever for turning burner tube and sleeve E.
G Annular air space between A and D.
b Channel in absorbent block.

The air inlets d and e to the carburetter B, the carburetted air outlets d^2, a from the carburetter B to the burner tube A, the inlets d^3 and a^1 for supplying uncarburetted air direct to the burner tube, are operated simultaneously by the movement of a single lever F. Perforated sleeves E, d^1 are respectively attached to the tubes A and D, so that when the tube A is turned by the handle F, the openings d, e, d^2 and a are simultaneously opened or closed. The openings d^3, a^1 are so arranged relatively to the openings d^2 and a that the former are closed or partly open when the latter are open or partly closed. Thus, by the movement of one lever, any desired mixture of air and carburetted air can be obtained.

Fig. 2 is a plan of the chimney-holder with orifice f to admit a lighted match or taper to burner. This orifice can be closed by pivoted arm-piece f^1. Apertures f^2 limit free admission of air to chimney.

Fig. 3 shows an alternative method of connecting sleeve E to burner tube A.

With the valves as shown in fig. 1, the whole of the air entering tube A passes through the carburetter; this represents the state of affairs when the lamp is nearly exhausted. At earlier stages, when richer gas is produced, the ports formed by a^1 and d^3 are partly open, and uncarburetted air passes through them from the annular space between A and D to dilute what enters by a, d^2. The necessary draught is started by means of the lighting torch introduced at the foot of the chimney (see f, fig. 2), and is thereafter maintained by the flame of the lamp itself.

the unabsorbed liquid flowed back again. After allowing a sufficient interval for drainage, the charged carburetter was unscrewed and refitted to the lamp, a plug being securely inserted into the opening of the vessel. In this way the pouring of gasoline from one vessel to the other in the open air was avoided.

Table lamps of the type last described, though they worked satisfactorily, had a very top-heavy appearance, as the carburetter had to be some distance above the burner in order that the carburetted air might flow down from the former to the latter. As many people objected to them on that account, it became advisable to try to discover some method of working which would render it possible to have the carburetter below the burner, like the oil reservoir of an ordinary lamp. The prime difficulty was, of course, that of forcing the carburetted air up to the burner against gravity. For small lamps a mechanical device is objectionable, even if practicable, and the only method which seemed promising was to utilise the draught produced by the flame itself when burned inside a sufficiently long chimney. Experiments, conducted in the works of the firm who manufactured the former lamps, showed that a lamp could be worked on this principle. In order to ensure a proper draught through the carburetter it was necessary to limit the access of fresh air to the foot of the chimney; while, in order to start the lamp, it was also necessary to provide a small door below the chimney to admit a lighted torch or match. The heat from the torch produced sufficient draught to suck up carburetted air, which then became ignited. The experimental lamps, while they showed that the principle was all right, were far from being a practical success, and the author was asked to devise a construction which would prove satisfactory in ordinary use.

After considerable experimenting a lamp was designed which met the requirements. Without a dissected specimen it is rather difficult to render the construction and working of the lamp perfectly clear, but probably the description and drawings on the preceding pages (from a Patent Specification) may render the general nature of it intelligible.

The advantages claimed for these lamps are as follows:—

1st. Safety. Notwithstanding the nature of the fuel used, the lamps are much safer in actual use than are ordinary paraffin lamps burning good oil, and for two principal reasons. There is no liquid which can be spilled and become ignited, and, further, as soon as a lamp is upset, or its chimney smashed, the flame is immediately extinguished owing to the failure of the through draught. (Since the original communication was made to the Society, tests have been carried out by the officials of the British Fire Prevention Committee in London, with most satisfactory results. Lighted lamps were knocked over, thrown among shavings and muslin curtains, etc., and in each case the only result was to extinguish the flame and demolish the breakable parts of the lamp; when these had been replaced, the lamp was again in efficient working order.)

2nd. Economy. Although motor-car spirit is dearer than ordinary petroleum or paraffin oil, the use of incandescent mantles results in a great increase in illuminating power for the same consumption of material. The consumption is, roughly, one gram per candle power hour; taking the sp. gr. of the gasoline at 0·700, one gallon weighs 7 lbs., or 3175 grams. The illuminating power of the lamp under normal conditions is equal to 40–50 candles, say 45. One gallon of petrol, therefore, yields a 45 c.p. light for fully seventy hours, and the cost of fuel per hour is barely one-seventieth of the price of petrol per gallon.

3rd. Cleanliness. The volatility of the spirit ensures that any liquid which, say in charging, may be spilt on the hands, the outside of the lamp, etc., evaporates very rapidly, and there is no disagreeable smell such as often proves objectionable when using paraffin lamps.

The details of the lamps can be modified considerably, adapting them for use as table, standard, bracket, or pendant lamps; also for outside use, enclosed in suitable lanterns. The drawings exhibit only the simplest type; although not indicated, the opening at the top of the lamp can be fitted so as to allow of the safety method of charging being adopted.

Carburetted air for house installations.—Such installations, in addition to a suitable carburetting apparatus, must include some appliance for pumping air through the system of pipes; the best of these, so far as the author's experience goes, is Keith's Compressor. This works by hydraulic pressure, and can be driven off any ordinary domestic water supply; it is automatic, and delivers a steady supply of air at any predetermined suitable pressure. An apparatus driven by falling weights, etc., is not nearly so satisfactory, although sometimes adopted. Where sufficient water pressure is not available, the Keith Compressor can be driven by a small hot-air motor, fed by carburetted air, but this also is not so convenient as the hydraulic one.

In most systems hitherto devised the air was simply passed through suitable vessels charged with free liquid gasoline; such an installation could not, with safety, be placed inside the house itself, owing to risks of leakage, etc. This, however, is avoided by using absorbent material; but, when the installation is placed inside the house, it is advisable that the carburetters should be removable for charging at the place where the stock of gasoline is stored. These points have been attended to in the system devised by the author, and such installations are therefore specially suited for small country houses.

One of the greatest difficulties with regard to installations is due to the variable quality of the carburetted air produced in consequence of the fractionation of the gasoline, already alluded to. If one large carburetting vessel is used, then it will give, when newly charged, a much richer gas than when it has become partially exhausted. This causes trouble at the burners, which, of course, can only work satisfactorily with gas of nearly constant composition. In some designs an attempt is made to get over this difficulty by using two or more carburetters connected 'in series,' so that the whole of the air to be carburetted passes through each in turn, beginning with the carburetter which has been longest in use since last charging, and finishing off with that most recently charged. A little consideration will show that this cannot improve matters to any great extent. A sufficiently satisfactory result can be attained, however, by using a number of carburetters 'in parallel,' dividing up the air supply so that only a fraction of it passes through each carburetter. By charging the carburetters in rotation, not simultaneously, they are kept at different stages of exhaustion, and at any one time each is producing gas of different richness; when the different fractions of the total gas current reunite to form one stream, a mixture of average quality is obtained. By suitably increasing the number of carburetters the fluctuations of this average may be reduced to any desired extent. With a large number, there is always one of the set (but, of course, different ones at different times) which is not far from being fully charged, and another which is nearly exhausted, while the remainder are in intermediate states.

The installation system devised by the writer works on this principle, which had not previously been adopted. Space will not admit of a full description (which would require a complete set of drawings to render it clearly intelligible), but details can be seen, by any one desirous of obtaining them, in the British Specification No. 2030 of 1902. The carburetters are provided with only one opening (similar to those already described for the lamp), the fitting of which screws on to a special swivel tap provided with inlet and outlet channels. Consequently, when a carburetter is to be removed for charging, disconnection has to be effected at one point only. The carburetters can also be so arranged that they are not removable except when the appropriate taps are closed, so that escape of gas when disconnection takes place is rendered impossible. The actual charging can be performed by the safety method already described.

For an installation such as that indicated the most volatile variety of gasoline is a desideratum; one of about 0·650 sp. gr. is advisable. The lamps, however, work well with a spirit of 0·7 sp. gr., because here the carburetter becomes slightly warmed in use, from its proximity to the flame; with the installation, on the other hand, the temperature of the carburetters falls very distinctly during use, owing to the evaporation without any direct application of heat. In neither case is it practicable during actual working to exhaust the whole of the gasoline from a carburetter. This is due to the fact that when the absorbent blocks become practically dry along the channels, the rate at which vapour is given off from the parts at some distance from any channel is so slow that efficient carburation cannot take place. The residuum does not consist of a very sparingly volatile residue (as has sometimes been suggested) if a good quality of gasoline is used, because the amount retained does not increase to any noteworthy extent after repeated chargings. Even in cases where a block has been 'choked' by charging with improper material, the lamp has been gradually brought back to its normal condition by continued use of suitable gasoline.

In conclusion it may be stated that any suitable carburetting material for apparatus such as that described in this paper must necessarily come under the description of 'highly inflammable'; but recent experience shows that liquids of this kind can be stored safely enough when proper precautions are enforced. Once the liquid is taken up by the absorbent it becomes safer to work with than a 'safe' paraffin oil.

REPORT BY COMMITTEE.

Your Committee have had one of these lamps for testing, and it has been examined photometrically and otherwise at the Heriot-Watt College.

We find that it burns ten hours of good burning, or has a maximum period of burning of twelve hours. For ten hours the candle power was from 35 to 50, or on the average between 40 and 45 candle power.

Its efficiency in round numbers is 1 gram per candle hour—to be exact, with new mantle ·9 gram per candle hour—hence the cost with petrol at 1s. 6d. per gallon against paraffin at 8d. per gallon is about one-half that of paraffin, light for light. (The paraffin figures are taken from Professor Vivian B. Lewes' Report on Ventilation.)

Ordinary petrol for motors was used, sp. gr. ·700 at 17° C. At starting the candle power was low (35 candles), and only rose to

50 after some three hours, which we believe to be due to the fact that with a fixed ratio of air to gas, the mixture is only correct at one particular density of petrol; hence the candle power is less at the beginning and end of one discharge of the lamp than in the middle.

Although to get the greatest lighting effect from the petrol a double system of regulating the vapour and air would be necessary, the arrangement of Dr Marshall's lamp with a single lever obtains a sufficiently good result with obviously many advantages for household use, and from the tests we have made, has evidently been most carefully calculated. The regulation is very simple.

In order to get the maximum brightness, an adjustment is required about every hour or two, as the light slowly diminishes owing to changes in the composition of the petrol.

We foresee that there will be an accumulation of the less volatile constituents of the petrol, which will eventually choke up the absorber and reduce the number of hours of burning, and we see no provision for avoiding this.

In the form of lamp supplied to us, the lighting by an ordinary match or taper is likely to cause smoking of the glass or breaking of the mantle.

Loss while not in use was tested and found to be very small, although if several lamps are left filled for any lengthened period, the room should be ventilated.

The lamp is somewhat susceptible to draughts.

The absorbent supplied could not be extracted, and we have therefore not been able to make any tests of its absorbing power, but it is evidently very efficient.

We consider, therefore, that the important points of this form of the lamp are its high efficiency, ease of regulation and length of burning. It is as portable as any mantle lamp can be, quite free from smell or creeping of oil, and as regards safety, it is extinguished when tipped over and cannot explode or spill any liquid.

We strongly recommend this to the favourable consideration of the Prize Committee, and suggest that the paper should be published in full.

FRANCIS G. BAILY, *Convener.*
G. H. GEMMELL.
HENRY O'CONNOR.

On an Apparatus for Maintaining Automatically exact Temperatures by Electrical Means. By BASIL A. PILKINGTON.* (With Illustrations.)

(*Abstract.*)

In the designing of an arrangement for electrically controlling temperatures the author first used mercurial thermometers, but found the effect to be as follows:—

1. If sealed, the thermometer is not adjustable, and is not readily made to a given exact temperature.

2. (*a*) In use, the arcing of the current—pressure 230

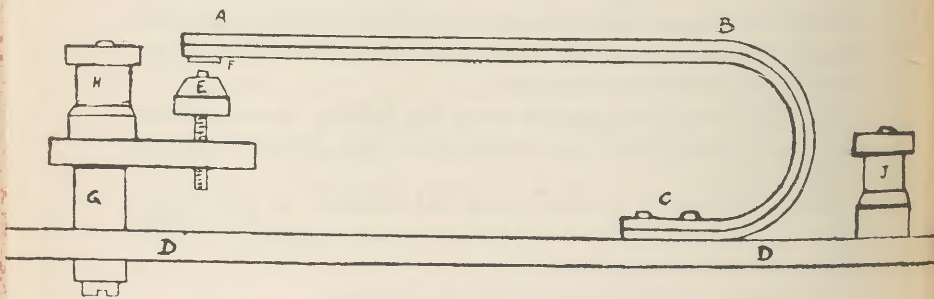

FIG. 1.—A, B, C, Hooked lever made of brass and iron; D, brass plate for mounting; E, adjustable contact, platinised; F, platinised surface on lever; G, insulation; H, J, connecting terminals.

volts—caused vaporisation of the mercury, which settled on the upper portion of the tube and raised the 'cutting out' temperature.

(*b*) Continued arcing destroyed the glass inside the tube, enlarging the bore, and still further raising the 'cutting out' temperature.

3. If unsealed, the arcing caused oxidisation of the mercury, and at once altered the 'cutting out' temperature. The principle of mercurial thermometers had to be abandoned, and another form of controller devised.

The thermostat itself (fig. 1) consists of a long lever A B C,

* Read and illustrated before the Society on 11th January 1904.

made of two metals having a different coefficient of expansion, and formed at one end into a semicircle B C. They are, in fact, strips of brass and iron brazed together, the brass being outside.

The effect of a rise in temperature is, of course, to slightly increase the length of this hooked lever. The small end of the curve C is fixed, and as the brass expands more than the iron, the curve curls inwards a little; this movement is

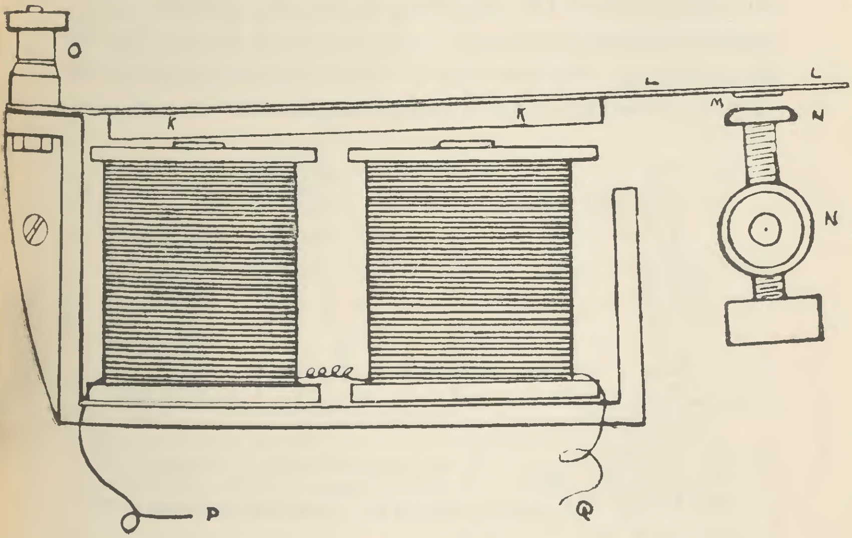

FIG. 2.—K, Iron armature, with L, extension, and M, platinised contact; N, contact stud and terminal; O, terminal; P and Q, connections from thermostat and battery.

intensified by the long lever, and is readily observable when the temperature variation is a few degrees.

The electrical connections are made by mounting it on a strip of brass D, and providing an insulated contact stud E on the end remote from the curve.

This stud is platinised, and made adjustable so that it may come in contact with the prepared and platinised surface F on the end of the hooked lever at A, and in such a position that a depression of the lever brings the two platinum pieces into metallic, and therefore electrical, contact.

It was found that this contact was suitable for carrying a useful amount of electric current supplied from—

1. Ordinary Leclanché batteries.

2. The Corporation supply, when controlled by a special arrangement described later.

This current operates an armature K on a double coil electro-magnet (fig. 2). This armature is provided with an extension L, and platinised contact M, working on to a stud or terminal N. The armature itself is a part of a high-pressure circuit, the supply coming from the Corporation, and by its contact with the stud N this circuit is completed and magnetises another pair of electro-magnets shown in fig. 3.

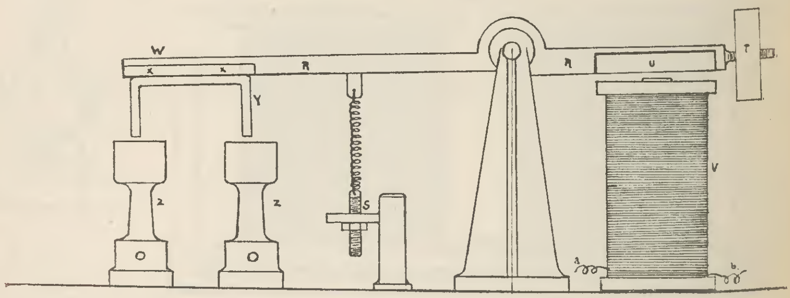

FIG. 3.—R, Balanced lever; S, spring adjustment; T, adjustable balance weight; U, iron armature; V, electro magnet coils; X, insulating block; Y, steel fork; Z, iron mercury cups; *a*, *b*, connections from fig. 2.

This instrument is the type usually used for breaking an electric circuit automatically or from a distance, and is in common use for many purposes. It consists of a balanced lever R, with a spring adjustment S at the long end and an adjustable balance-weight T at the other.

An iron armature U is drawn down to the coils V as soon as they become magnetised by the current passing through them.

The effect of this is to raise the lever at W. This end of the lever has an insulated block X on it, and is fitted with a steel two-ended fork Y, each prong of which dips into an iron cup of mercury Z, and is a portion of the main current supplying the heating energy.

The heating arrangement proper may take any form consuming electrical energy, and in this case is a boiler or hot-water cylinder, heated by electric current passing through a number of fine wires of high resistance imbedded in enamel, inside the base of the cylinder filled with water, which, as it gets warm, circulates round copper pipes run several times round the room to be controlled.

The temperature of the water rises continually until it boils, or the current is cut off.

Fig. 4 shows the several portions of the arrangements connected up as in actual use. The current, before passing through the thermostat (fig. 1), passes through two lamps of small candle-power arranged in series. This allows sufficient current to pass to magnetise the coils of the 'cut in' (fig. 2), and yet no injury is done to the contacts of the thermostat, though the break, being operated by the rise and fall in temperature, is naturally extremely slow and small.

The thermostat with its lamps is in series with the coils of the 'cut in,' and forms one complete circuit from the Corporation supply.

The series arrangement of lamps enables a very small amperage to be obtained with lamps of standard candle-power, and even a short-circuited lamp does no damage.

The current passing through the armature of the 'cut in' is first passed through two lamps in parallel, then through the coils of the 'cut-out.' The object of this arrangement is to ensure the instrument working, even if a lamp filament breaks—the contact in this case being made and broken smartly, and the lamps almost fully incandesced. This forms a second complete circuit from the Corporation supply. The third complete circuit passes through the mercury cups to the heater, and so back to the supply. All three circuits can be controlled by one switch of either single or double pole, and no setting is necessary, the switching on of the current bringing all the parts into operation when the required temperature is reached, and maintaining same.

By placing the resistance lamps outside the room heated, it is possible to note when the heater is consuming current and when cut out without opening the door; it also shows when the change from action to inoperation takes place.

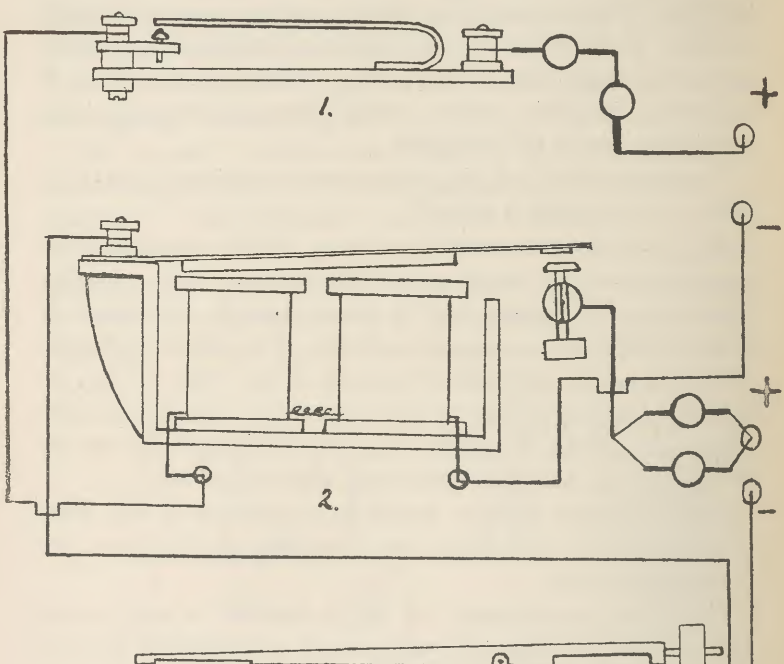

Fig. 4.—1, Thermostat; 2, cut in; 3, cut out; 4, heater.

It was found that the variation did not exceed one-half of one degree Fahrenheit, the capacity of the rooms being some 300 cubic feet.

REPORT BY COMMITTEE.

The Committee appointed to report upon Mr Pilkington's paper, read before the Royal Society of Arts on 6th January 1904, "On an Apparatus for Maintaining Automatically exact Temperature," have carefully considered the matter and inspected the apparatus as installed at the Usher Institute, and are of opinion that the paper should receive the favourable consideration of the Prize Committee.

The incubating chambers at the Usher Institute are heated by Crompton electric boilers, provided with circulating pipes which pass round the walls. The electricity for those is obtained from the Corporation mains, and as the temperature falls or rises this current is automatically cut out or in. A variation in temperature of $1\frac{3}{4}°$ is the maximum desirable, but with the old method of thermometer regulation this variation would reach sometimes 6° or 7°.

Improved apparatus became necessary, and Mr Pilkington devised his apparatus as an improvement on the ordinary methods adopted for this automatic control, with the result that the temperature variation, we understand, does not now exceed 0·4° F.

The special features of the apparatus consist in—

(1) The design of an adjustable thermostat extremely sensitive in its action.

(2) The design of special contacts suitable not only for battery circuits but for the 230-volt Corporation supply in series, with small incandescent lamps.

(3) The adaptation of ordinary electrical apparatus to suit the particular requirements.

ARCHIBALD WILSON.
ALEX. OGILVIE.
MATHEW BUCHAN, *Convener.*

The School Training of Future Engineers.

By A. J. Pressland, M.A., F.R.S.E.*

The Scotch Education Department has recently adumbrated a scheme for the issue of technical certificates to pupils attending schools which have a definite technical curriculum. The Department intimates that in technical work local needs are probably more varied than in commerce, and on this account it does not prescribe any rigid or stereotyped course. In every case, however, the main subjects of the course will be the further study of science and mathematics, with such subjects as instrumental drawing, machine or building construction, and wood or iron work. English composition and the study of English literature will be an obligatory subject for all candidates.

In a previous circular which referred to the issue of commercial certificates, school-managers were advised to consult the local chambers of commerce, and to enlist the sympathy of the commercial community, so as to obtain, if possible, some practical recognition of the certificate by business men. The advice applies with greater force in the case of the technical certificate. The object of this paper is to effect an interchange of views which will ensure the co-operation of school and works in the task of solving these difficulties.

Before commencing a detailed discussion, it is desirable, for the sake of reference, to consider a standard school system and a standard organisation of technical workers. For the former the Scotch system will be taken, for the latter the system in use in the Canton Zürich, where the author has inspected schools and works for some years on behalf of the Board of Education.

In Scotland every pupil, as a rule, receives a primary education up to the age of twelve. Excellence is attested by the merit certificate. Boys who gain this proceed to higher elementary schools or to secondary schools. Each

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* Read before the Society on 25th January 1904.

kind of school is inspected and examined, both orally and on paper, by the Department. Two kinds of certificate are granted. One, the Intermediate Certificate, which represents a good education without specialisation, can be gained at the age of fifteen. The other, the Leaving Certificate, represents ripeness for university study, and can be gained at the age of seventeen. Special Leaving Certificates are, the Commercial Certificate and the Technical Certificate, each of which represents a certain amount of specialised study.

It is not likely that any but the abler boys will gain these certificates at the ages mentioned. Complaints are frequent that boys leave school too early, and that they are overworked in order to gain the certificates at the earliest opportunity. Their physical training is also neglected, and they fail to benefit by the corporate life of the school.

The Zürich organisation of workers may be briefly described. There are three classes :—

I. Skilled mechanics, who have served an apprenticeship and passed through the technical course of the Continuation School.

During apprenticeship an apprentice gang is often formed under the guidance of a skilled workman. No lectures are given at the works, but attendance at a continuation school is compulsory. Apprentices are sent to school for two half-days per week, at the employer's expense.

II. Works engineers, who have passed two full years in study at a technical institute after they have qualified as skilled mechanics.

III. Laboratory engineers, who have received the best secondary education, supplemented by four years of consecutive study at a technical university and two years' practice in works.

As these names are distinctive, they will suit our purpose. The organisation cannot, however, be described as stable. The tendency in Switzerland, as elsewhere, is to form three classes: machine minders, who supply intelligent but unskilled labour, engineer foremen, and engineers.

Consider a class of boys at a primary school who are entering for the merit certificate. Those who fail will remain at the primary school until attendance is no longer compulsory. Those who pass will join a higher elementary school, or a school of science, with a view to gaining an Intermediate Certificate. At the age of commencing apprenticeship, which should not be less than sixteen, the following two classes of boys will offer themselves:—

I. Those who have been at school continuously up to the date of commencing apprenticeship, and possess at least an Intermediate Certificate.

This class it is desirable to encourage. The precise manner in which encouragement is given must depend on local considerations. What teachers desire to see is some real inducement for boys to remain at school beyond the age of compulsory attendance.

II. Boys who have left school before the date of apprenticeship and have no certificate.

These boys will probably have spent some time in counting-houses. It would be well for employers to demand a year's service on probation from them, the probationary period to count towards apprenticeship if a boy gained his certificates in the continuation school.

Some pupils from primary schools will go to secondary schools with bursaries. Their schoolfellows will be boys who were destined for a professional career from the commencement. The school course will cover the period between twelve and nineteen years of age, but it will only be completed by the abler and the wealthier.

There are thus three types of school for which provision must be made:—

I. Continuation Schools.

II. A five-class Secondary School, for which we have not yet a distinctive name. It corresponds to the German *Realschule*.

III. An eight-class Secondary School, which corresponds to a German *Gymnasium*.

The Continuation School is distinguished from the others by the fact that it is a professional school. Most of the classes will be held in the evening, though there will be a number of day classes. The latter are a regular feature on the Continent, and appear to be gaining in favour in Great Britain. The Municipal School of Technology at Manchester and the Swindon Technical School are two institutions where day continuation classes are held.

Teachers of continuation classes will be either registered teachers or skilled workmen. The Code provides for the grant of a certificate to pupils which will entitle the recipient to recognition as a teacher of these classes.

In the past, pupils have been attracted to continuation classes by Sunday-school methods. It is not right that these schools should be filled with a lot of young people who find a difficulty in killing time. One would like to see the more earnest in regular attendance—those who are ready to sacrifice their time, their amusements, and even their pay. Any arrangement which continues education beyond the age at which attendance ceases to be compulsory will assist towards the attainment of that high standard of organised intelligence on which the prosperity of our country depends.

The five-class Secondary School will prepare pupils for the Intermediate Certificate. It will not give a professional education nor a specialised education.

Some of the pupils will enter works, others will join commercial houses, and a number will proceed to training colleges and become teachers.

It may be necessary to make six classes in this school, the lowest being a primary class. The curriculum would be approximately—

Age Class	11–12. I.	12–13. II.	13–14. III.	14–15. IV.	15–16. V.	16–17. VI.
	Periods per Week.					
English,	12	9	8	6	4	4
French,	...	6	5	5	4	4
German, or Manual Work,	...	...	...	...	5	5
Mathematics and Drawing,	9	7	7	7	6	6
Physics,	...	...	4	4	5	5
Chemistry,	...	...	2	4	5	5
Natural History,	3	2	...	...	...	...
Freehand Drawing,	2	2	2	2	2	2
Gymnastics,	2	2	2	2	1	1
Singing,	2	2	...	...	...	...
Total,	30	30	30	30	32	32

A pupil who took this course might obtain an Intermediate Certificate in Class IV. He would then have the option of commencing apprenticeship or of proceeding to a secondary (eight-class) school. It might be possible for an exceptionally able pupil to gain the Technical Certificate in Class V., but the attempt should be discouraged. In many cases it has proved a cruel kindness to tempt a poor boy to gain the highest scholastic distinctions. He has thereby unfitted himself for work which he is capable of doing well, and brought himself into unequal competition with others of wealth and influence.

It would be idle to attempt to conceal the rivalry throughout the educated world between the two kinds of secondary schools. It is not due to differences in the constitution of governing bodies. It is rendered somewhat acute by the absence of compulsory training for secondary schoolmasters. It will persist until the public learns the difference between the functions of the two schools, a difference which was aptly illustrated to the author by a Swiss schoolmaster. "The intermediate school," he said, "can pay a good dividend from the outset, as it needs not accumulate a reserve fund."

An eight-class secondary school will be divided into a classical side, a technical side, and possibly a commercial side. The division will commence in Class IV., where Greek becomes alternative to Science, and be complete in Class VI. As few of the pupils make an early choice of a profession, Latin must be a subject of the curriculum until the pupil qualifies for the Intermediate Certificate.

On the technical side, future engineers, architects, and surveyors will be enrolled. The curriculum will be approximately as follows :—

Age / Class	11–12. I.	12–13. II.	13–14. III.	14–15. IV.	15–16. V.	16–17. VI.	17–18. VII.	18–19. VIII.
				Periods per Week.				
Latin, . .	8	8	8	7	7	...	...	..
Mathematics and Drawing,	7	7	7	7	7	8	8	8
Physics, . .	...	...	...	3	3	6	6	6
English, . .	11	11	6	4	4	5	5	5
Botany, . .	...	...	2	...	...	...	...	...
French, . .	...	...	3	4	5	4	4	4
German, . .	...	...	...	3	4	4	4	4
Chemistry, .	...	...	...	...	...	4	4	4
Singing, . .	2	2	2	...	...	...	...	...
Gymnastics, .	2	2	2	2	2	1	1	1
Total, .	30	30	30	30	32	32	32	32

Freehand Drawing and Manual Work as extras.

A few remarks may be made on the various subjects.

In modern languages, the language taught should be the medium of instruction. Pronunciation should be taught on phonetic principles. In the senior German class a science text-book should be read.

The mother-tongue must be the subject of care in every lesson where it is used. It is useless to expect precision in writing or speaking when only a few hours are given to the study of history and literature. Much can be done to improve composition and handwriting by improved methods of teaching, and these will result from pedagogic training.

The same master should teach mathematics, physics, and instrumental drawing. The best boys should know the calculus, so far as practical applications are concerned.

These curricula can be modified to suit local requirements. They have been framed so as to ensure a high standard of culture rather than early proficiency in any special subject. This is of importance, for it is most necessary that boys who join the technical side or the commercial side should feel that they are under no social or intellectual stigma. They must not be subjected to nicknames, such as "the Blacksmiths" or "the Grocers," nor must they be permitted to imagine that they exist at school only on sufferance.

The amount of practical training in wood and iron work which should be given is not easy to determine. Some schoolmasters think that it is not the function of a school to supply it. Others believe that the object will be attained more easily if pupils spend a year at a special metal- or wood-working shop before joining a works. If foreign example were followed, cardboard- and wood-work would be a compulsory subject in the primary schools and an optional subject in secondary schools. It would be difficult to find the time for manual work in secondary schools if many boys were being prepared for competitive examinations. It is to be feared that school-managers may spend large sums in fitting up apparatus as an advertisement, and that the teaching will be starved. There is a further danger that teachers may be inclined to undertake too much of the work of the shops, to the neglect of what is within their own province. The subjects of manual work and drawing present many difficulties, in the solution of which practical needs must receive first consideration.

A general sketch of this nature only emphasises the necessity for co-operation between employer and teacher. Among the duties of the latter is one of increasing importance—that of suggesting a career for his pupils. One sometimes hears an employer say of a boy, "Give him a good education and let us have him to train at sixteen." On inquiring about the boy later, it is found that he gets no training, and is merely a works drudge. If a boy enter works and no provision be made for his future instruction, he is apt to adopt the manners and language of the workmen, becoming a pest at home and a deterrent to his schoolfellows who are led to prefer the false gentility of an office to the rough custom of works.

From a number of sides objections are raised to a prolonged school training. Persons trained at a time when mother-wit and common-sense were the engineer's most valuable qualities, still believe that it is good for a boy to become acquainted with drudgery at an early age. This view has been given up by the modern school, which attributes the success of the foreigner to his employment of the most highly trained labour. (It is well to recollect here that almost every commission that has studied the question has discovered that the foreigner begins his special training at an age when it is considered here that it should cease.) Men highly trained in this manner do not join the academic proletariate. One large employer of labour in Switzerland told the writer that, whereas twenty years ago five university men per thousand was considered ample provision, he was now obliged to employ twelve. In our own country the most lucrative posts are likely to be filled in the future by the highly trained man who has the knack of managing workmen.

It is not right to think that in our secondary schools boys are trained to despise manual labour. The author has questioned former pupils, and found that physical effort never deters them. Their objections are directed to men whose language and manners lack refinement, and whose interest in their work is wholly pecuniary. A man who has received a good education has broader sympathies, which teach him the dignity of labour, and, if admitted freely, he raises the tone and intelligence of the works.

The aim of the schoolmaster is to turn out boys who love work and respect learning. For this purpose he must see that they get leisure, and endeavour to teach them how to use it. He must not regard mere intellectual skill as the best outcome of education. His aim must not be the production of prodigies of learning, who will give employers no anxiety about their training and will form a convenient source of cheap labour. It is better to give a boy orderly habits of thought, work, and conduct, and a sense of his duties to the community, than to attempt to fill his mind with the sum of all knowledge.

It is erroneous to infer that the school regards the works or the college with antagonism. Schoolmasters are willing, within reason, to modify their curricula to suit technical requirements, and to recommend boys to follow a technical career. But they wish to be sure that success at school is recognised by employers, and that a boy's further training is not left to chance.

There are many points which have not been considered, the most notable being the question of syllabuses of instruction. These will prove of little difficulty if the spheres of action of the school, the works, and the college be once defined. The task should not prove impossible if it is undertaken by a body which can command the assistance of those best qualified to speak, and can lend authority to their joint conclusions.

REPORT BY COMMITTEE.

Your Committee desires to express its high appreciation of Mr Pressland's communication. It deals with a subject of the highest importance to the country, and one which cannot be neglected if we are to retain our position as a great manufacturing nation.

Old ideas and many of the old prejudices in educational matters are passing away, and our systems of primary and secondary education have been practically cast into the melting-pot, and we hope that the result will be a great and general improvement in secondary education all over the country.

Mr Pressland's communication shows how much care and thought are being devoted by the masters of our great secondary schools to the organisation of satisfactory curricula to meet modern requirements, and your Committee is of opinion, without committing itself to approval of all the details, that the curricula Mr Pressland suggests for a five class and for an eight class secondary school go a long way towards meeting the demands of engineers and other employers of labour—that the lads who come to them as apprentices or pupils shall have had a thoroughly good general education to start with, and then a specialised education as far as it is possible to give this latter in the school while boys leave school at the comparatively early age now so customary.

Your Committee desires to recommend strongly this communication to the notice of the Prize and Publication Committee.

T. Hudson Beare, *Convener.*
Richard Stanfield.
A. P. Laurie.
D. W. Kemp.
R. M. Ferguson.

The Plotting of certain Intrinsic Equations. By E. M. Horsburgh, M.A., B.Sc.*

It is possible in certain cases to draw curves with tolerable rapidity and accuracy when the intrinsic equation is given. This is the relation between s, the length of arc, and ψ, the angle turned through by the tangent as it moves along the arc; and the name is given from this relationship being independent of an arbitrarily chosen pair of axes.

If $s=f(\psi)$ be the equation, the radius of curvature is $\rho=\dfrac{ds}{d\psi}=f'(\psi)$, and also $\delta s=\rho\delta\psi$ approximately. Taking $\delta\psi$ as a small constant quantity, a series of values of ρ, assumed constant through each small interval $\delta\psi$, may be calculated. The lengths of the successive small elements of arc δs are then obtained from the equation $\delta s=\rho\delta\psi$. Each element of arc is drawn by means of a pair of compasses set at the proper radius of curvature, commencing, if need be, at ρ_0. Thus the shape of the curve is approximated to by means of a series of circular arcs, the direction of each new radius of curvature being that of the final radius of the last arc. This method is in fact the drawing of a curve as an involute.

It is convenient to tabulate as follows :—

$\delta\psi$	Interval ψ	Average value of ψ through interval	$\rho=f\psi$	δs

The smaller $\delta\psi$ is taken, the more accurately are the values of ρ and δs obtained. The accuracy of the result is checked before drawing by adding up the last column (δs) and comparing with the value of s given by the intrinsic equation.

It is interesting to notice that though the difficulties of graphic differentiation are well known, yet it is easy to differentiate graphically a curve drawn in this manner, as

* Read and illustrated before the Society on 11th April 1904.

the direction of the tangent at any point is obtained at once by simply drawing a line at right angles to the radius of the arc.

REPORT BY COMMITTEE.

Your Committee beg to report that they have examined this second communication by Mr Horsburgh on the Plotting of Intrinsic Equations.

The method proposed by the author for drawing certain curves given by their intrinsic equations is very neat, and apparently susceptible of a fair degree of accuracy. It would, however, add to the value of the communication if the author were to submit some examples of curves drawn by the method he proposes.

Your Committee are of opinion that the best thanks of the Society should be given to the author for this communication.

T. Hudson Beare, *Convener.*
Richard Stanfield.

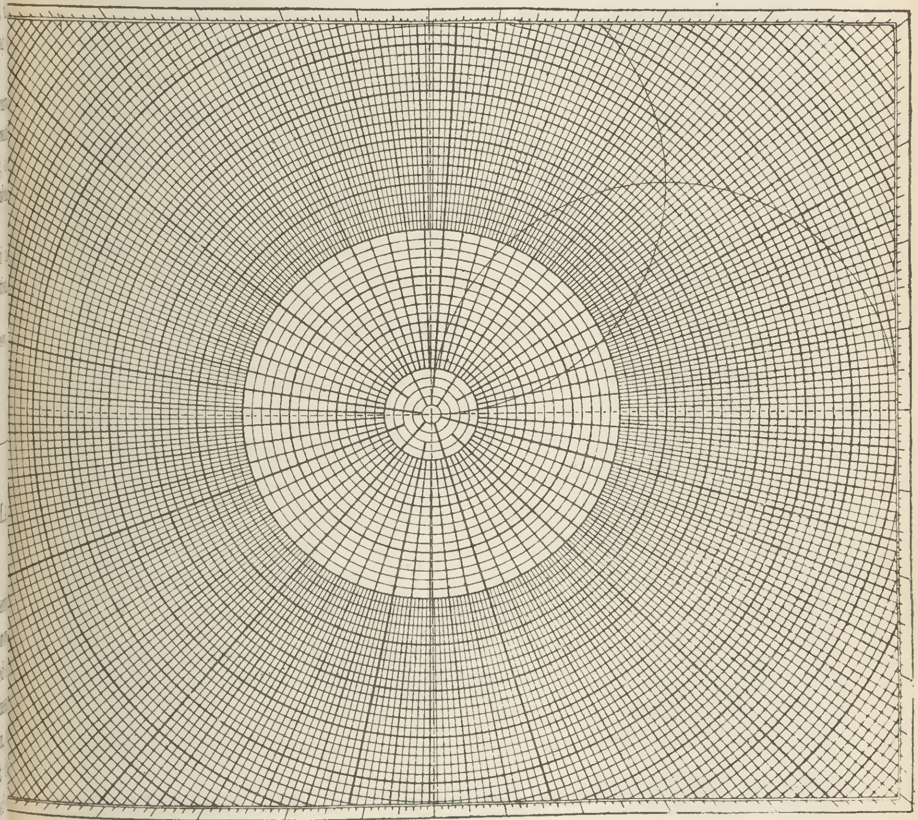
An Improved Polar Paper. By E. M. Horsburgh, M.A., B.Sc.* (With Illustrations.)

By means of squared paper a large number of engineering and physical problems may be attacked and solved approximately, frequently with as much accuracy as is required in practice. Such problems as, for example, the measurement of work done by a variable force, work done in traction, or work done in a cylinder, the measurements of output by hydraulic or electric prime movers, the measurement of a volume the areas of the cross sections being known, all reduce to the evaluation of an integral such as $\int_a^b y dx$, where y is a function of x, and a and b are the given working limits.

With squared paper, however, one is excluded from direct

* Read and illustrated before the Society on 11th April 1904.

angular measurements, as only those graphs can be drawn which involve linear measurements parallel to two given arbitrary directions. But a point can be fixed equally well by measuring a length in a given direction. This is the method used in setting out by means of a chain and an angular instrument, and it employs the mathematical



method of polar co-ordinates. The linear distance from a fixed point or pole is usually denoted by r, and the angular distance from a fixed position or initial line is called θ. Hence, if paper be ruled so as to give the various angular distances in degrees from the initial line, and also the linear distances from the pole, it is evident that polar graphs whose equations are of the nature $f(r\theta)=0$, or $r=F(\theta)$, may be drawn upon it.

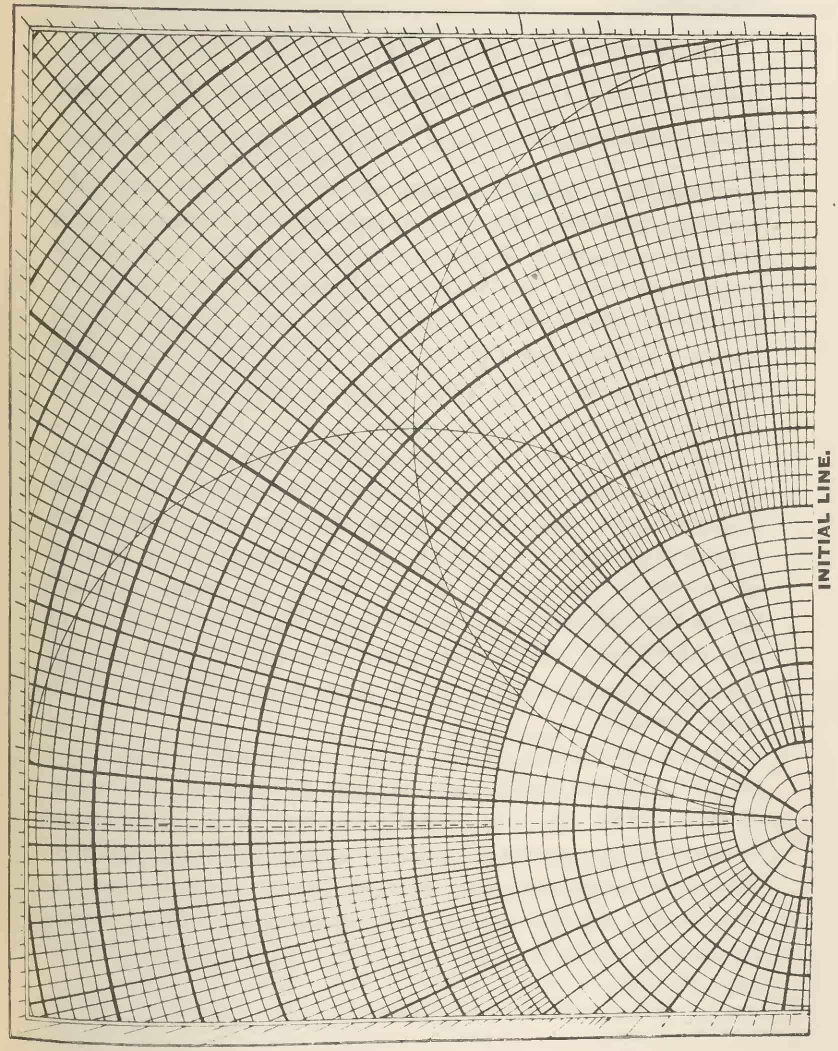
A paper so prepared would have the serious disadvantage that certain areas and lengths represented upon it, when read directly, would be meaningless, being the product of some scalar quantity and a number of degrees; and so this paper could never have for polar curves the great advantage that squared paper has for cartesians.

This disadvantage is got rid of by graduating the paper angularly in radians and decimals of a radian. Areas and lengths have now a definite meaning, and the paper has now many of the advantages of squared paper, with several additional advantages.

To increase the usefulness of the paper a scale is put round the edge giving the angles in degrees, so that instant conversion may be made from radians to degrees, or conversely. On the prime radius vector, and on that at $\frac{\pi}{2}$, semicircles have been described on a diameter decimally subdivided. Hence the lengths intercepted on any radial line between these and the pole give the cosine and sine of the angular direction in which the radial line is drawn. By direct division the value of the tangent is obtained. Hence we get on the paper the values of the trigonometrical functions of any angle, and by looking along the radius vector to the outer scale the angle, if in radians, may be converted at a glance into degrees, or conversely. This greatly facilitates the plotting of polar curves, as tables of the trigonometrical functions are not required.

If a polar graph such as $r=f(\theta)$ has been drawn, suppose it is required to evaluate $\int_a^b r d\theta$. This is the same as evaluating $\int_a^b y dx$ where $y=f(x)$, which is represented by an area on squared paper.

As, however, in a circular arc $\delta s = r\delta\theta$, the former integral represents on polar paper the sum of the small elements of arc of the curve $r=f(\theta)$, each resolved perpendicular to its mean radius vector, *i.e.* it represents a length, which can be estimated by eye, or by scale, or calculated in the following way. Read the mean radius vector to the centre of each element of arc at equal small angular distances, sum these,



and multiply by the same small angular distance. In other words, if we take the angular distance as ·1, it is merely necessary to add the mean radii vectores and shift the decimal point one place forward in the result. This important output integral is thus evaluated more simply than by squared paper, where a more complex process needs to be employed.

The important integral $\int_a^b r^2 d\theta$ or $\int_a^b y^2 dx$, where $r=f(\theta)$ or $y=f(x)$, is also directly evaluable by means of this paper. Since $\frac{1}{2}\int r^2 d\theta$ represents the area of an elementary triangle bounded by a small element of arc, and two near radii vectores, including the small angle $\delta\theta$, hence the complete area, being the sum of these, gives the value of the definite integral required. Its value may be got by a rule similar to that which has been mentioned, the only difference being that the value of each mean radius vector must be squared before summing. The value may, of course, also be estimated by eye or by triangulation.

As the length of the prime radius vector may be read as any decimal multiple or submultiple of unity, it is evident that when any portion of a graph becomes too small or too large to be conveniently dealt with in any sector, it may be magnified or diminished in that sector by merely altering the scale without to any extent affecting the simplicity of the calculation. It is unnecessary to add that all graphic representation should be on as large a scale as the sheet of paper permits.

If the scale of length be traced or pricked through to a strip of paper tangents may be read to scale on the border of the ruling. If a set square be used, it is evident that the ordinary processes of graphic arithmetic (multiplication, division, proportion, squares, and square roots) may be carried out on this paper without further drawing, while reciprocals are given by a ray of its length intercepted by the semicircle.

REPORT BY COMMITTEE.

The Committee beg to report that they have carefully considered Mr Horsburgh's communication dealing with an improved polar paper for plotting work.

Mr Horsburgh in this communication points out how extremely useful ordinary squared paper is in saving time and labour in working out many engineering problems and in recording results of experiments and observations. Such paper makes use of the principle of rectangular co-ordinates for fixing the position of a point in a plane, but the author points out in his communication that it is often desirable to employ polar co-ordinates for this purpose rather than rectangular co-ordinates.

Paper, however, ruled merely so as to give angular distances in degrees would be useless in many respects, as areas on such a paper would be meaningless. The author therefore proposes to rule the paper angularly in radians and decimals of radians, since on such paper areas and lengths have a definite meaning, and such paper is quite as useful as, and in fact more useful than, for certain purposes, squared paper. By drawing two semicircles on such ruled paper, one on the prime radius vector and the other on the $\frac{\pi}{2}$ vector, the values of the simple trigometrical functions can at once be read off the paper, and therefore mathematical tables are not necessary when plotting: this much facilitates the plotting of polar curves.

The author then explains how simple it is to evaluate by the use of this specially ruled paper such integrals as

$$\int_a^b r d\theta \quad \text{and} \quad \int_a^b r^2 d\theta \, .$$

Your Committee consider, however, it would add greatly to the value of this paper, when printed in the *Transactions*, if the author furnished some examples of such plotted curves for reproduction as illustrations of the communication.

Your Committee are of opinion that such improved polar paper will prove extremely useful to engineers, physicists, and other scientific men.

They desire strongly to recommend this communication to the notice of the Prize and Publication Committee.

T. Hudson Beare, *Convener.*
Richard Stanfield.

On Electrolytic Interrupters. By CHARLES NORMAN KEMP.*
(With Illustrations.)

It is only within the last two or three years that electrolytic interrupters have become more than mere scientific curiosities. The idea of using a voltameter to interrupt the current in the primary circuit of an induction coil is, however, by no means new.

Writing in *Nature*, March 30, 1899, Mr Wm. Webster says: "In reference to the Wehnelt current interrupter, in 1874 I used a similar interrupter on a coil with 50 Groves cells. The idea was not even then new, for, although my experiment was due to accidental short-circuiting of electrodes during electrolytic experiments, which led to my final application of the so-called interrupter as a resistance to current, and then as a rapid make-and-break, I found that some of the old masters of electrics had evidently used it before."

In the *Proceedings* of the Royal Society of Edinburgh, vol. xxv. 1877, there is a description of stratified discharges by Mr W. Spottiswoode, whose name is famous in connection with induction coils and all pertaining to them.

In this paper occurs the following:—

"Another form of contact breaker was also occasionally used. The principle upon which it was based was the sudden disruption of a thin film of conducting liquid by a discharge between the electrodes of a circuit. The mode of effecting this was to make one electrode terminate in a platinum plate fixed in a horizontal position, and supplied with a uniform film of dilute sulphuric acid; the other in a platinum point, the distance of which from the plate is capable of delicate adjustment by means of a screw. Electromotive force required for this break is not less than that of 5 cells of Grove (*i.e.* about 9·5 volts).

"As soon as the current passes, the fluid between the plate and the point will be decomposed, and electrical continuity broken. This done, the fluid flows back again, and continuity

* Read and illustrated before the Society on 11th April 1904.

is restored. By a proper adjustment of the supply of fluid, and of the distance of the electrodes (the latter varying from ·05″ to ·001″), the number of interruptions may be made to attain 1000 per second. The currents delivered by this form of break are exceedingly uniform, and the effects produced are quite equal in delicacy to those produced by the electro-magnetic or by the wheel break."

These early experiments had either been neglected or entirely forgotten till Röntgen's famous discovery of the X-rays, and other advances in electrical science, created a need for a break more rapid than those then available.

This need was supplied by Dr A Wehnelt, of Charlottenberg, in 1899.

An exhaustive account of his apparatus and experiments is to be found in Wiedemann's *Annalen* for 1899, in a paper entitled "Elektrolytischer Stromunterbrecher."

Though, in his introduction, he acknowledges similar researches by Davy, Planté, and others, he makes no reference to the early experiments quoted, from which it may be assumed that they were unknown to him.

In the *Comptes Rendus* (January–June) for 1899 there is a paper entitled "Perfectionnements à l'interrupteur de Wehnelt, Note de M. J. Carpentier présentée par M. D'Arsonval," of which the following is a free translation:—

"This savant, by the consideration of the undulatory form assumed by an electric current traversing certain liquid electrolytes (acidulated water in particular) in a voltameter provided with very unequal electrodes, was led to include such a voltameter in the primary circuit of an induction coil.

"He obtained at once an original and extraordinarily efficient interrupter. Actuated by a fairly high voltage (about 120), the apparatus is capable of producing a number of interruptions which may easily attain the order of 1500–2000 per second, and set up between the secondary terminals of the coil a stream of sparks so closely packed together that they unite, so to speak, into one arc, which assumes the form of a long, undulating furry caterpillar."

The earliest form of Wehnelt's interrupter was simply a beaker of dilute sulphuric acid, containing a large lead plate as one electrode, and a small platinum point, just dipping into the liquid, as the other. When in action the acid was found to spurt up, so this apparatus was soon improved by enclosing all but the tip of the platinum wire in a glass tube which dipped further into the acid.

Various other improvements naturally suggested themselves, both to Wehnelt and other investigators.

The form exhibited before the Society is a modification by Mr A. A. Campbell Swinton of the Wehnelt-Caldwell

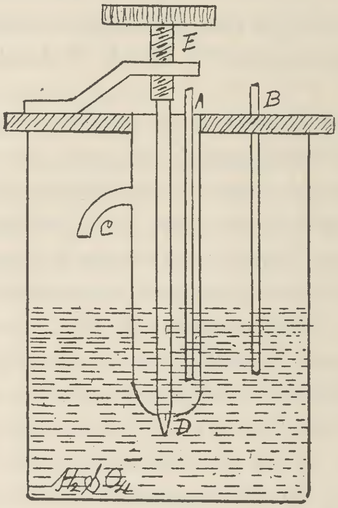


FIG. 1.

Interrupter, a description of which is to be found in *Nature* for July 6th, 1899.

Fig. 1 gives a diagrammatic view of the parts of this apparatus.

The containing vessel is of glass and is about half filled with dilute sulphuric acid (1 in 6 by volume). The ebonite lid carries a glass tube C D about $1\frac{1}{2}$ inch in diameter, provided with a side tube at C and a circular orifice about $\frac{1}{4}$ inch in diameter at D.

The screw E regulates the taper-pointed glass rod (seen in the centre of the tube), wherewith the size of the opening at D can be increased or diminished.

The electrodes are of sheet lead, one (A) being placed inside the glass tube and the other (B) externally to it.

The overflow tube C is provided for the escape of the electrolyte which rises in the glass tube when the interrupter is in action. The author found that the action of the apparatus was rendered somewhat erratic by the precipitation of oxide of lead from the internal electrode into the orifice at D. This defect was removed by enclosing the electrode A in a perforated glass sheath.

Fig. 2.

The lid is provided with suitable valves for the escape of the gases evolved. For protracted use it is advisable to have the glass jar enclosed in a water cooling bath, as the acid electrolyte becomes very hot in a comparatively short time, the heating, however, rather assisting than impeding the action of the apparatus.

The opening at D gradually wears larger, and in the form exhibited the rod and hole have ground themselves to a perfect fit, though originally smooth from the blowpipe flame.

Fig. 2 is a photograph of the Interrupter, as constructed and exhibited by the author.

Fig. 3 illustrates a type of Carbon Electrolytic Interrupter.

The central glass tube is a thistle funnel, provided with a stirrup and opening as seen at A. Into this loosely fits a carbon rod about 3 mm. in diameter and copper plated to within a few mm. of the tip. The end of the rod rests on the stirrup, and as it gradually wears away, slides down in the tube. The electrolyte is a 20 per cent. solution of potassium hydroxide contained in a lead jar which forms the negative pole, the carbon rod being the positive electrode.

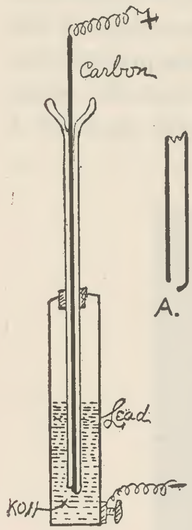


Fig. 3.

This interrupter is said to be reliable, and suitable for X-ray work.

The theory of Wehnelt's apparatus has been very fully made out by various investigators. The following description gives a fair idea of what takes place. After the current is started it increases in strength till sufficient heat is developed to cause the vaporisation of the electrolyte round the active electrode, or, in the case of the improved interrupter, round the aperture in the glass tube.

If we translate this into symbols, and take

H = heat developed in calories,
C = current strength,
R = resistance,
t = time,

we have, by Joule's Law,

$$H = C^2Rt \times \cdot 24 \quad . \quad . \quad . \quad . \quad (1)$$

(C being a complicated function of the self-induction, E.M.F., resistance, etc., which it is unnecessary to introduce).

It has been shown that the current does not increase uniformly, so that the total heat may be expressed thus:

$$H = \cdot 24(C_1{}^2R_1t_1 + C_2{}^2R_2t_2 + \ldots\ldots) \quad . \quad . \quad (2)$$

or more simply,

$$H = \cdot 24\int_{t_0}^{t_1} C^2R\,dt \quad . \quad . \quad . \quad . \quad (3)$$

When the integral (3) reaches a certain definite value the electrolyte is vaporised; in fact, spectroscopic examination shows that the gases evolved are rendered incandescent. The immediate effect of the vaporisation is the rendering infinite of the resistance of the cell, and the consequent stopping of the current. This constitutes the break. Immediately thereafter the cooling process, which naturally follows, causes the condensation of the gases and the re-making of the circuit.

This, however, does not explain all the facts. Ruhmer has shown that self-induction of the system plays a very important part, as the following simple experiment devised by T. Mizuno shows. If an electrolytic interrupter be connected in series with a helix of wire and a suitable source of current, and matters so adjusted that the interrupter just does not work, the introduction of an iron core into the helix causes an immediate starting of the interruptions, and shows the important part played by the self-induction of the circuit. It is exceedingly interesting to compare the action of an electrolytic with that of an ordinary mechanical interrupter. Mizuno says on this point:—

"In the induction-coil the suppression of the spark due to extra-current is indispensable, so that a capacity of a certain requisite value must be inserted across the interrupter. The deficiency of capacity diminishes the oscillations in the primary circuit in consequence of the spark due to the extra-current, and therefore the latter spark must be avoided as much as possible.

"On the other hand, in Wehnelt's interrupter the spark due to the extra-current is necessary in order to keep up its action.

"Without such a spark the vapour at the active electrode cannot be got rid of, and consequently sufficient current cannot be established anew.

"The actions of capacity and self-induction are thus directly opposite to each other in the two cases."

Referring, in a word, to the use of the electrolytic interrupter, the following quotation from an article in *Nature*, March 9, 1899, by Dr John MacIntyre, President of the Röngten Society, may be cited. He says—". . . No one can doubt the great advantages of Dr Wehnelt's instrument in reducing the time of exposure of photo-

A B

Fig. 4.

A B

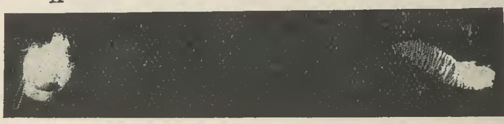


Fig. 5.

graphic plates, the brilliancy and steadiness in the fluorescent screen, not to mention its cheapness. . . ."

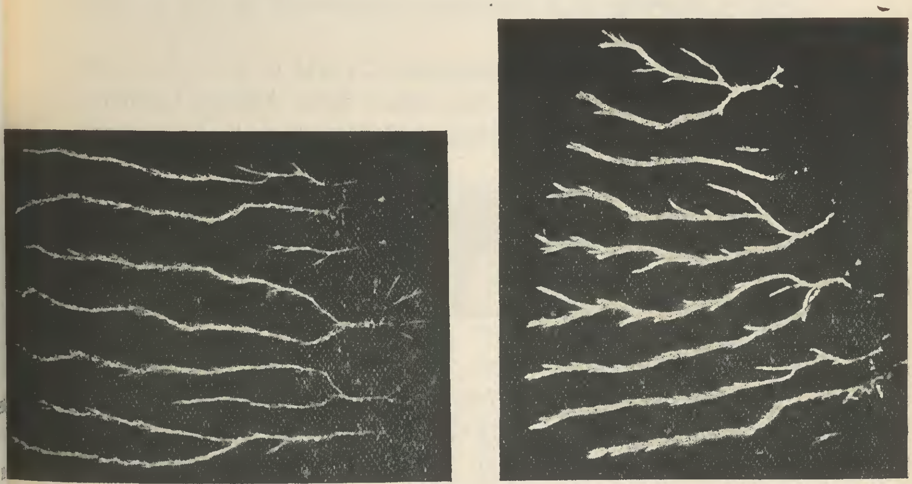
The phenomena accompanying the spark discharge of an induction coil actuated by an electrolytic interrupter present some features of novelty and interest. These were studied by means of 'carbographs' (as they may be termed for

Fig. 6.

convenience), which are prepared by coating a glass plate with soot from a candle or gas flame, the secondary terminals of the coil being connected to this by thin wires simply laid on the soot at a suitable distance apart. When the experiment is performed with a coil provided with a mechanical contact-breaker, the spark either just leaps across from one wire to the other or brushes off the soot in an irregular manner.

With the electrolytic interrupter, however, under suitable conditions, a carbograph as fig. 4 is produced.

A and B represent the points of contact of the wires with



FIGS. 7.

the glass, and A B is the track of the discharge. The design is not only burnt out of the carbon, but is etched into the

FIG. 8.

glass itself. This is forcibly brought home to the experimenter, as the glasses frequently crack along the line of the discharge.

Fig. 5 is a carbograph in which the discharge has not travelled all the way from A to B.

Fig. 6 is a photomicrograph of the white portion at B fig. 5 showing how the glass is shattered at the point of contact with the wire.

Figs. 7 are photomicrographs of parts of B in fig. 5, and fig. 8 is a portion of the same more highly magnified. Fig. 9 is another carbograph, and fig. 10 a photomicrograph

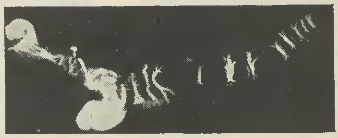


Fig. 9.

of a portion of it. (Unfortunately the reproductions do not bring out the finer details of the originals.)

One more application of the Electrolytic Interrupter remains to be noticed. The author thought of investigating the effects produced by connecting a Tesla coil to an induction

Fig. 10.

coil actuated by an electrolytic break. The increased frequency of the break and the consequent augmentation of the voltage of the secondary discharge powerfully increase the discharges of the Tesla Coil, and render all the usual experiments much more striking. The physiological effects of the current are, however, apparently in nowise different; the secondary terminals of the Tesla coil may be handled with perfect safety.

In conclusion, it may be remarked that the phenomena accompanying the production of carbographs, and the applications of the Electrolytic Interrupter generally, are subjects well worthy of further study and research.

REPORT BY COMMITTEE.

The members of your Committee have examined Mr C. N. Kemp's Electrotype Interrupter and tried it in action. They consider that the addition of the glass envelope to the inner electrode is an advance in the construction of the instrument. The carbographs shown by him are interesting and suggestive, and show considerable manipulative skill. They accordingly recommend the paper to the consideration of the Prize Committee.

ARCHIBALD WILSON.
ALEX. OGILVIE.
FRANCIS G. BAILY, *Convener.*

Address by the President, DAWSON TURNER, M.D., *delivered at the Annual General Meeting of the Society, held on* 14*th November* 1904.

FELLOWS AND ASSOCIATES OF THE ROYAL SCOTTISH SOCIETY OF ARTS,—On our roll last year there were 206 Fellows and one Associate. We have since admitted eight new Fellows (one of whom, however, has not yet taken up his diploma). Owing, however, to deaths and resignations, there is a net decrease of seven, making the membership 199 Fellows and one Associate. Seventy-three of these pay annual subscriptions, while the balance are life members. I suggested when I had the honour of addressing you last year that an earlier hour of meeting might be more convenient for some of the Fellows, and that it might have the effect of attracting those of us who rarely venture out at night. For various reasons it was not possible last session to carry this into effect, but I trust that during the coming winter one meeting at least may be arranged at an earlier hour.

Twelve papers were during the last session brought before the Society: their titles were as follows:—

(1) On Improvements relating to the Use of Carburetted Air for Lighting and other Purposes . . . By Hugh Marshall.
(2) On Steam Turbine Machinery . . By A. A. W. Wynne.
(3) On Apparatus for maintaining Exact Temperatures automatically by Electric Means . . . . By B. A. Pilkington.
(4) On a Combined Level, Plumb Rule, and Batter Gauge . . . By W. T. Muir.

(5) On the School Training of Future Engineers	By A. J. Pressland.
(6) On the Royal Institution and its Future	By D. W. Kemp.
(7) On the Pearson Fire Alarm . .	By W. Finlay.
(8) On the Chamounix Railway . .	By Archibald Wilson.
(9) On the Technical Education of the Engineer	By A. P. Laurie.
(10) On a Method of plotting Certain Intrinsic Equations . . .	By E. M. Horsburgh.
(11) On an Improved Polar Paper and its Use as compared with Squared Paper	By E. M. Horsburgh.
(12) On Interrupters for Induction Coils, with special reference to Recent Electrolytic Interrupters . .	By C. N. Kemp.

In February 1904 the Society had to deplore the loss, at the early age of forty-eight, of one of its most brilliant Fellows—Robert Milne Murray. He got a wetting while driving to see an invalid in the country, sat a long time in his wet clothes, and neglected proper precautions; this was in November 1902. Pneumonia set in, followed by a basal phthisis. It is characteristic of the man that he struggled on with his work, and even attempted to lecture to his class of 130 students while pneumonia was upon him. After rallying from the pneumonia he visited health resorts in Italy and France; but the hopes of his recovery were doomed to disappointment, and as a last resource an operation was attempted on Sunday, 14th February. He died of heart failure shortly afterwards. He was a fellow of many distinguished Societies, and a Vice-President of our own from 1892 to 1894 (he joined in 1884), and he contributed to the Society the following papers:—

Jan. 12th, 1891. On an Electrical Bench for Physiological Research. (Keith Prize, £21.)

Mar. 9th, 1891. On a Galvanometer.

Feb. 27th, 1893.	On a Wheatstone Bridge specially arranged for Physical and Clinical Research. (MacDougall-Brisbane Prize, £10.)
Feb. 27th, 1893.	On a Reflecting Galvanometer with Interchangeable Coils. (Hepburn Prize, £5.)
Mar. 23rd, 1896.	On a Simple Ammeter suitable for Lamp Testing.
Mar. 23rd, 1896.	On a Water Manometer for recording Minute Variations of Pressure.
Mar. 24th, 1902.	On a Switchboard for adjusting the Current from the Main for Medical and other Purposes.
Mar. 24th, 1902.	On a New Form of Induction Coil especially designed for Medical and Physiological Uses.

For the two latter papers he was awarded a Keith Prize of £20.

All the above papers are printed in our *Transactions*, except the paper on a Water Manometer, and of this a description will be found in the *Proceedings*.

Many of these papers were very valuable. The electrical switchboard which he designed and exhibited to the Society has found its way into the common use of our hospitals and consulting-rooms. Dr Milne Murray was an excellent teacher and a skilful physician. He was a many-sided man : he took a deep interest in many other subjects besides his own proper subject of midwifery. Thus, he was no mean chemist ; he was a geologist and a mineralogist ; and in his especial hobby of medical and physiological electricity he was a master. I take the following tribute from a friend writing to the *Medical Journal* : "No medical man in the city of Edinburgh was so much beloved, not only by those who were his patients, but by the members of his own profession. He loved, and was loved by, people the most varied in age, in intellect, and in station. He had no enemies; and no wonder, for he was the most genial of men, he was so pleasant, simple, frank, straightforward, friendly, sympathetic, and so ready to help everybody." All this I, who was both his pupil and his assistant, can most thoroughly endorse.

I should like to-night to refer briefly to physical agents, other than drugs, which are used in the prevention and treatment of disease, and to advances which have recently been made in this direction. A complete list of such agents would be formidable. I can only refer to a few.

Amongst such agents we can class hydro-therapy, mechano-therapy or graduated physical exercises, pneumo-therapy, helio- or photo-therapy, and electro-therapy. Each of these is a complete branch of the physician's art, and would require a whole evening for its discussion.

Hydro-therapy, or the treatment of disease by the internal administration or external application of water, is an ancient and valuable remedial measure; it includes the use of mineral springs, such as the sulphurous waters at Strathpeffer, Harrogate, Baden, and Aix-la-Chapelle; chalybeate waters, as at Hartfell Spa, Harrogate, and Schwalbach; earthy mineral waters, as at Bath and Contrexeville; alkaline waters, as at Royat, Vichy, Marienbad, and Carlsbad. At Bridge of Allan and at Droitwich there are sodium chloride waters. Commonly these waters are both drunk and administered externally in the form of baths. Rheumatic and gouty patients are chiefly benefited.

Passing on to mechano-therapy, we find that, though massage and medically regulated movements have been practised since the earliest days, yet it was not until the time of the Swede, Henrick Ling, that a serious attempt was made to arrange such methods on a scientific basis. A Royal Gymnastic Institute subsidised by the State was opened in Stockholm, and Ling was appointed its first Principal. The chief physiological effects produced by Swedish movements are that the absolute power of the muscles and their growth are increased, the joints are exercised and rendered more supple. The heart is stimulated, while the respirations become slower. The blood-vessels are at first pressed upon and contracted, and then relaxed and opened; the result is that the circulation of the blood and lymph is aided, and a depleting effect is produced. The nerves are elongated, and so stimulated. Ling regarded muscle gymnastics as nerve gymnastics. The body as a whole becomes invigorated and better nourished.

The movements are divided into active and passive. Active movements are those done voluntarily by the patient, and these movements are as a rule resisted by the physician. Passive movements are those applied by the physician without the patient's aid.

Swedish movements are used in the treatment of a large number of diseased conditions, and are chiefly of service in general weakness and exhaustion, such as may follow convalescence after some acute disease. They have also been used in the treatment of heart disease by Oertel and Schott: the latter combined carbonic acid baths with the movements. The chief exponent in more recent years of Ling's methods is Henry Kelgren.

Pneumo-therapy treats of the air as a therapeutic agent. It treats of the purity and bacteriology of the air, of the open-air treatment for consumptives, of the bad effects of vitiated air, of the uses of hot air or Turkish baths, of cold air, and even of liquid air. The latter has been used by Campbell White to relieve pain. A small brush is dipped into the solution and applied to the diseased part; by means of its refrigerant effect, complete insensibility to pain is temporarily produced; thus it might be of service in small surgical operations. The application, if prolonged, would produce a burn and frost-bite.

Alterations in air-pressure are also made use of. These alterations may be natural or artificial. Thus, at high altitudes attained by mountain-climbing or by balloon ascents, air naturally rarefied exists; the barometric pressure diminishes roughly about half a pound to the square inch, or about one inch of mercury, for every 900 feet of elevation above the sea-level. To obtain air naturally at greater pressures and densities is more difficult; there is no valley on the surface of the earth where the barometric pressure is markedly increased, but it is said by Cohen to be greatest in the region of the Dead Sea, which is about 1300 feet below the sea-level. Greater depths can only otherwise be obtained by descending mines.

Both compressed and rarefied air can be produced artificially, and are actually used in the treatment of diseases of the lungs.

Certain ill effects are produced by unduly increasing the atmospheric pressure. Thus, divers and workers in caissons building the foundations of bridges are subject to certain symptoms, such as earache, inability to speak or whistle, muscular pains, and intense itching. The respiration and pulse are slowed. Sometimes more serious effects, such as paralysis and sudden death, may follow, particularly if decompression has been too sudden; some ascribe such accidents entirely to a too sudden decompression, and term them accidents of decompression. The return to normal atmospheric pressure should therefore be made gradually—say, at the rate of ten minutes for each atmosphere. Further, a compression of more than five atmospheres is dangerous. The physiological cause of these grave effects is believed to be associated with a too rapid escape of the gases of the blood. Aquatic life is now known to exist at depths corresponding to pressures of 400 atmospheres.

The effects of naturally rarefied air are well known; thus, the ascent of a mountain may produce mountain sickness; up to a certain altitude the only feeling is one of fatigue, but this may be followed, if the ascent be pushed, by difficulty of breathing, palpitation of the heart, noises in the ears, dizziness, and vomiting. J. J. Ischudi gives the following account of the symptoms he experienced in climbing a mountain in Peru:—

"I was beginning sturdily the ascent, when I felt a strange uneasiness, due to the rarefaction of the air. I had to keep perfectly still so as to be able to breathe; when I tried to go on I was seized with indescribable anxiety and distress. I could hear my heart beating against my ribs; my breathing was short, I felt as if there was an enormous weight on my chest. Sight, hearing, and sense of touch were affected; a heavy cloud floated before my eyes—I even shed a few blood-stained tears; I felt as if I was hovering between life and death; my head turned; my senses left me, and I stretched myself full length upon the ground. If unbounded wealth and immortal glory had awaited me a few hundred feet higher up, it would have been a physical and moral impossibility for me even to have stretched out my hand toward them."

Much the same symptoms have been recorded by balloonists. Death may occur suddenly, as occurred to Sivel and Spinelli, who reached an altitude of some 28,000 feet, where the barometric pressure would be only equivalent to about ten inches of mercury. The cause of these untoward effects has been disputed; the most efficient cause is probably to be found in the diminution in the tension of the oxygen, while the escape of the gases of the blood may also play a part.

Differential pressure methods are also employed.

The composition of the air may also be varied. It may be medicated; it may be made to assimilate to the air of certain climates known to be beneficial in certain diseases. Thus a patient, without leaving his own home, may be caused to breathe the ozonised air of the Swiss health resorts, or air made fragrant by the eucalyptus or the pine. The practice of such inhalations is a very ancient one; the Romans, for instance, made use of the sulphurous vapours emitted by the crevices of Vesuvius and Etna. The substances used for inhalation in modern times are very numerous—oxygen, ozone, steam, hydrogen sulphide, nitrous oxide, chloroform, creosote, etc. The method is chiefly of service in diseases of the respiration, such as bronchitis and consumption. Doubtless benefit would follow more earnest attempts to elucidate the mysteries and to reproduce the conditions of climate. The virtues of high altitudes may not depend solely on the purity and rarefaction or chemical constituents of the air, but may be in part due to the increased electrical potential and greater radio-activity which have been observed at such heights. Quite recently air rendered radio-active by the emanations of radium and thorium has been used.

Professor Niels Finsen's name will be for all time associated with helio- and photo-therapy. He may almost be regarded as the founder of photo-therapy, and his death, after much suffering, at the early age of forty-four is a loss which the whole world will feel. Struggling against a pitiless, exhausting disease, he still carried on his researches, and he lived long enough to see his methods and his treatment generally adopted. Such a reward as this is too often denied us.

The physiological effects of light appear to be chiefly due to the actinic and to the calorific rays. Either of these, by the use of suitable filters, may be made use of. Thus, a thin piece of ebonite or of red glass will cut off the actinic rays, and permit the rays from the red end of the spectrum to pass through; the calorific rays could also be separated by the proper use of a rock-salt prism.

Finsen, noticing that small-pox patients were most deeply scarred on the hands, wrists, and face, showed that the actinic rays were decidedly injurious in this disease, and that the course of the disease could be shortened and the tendency to pitting be diminished by hanging red curtains over the windows of the sick-room. In Denmark the small-pox wards of the hospitals are furnished with ruby red photographic glass windows, for the exclusion of the chemical rays must be absolute. Sunburn has been shown by

Wilde and Finsen to be due also to the actinic rays. Pigmentation of the skin is nature's protection against sunburn. White cows suffer from sunburn, while red and black cows escape. Treatment by coloured light is termed chromo-therapy. The longer wave-lengths of the visible spectrum appear to have an invigorating action; the shorter wave-lengths, a soothing and depressing action. Goethe observed that red and yellow lights were bracing, green and blue depressing. Mental afflictions have been thus treated; patients suffering from depression are exposed to red light, and patients suffering from excitement to blue light. Sunlight in moderation is a powerful tonic; the calorific rays tend to raise the body temperature, to dilate the superficial blood-vessels, and to induce an active perspiration, while the actinic rays stimulate the nervous system. In high altitudes the sun's rays are more powerful, and care must be taken to avoid over-exposure. General sun-baths are chiefly of service in cases of deficient blood-making capacity. Locally, the actinic rays are used for the treatment of certain skin diseases. For this purpose the electric arc light or a condenser spark may be substituted for the sun: the advantage of the latter is that it is deficient in calorific rays and yet highly actinic. On the other hand, when the arc light is used, some means must be adopted for stopping off the calorific rays. Finsen found that the actinic rays could penetrate our tissues most readily when the blood had been as much as possible expressed. He placed a strip of photographic paper on one side of a man's ear, and caused a beam of light to fall upon the other side of the ear: no effect was produced in five minutes. He now squeezed the blood out of the ear by compressing it between two glass plates, and tried the experiment again: the paper was now distinctly blackened in twenty seconds. It is usual, therefore, in applying the Finsen treatment, to compress the affected part, so as to make it as bloodless as possible. Rock-salt, ice, or quartz are used as compressing agents, because they are fairly transparent to the actinic rays. Quite remarkable results have been obtained in otherwise intractable skin diseases by the Finsen method, and it is stated that in the magnificent Light Institute at Copenhagen benefit has resulted in every suitable case that has been treated.

No small addition has been made in recent years to our physical therapeutic agents; we possess, besides the Finsen light, the X-rays, the radium emanation and rays, and high-frequency currents.

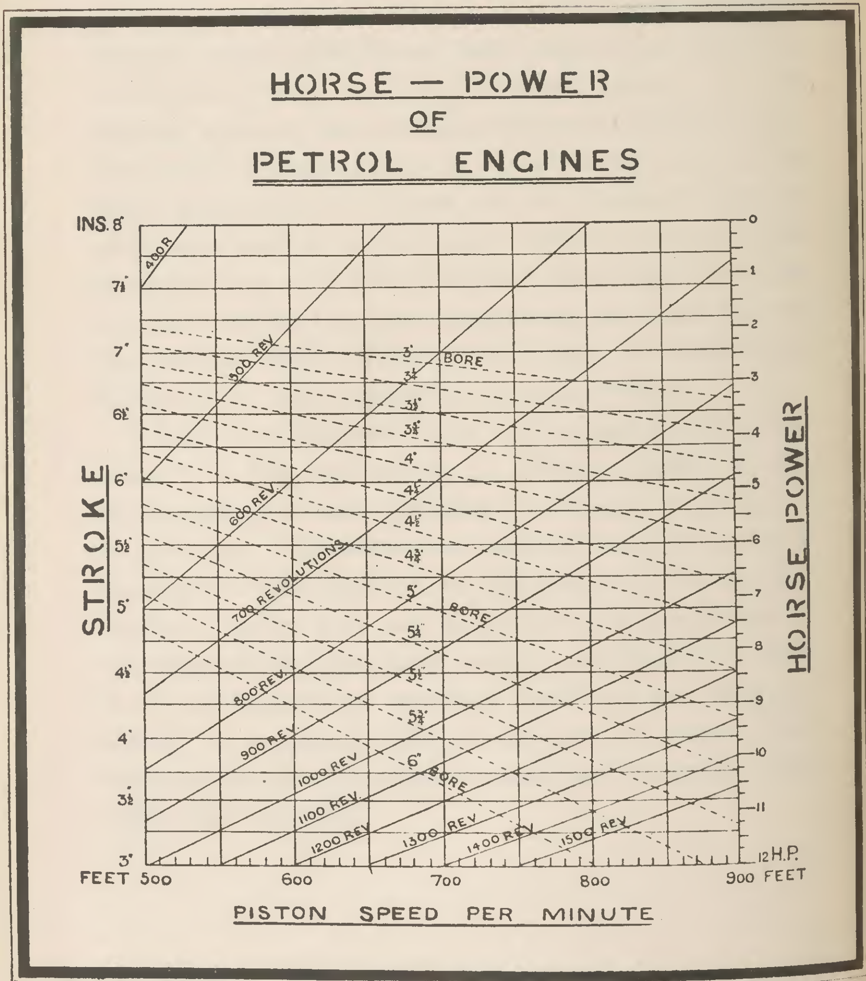
The X-rays are now as largely used for therapeutic purposes as for surgical and purely diagnostic purposes, and they have in suitable cases proved very serviceable. Some sensation has recently been occasioned by reports in the public press of X-ray burns. Two classes of these can be distinguished—one acute, the other chronic. In the acute form the skin may be shed and there may be much irritation; in the chronic form, which is apt to occur in X-ray operations, the skin becomes dry, dark red, and cracked, and warts may appear; the nails are also affected. Neuralgia may also be set up, and there is a sensation of burning and itching. The disease is most common in the hands, but may attack the arms, body, and even the feet. The chronic form appears to be incurable. But there is worse to follow, for several cases are on record of cancerous tumours following this chronic affection, and more than one operator has so sacrificed his life. Thus the X-rays may be said to have a homœopathic action; for while they may and do benefit certain cases of cancer, they may set up in the healthy the very disease they are antagonistic to. Edison reports that the focussing power of one of his eyes has been lost. Many medical men have in consequence given up the use of these rays. How the X-rays produce their effects on the body is not yet known. Their ionising and oxidising power may play a part. If the tissues be ionised, they must be disintegrated; the molecules are broken up into atoms. The X-rays, then, may be a potent agent for either good or evil, and their application should be restricted to duly qualified medical men.

The medical employment of radium has not, owing to its excessively high price, extended very much during the past year, though there can be no simpler or more convenient or adaptable method of developing and applying rays; but that it is of benefit in certain diseases has been abundantly proved. Its injurious effects appear to resemble those produced by the X-rays, but are more penetrating. Short of this, the radium rays have a stimulating action on the skin and nervous system. The gamma rays do not appear to be identical, as was at one time supposed, with the X-rays. Photographs of the human tissues taken by me with radium show no differentiation between the skin and the bone; the bones do not cast denser shadows, nor can they be seen on the fluorescent screen. Thorium has only about the one-millionth of the radio-activity of the best radium; but as it is cheap it has been used in plasters and in inhalations as a substitute for radium. The direction in which advance has been attempted with these agents has been in rendering the blood and tissues of the patient fluorescent by administering such substances as quinine and æsculin, and by then applying the Röntgen or radium rays. Dr Morton, who introduced this method, refers to it under the somewhat fanciful term of "liquid sunshine."

An interesting research bearing upon the subject has recently been published by E. C. Wilcock in the *Journal of Physiology.* Wilcock tested the effect of the beta rays of radium on some of the lower organisms. He found that those organisms which contained chlorophyll very quickly moved out of the path of the rays, while those organisms which contained no chlorophyll did not attempt this movement, but, remaining where they were, speedily died and were disintegrated. The experiments with the two common forms of hydra were especially interesting. *Hydra viridis* showed a great power of resistance to the rays when prevented from moving out of their sphere of influence, although whenever possible the animal would move out of the path of the rays as quickly as possible. *Hydra fusca*, on the other hand, an animal which does not contain chlorophyll, did not move out of the path of the rays, but was rapidly killed by them. The fact that chlorophyll is a substance of very marked fluorescent properties is no doubt related to this curious effect. Bence Jones discovered in 1866 that blood is fluorescent; Rhoads and Pepper followed up this suggestion, and noticed that in malaria the fluorescence of the blood was diminished, and that the administration of quinine restored the fluorescence, and with the return of the fluorescence the fever abated. Elster and Geitel have shown that air which has penetrated into the interstices of the soil contains a radio-active emanation. A fall in the barometer provokes an uprising of the subsoil air; hence, when the barometer is low the air is particularly radio-active. For this reason water arising from deep sources is radio-active; thus the remedial action of thermal springs if used at the source may be partly explained. Liebenow has shown arithmetically that the whole of the internal heat of the earth may be accounted for by the supposition that there is distributed throughout the mass of the earth some two hundred thousand million kilogrammes of radium, or the one-five-thousandth of a milligramme per cubic metre.

The physiological effects of static electricity and of electrical currents, continuous, interrupted, and alternating, and their application to diseased conditions have long been a matter of study, but it is only within the last few years that the attention of physicians has been, mainly through the researches of d'Arsonval, directed to so-called high-frequency currents. The essential differences between high-frequency currents and currents developed by other methods are that the alternations or reversals of the direction of the high-frequency currents are far more rapid, and the electro-motive force exceedingly high; thus, the alternations produced by a Neef's hammer attached to an induction coil may be some fifty a second, or with a Wehnelt interrupter some thousands, but the alternations of the high-frequency current may attain to a million per second. It is an extraordinary fact that these currents do not stimulate our senses or muscles, provided no sparks are drawn. M. Cornu allowed electrical energy at the rate of nearly one horse-power to pass through his body without experiencing any sensation except that of warmth. Six lamps (125 volts, 0·8 amperes) were illuminated. What the precise physiological effect is, is still an open question, though statements have been made that nutrition is improved and the blood-tension raised. In the writer's opinion, the beneficial effects claimed for high-frequency currents are to be mainly attributed to the spark discharges, and these can be obtained quite as effectually and far more simply from a static electrical machine, but with this difference, that the current is a continuous and not an alternating one, and that so the patient feels it more; and this, by aiding his imagination, may sometimes be an advantage.

I have but touched upon my subject to-night, but there is in the application of physical agents to the alleviation of human suffering an illimitable harvest to be gathered. Experimental physics should be given a more prominent position in the training of a medical student; a real and not a perfunctory knowledge of the subjects of light, heat, sound, and electricity, with their bearings upon practical medicine and surgery, should be acquired; for if we are to expect real advances in this direction, science and medicine must walk hand in hand.


HORSE — POWER
OF
PETROL ENGINES
STROKE
HORSE POWER
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FEET
PISTON SPEED PER MINUTE
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800 REV.
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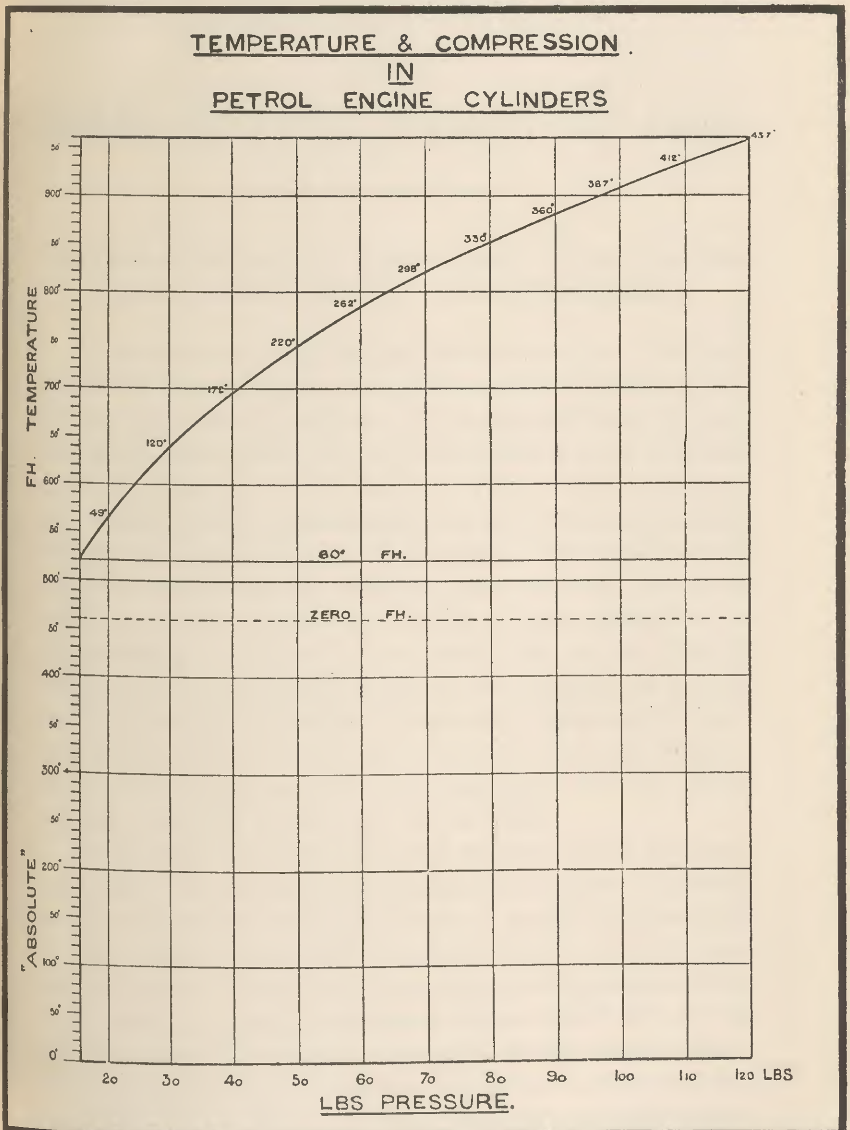
1300 REV.
1400 REV.
1500 REV.
BORE
12 H.P.
500
600
700
800
900 FEET

Mr A. Clark.


TEMPERATURE & COMPRESSION.
IN
PETROL ENGINE CYLINDERS
"ABSOLUTE" FH. TEMPERATURE
0°
100°
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300°
400°
500°
600°
700°
800°
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437°
60° FH.
ZERO FH.
20
30
40
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60
70
80
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100
110
120 LBS
LBS PRESSURE.

Mr A. Clark.

TRANSACTIONS

OF THE

ROYAL SCOTTISH SOCIETY OF ARTS.

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*The Tram and Road Cars of the Future.** By ALEXANDER CLARK, Assoc.M.Inst.C.E. (With Illustrations.)

IF we were to judge by the enormous sums of money which are annually spent on vehicles of all kinds for the purpose of conveying all sorts of people, including all their belongings, from place to place, we would at once conclude that the question of locomotion was a very important one indeed, nearly approaching to, if it had not already become, the leading national industry. We shall not go into the details of the amount spent in this enormous traffic, as it would only be straining your memories by endeavouring to follow figures which are of no positive value; but we may briefly mention the amount of capital invested in some of the most important centres of population in the United Kingdom in order to show the importance of the tramcar, and the necessity for the most perfect construction that can be devised.

In the returns of tramways up to the end of the year 1903, there are enumerated eighty-eight electric systems having a length of 1,368 miles, with a capital expenditure of £32,522,319, which shows a total cost of £23,774 per mile of route. As most of these returns are made exclusive of the cost of power installation, there would fall to be added a part of the capital expended on the electric power station proportionate to the number of units absorbed by the tramways for electric power. In some cases the power absorbed by the tramways is equal to one-half of the total

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* Read and illustrated before the Society on 28th November 1904.

output of the station, and in others one-third or one-fourth according as the electric lighting has been developed in the various districts. Adding, therefore, this proportionate amount to the capital of the tramways previously mentioned, it would give a total addition of £6,206,500, or an amount of £4,530 per mile, making a total expenditure of £38,728,819 or £28,304 per mile of route.

Of steam tramways the returns give six systems, having a length of 73 miles, a total cost of £418,407, or an average price of £5,732 per mile.

With horse tramways there are twenty-three towns or districts served, having a total length of 112 miles, and a capital of £1,511,201 or an average of £13,517 per mile.

There are also two cable tramways with a total length of 24¼ miles, and a capital of £1,360,565 or £56,106 per mile.

The united capital of all these tramway systems amounts to £42,018,922.

Besides these there were 230 miles finished or under construction at the end of 1903, with a prospective capital of over £8,500,000, from which the returns are meantime very imperfect.

The question of the tramcar cannot be separated from that of the method of propulsion. In its early days it was a perfectly inert, passive creature, incapable of good or evil until the horse or the mule put life into it. In later days the ponderous locomotive with the soot and the black smoke took it in hand, when it required a covering on the top of the double-decker to protect the poor outside passengers from its ill effects. Still later the car was provided with one-half of the means of motion in the shape of electric motors fixed on its axles, but it still required the current from the power station to breathe upon these rudimentary muscles and set them in action before the car could move. Now, at the present time, we have reached that higher state of development when the car may be a complete organisation in itself, provided with all that is necessary for motion, requiring only the hand of the skilled artisan to wake up its energies, and requiring no connections by ropes or wires with other parts of the world, and capable, if rails there be, of running upon rails but capable also, where there are no rails laid, of pursuing its way, wherever there are good roads, with the greatest ease and comfort.

As the system of electric traction with wires or cables either overhead or underground, still holds the place of honour in the dispensations of life in large centres of population, we shall have some remarks to make later on with regard to the expense of working that system, but our object is in the first place to examine in detail the construction and development of a self-propelling and independent Tramcar, and thereafter shortly to describe the Road car.

When we call the Auto-tramcar the highest development of the present time, we would by no means seek to cast any doubt on the possibility of still further improvements in the future which may completely overshadow anything we may now have in our minds. For the same reason we deprecate the continual carrying out of electric systems of traction after it has been shown that a much better solution of the question is ready to our hand. More especially is it inadvisable to spend large sums of money meantime on electric traction when the same object can be achieved for one-half of the expense, by the Auto-tramcar.

Car Body.—The portion of the car which first appeals to the public is the accommodation for the passengers, and the general finish of the outside and inside of the car body (see Figs. 1 and 2). In the new tramcar it is not proposed to interfere with the arrangements of the ordinary type of car, in fact the usual form was supposed to be that which was most approved. It was thought that if any deviation were suggested in this respect it might be inferred that this was a necessity of the new method of propulsion, and as nobody would like it the car would be objected to on this ground alone. Let it be clearly understood, therefore, that the ordinary type of car can be accepted and fitted up to suit the new engines and gearing, and whatever good may be supposed to be attached to the ordinary use and wont in tramcars it is not necessary that it should be changed in the new cars.

While, however, a change in form or arrangement is not a *necessity*, it is not admitted that the present arrangement is quite as ideal as it might be, and we submit a design for the inside seating, which would at least be a

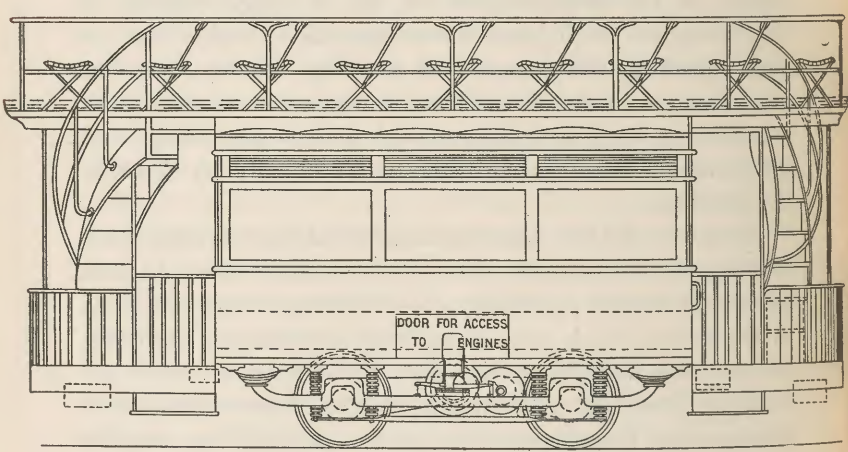


FIG. 1.

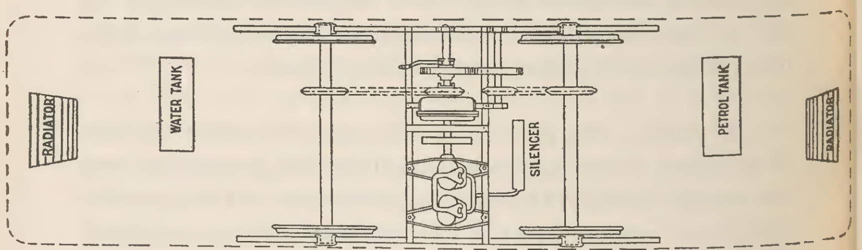


FIG. 2.

new and also, we suggest, a more agreeable arrangement (see Fig. 3). In the plan before us there is a variety of view which should make the car journey more interesting to the passengers, and presumably more pleasant. The seats in this case take the form of single chairs, and there could be no overcrowding as the seats are all reserved. The seats on the upper deck are of the usual form, except the two end ones, which are

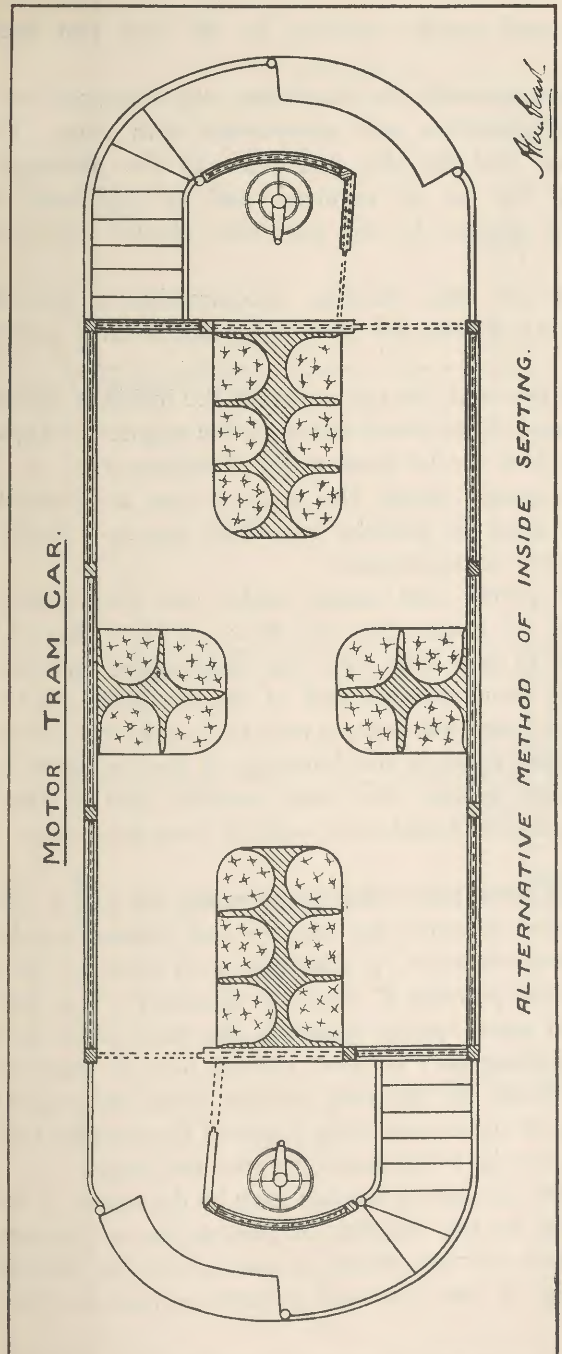


FIG. 3.

curved and made suitable to fill the two irregular spaces.

The apartments for the driver and conductor are shut off by themselves, and surrounded with glass. Tickets could be sold by the conductor to the passengers on entering the car if required, and an additional brake could be worked by the conductor should any necessity arise.

This car has seating accommodation for twenty passengers inside and thirty outside, or fifty passengers in all.

The two seats in the centre of the inside of the car are made movable to afford access to the engines and gearing, and the floor can be made to lift, if necessary.

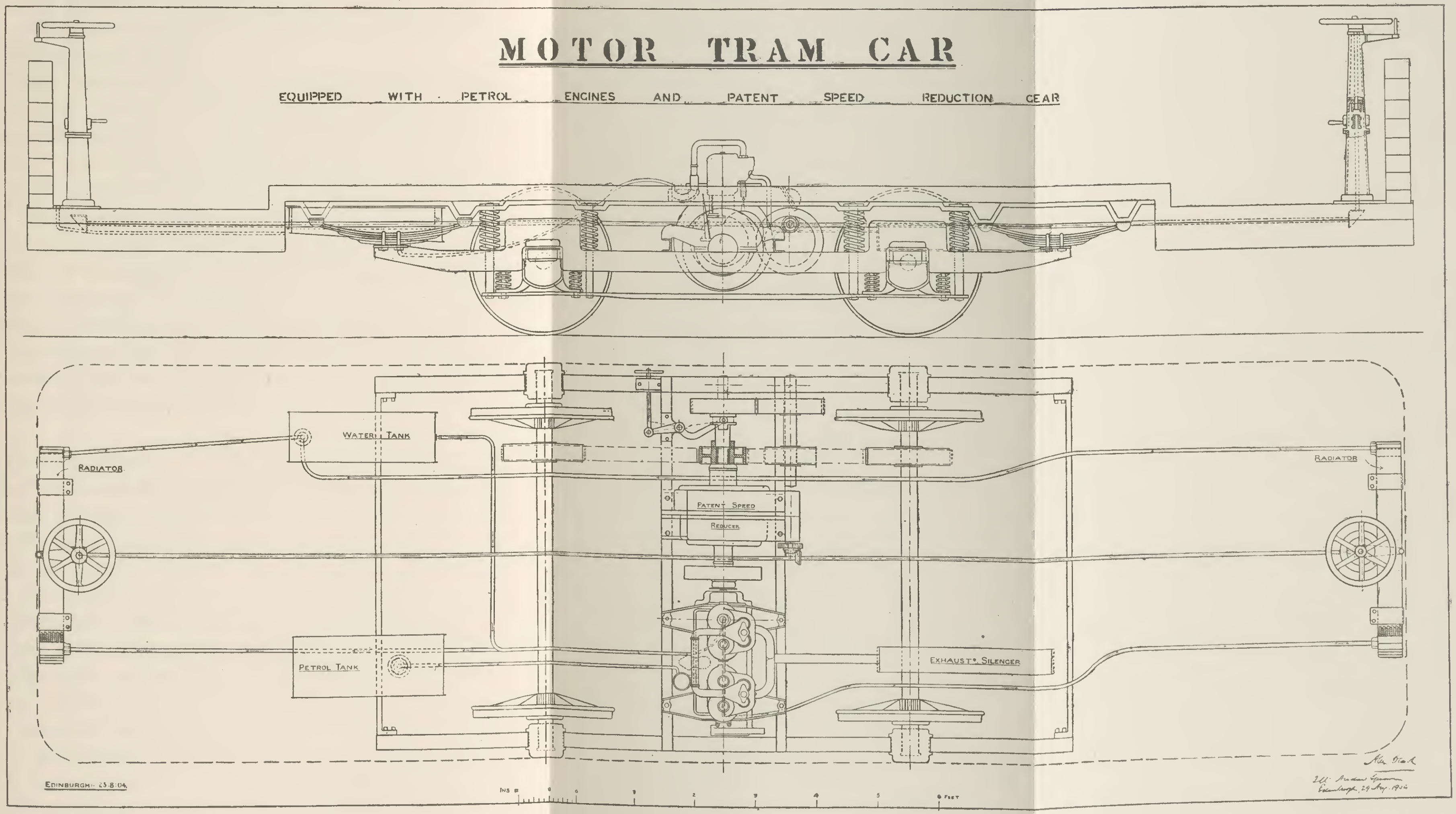
The spaces under the stair at the conductor's end may be used for parcels, for which access is made from the private compartment.

The petrol and water tanks and the silencer are disposed of under the car floor, so that they do not interfere in any way with the passengers, and the two radiators stand at each end of the car either on the top or on the lower platform, as may be found most convenient.

In other respects the finishing of the car both outside and inside is after the usual method, and of the style which has been found most suitable from experience.

Bogie below Car.—The bogie under the car is specially constructed to carry the engines and gearing (see Fig. 4). It has four wheels $2' \; 7\frac{1}{2}''$ diameter, with axles $3\frac{1}{2}''$ diameter, and outside journals $8''$ long $\times \; 3''$ diameter. It is provided with two spiral springs carrying the main truck frame on the projecting ears at each journal box, or eight springs in all. These are the only springs under the engines and gearing, all the others being required for carrying the main body of the car in its position above the bogie.

As the springs of the car may be depressed or relieved according as the number of passengers is increased or diminished, all the levers or rods which are attached to the body of the car and require connection with the



Mr Alexander Clark, A.M.I.C.E.

Fig. 4.

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machinery on the bogie, must be so constructed that this change of relative position does not affect them. Thus the rods from the controllers on the car are connected with the rods on the bogie for operating the change gear speeds with universal joints.

It is most important to bear in mind this distinctive feature of the design, viz., that the engines are not connected with the body of the car, and consequently do not affect it with their vibrations, because it has been contended in some quarters that the engines should be attached to the upper frame of the car, and that it is impossible, or at least unsuitable, to place the engines on the bogie in the middle of the car. One reason given against the fixing of the engines on the bogie was that they were inaccessible, and it may be well to point out, in this connection, that an opening with a door is fitted on each side of the car which makes access to the engines and gearing a very easy matter.

The Driving Wheels.—On each of the axles a sprocket chain wheel is fixed, and these are driven by chains from the pinions on the main axle and on the countershaft. Each of the axles is alternately in front as the direction of the car is altered, and it is always the leading axle to which the power is applied. When the car is driven directly from the main shaft the spur wheel, which is mounted on a movable sleeve, engages the chain pinion, the leading axle being driven by the chain as above described. When the car has to be reversed this spur wheel is relieved from contact with the chain pinion on the main shaft, and set in gear with an equally sized wheel on the countershaft. A chain pinion equal in size and pitch to that on the main shaft is fixed on the countershaft, and from this chain pinion the motion is communicated to the other axle, which in this case is the front or leading axle. When the car is driven from the countershaft the main shaft runs free through the chain pinion first described, and it is only driven by means of the spur wheel when it has been engaged with the clutch.

There is no possibility of any damage being done by means of the gearing becoming locked.

Speed-reducing Gear.—We have so far not dealt with the question of speed, but, as the revolutions of a petrol engine are greatly in excess of the number of revolutions of the car wheels, a method of reducing the speed is necessary to satisfy the conditions (see Figs. 5, 6, 7). There are many ingenious inventions designed to meet the circumstances. The device which is used in this car is that of an epicyclical gearing in which a central pinion works into toothed wheels and causes them to revolve, whilst on the outside the teeth of the revolving wheels engage with the teeth on the inside of an outer rim which surrounds the whole system. If the axles of the two second motion wheels be fixed the motion from the central pinion will be communicated to the outer rim, and it will move in the opposite direction from the pinion; but if, on the other hand, the rim of the outer wheel be held by a brake band, or similar contrivance, the two intermediate wheels will move around the centre pinion instead of causing the outer rim to move. If, then, the axles of the two moving wheels be connected rigidly by a plate or a casting which forms part of a sleeve on the axle, the speed will be reduced in the proportion of the respective diameters of the outer rim and the centre pinion.

By the use of various diameters of wheels and pinions any reduction of speed can be got that may be required. A reverse motion is also provided in a very simple way. The axles of the two revolving wheels are produced and two pinions are fixed upon them,—these in their turn are constructed to work into two other revolving wheels moving in a plane just outside of those before referred to, and thus the reverse motion is accomplished. The reverse motion is only used in an emergency such as an obstruction coming suddenly in the way or when there may be any danger to life. It is not intended to be used in the ordinary running of the car.

The perfect balance of this gearing and the want of

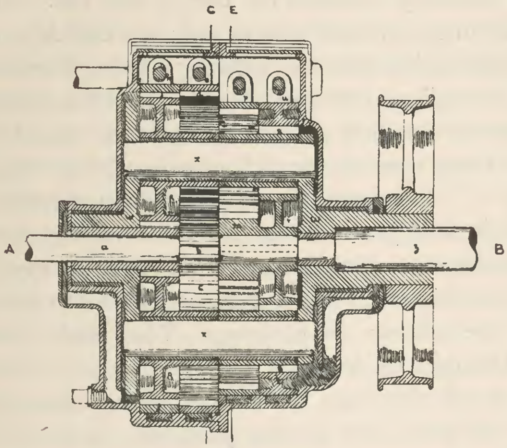
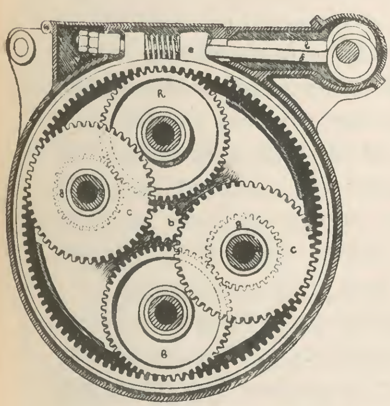
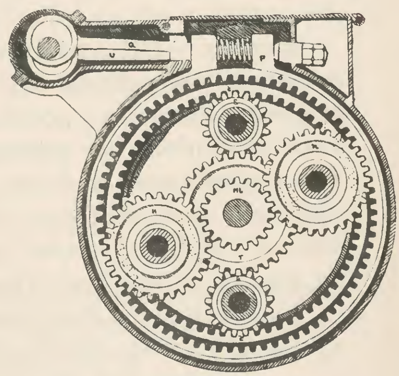


FIG. 5.



SECTION ON LINE C.D
LOOKING TOWARDS. A.

FIG. 6



SECTION ON LINE E.F.
LOOKING TOWARDS. B

FIG. 7.

shock in changing from one speed to the other are the most noticeable features in connection with its use, and it has been specially adapted for use in this car. The teeth are always in mesh and run in oil; no clutch is required between the engine and the gearing as the wheels run free between the various changes of speed, and the various band brakes can be applied so gently that the speed will rise gradually from rest up to full speed without any shock being felt if the controller be carefully handled. The brake bands and jaws are of steel for taking the strain, and as these slip slightly as the power is applied it is scarcely possible even for a careless driver to damage the teeth of the wheels or pinions. The shaft giving the different changes of speed is arranged so as to work from either end of the car, a clutch being placed in the controller at each end of the platform so that the gear can only be operated from the driver's end.

The full speed of the car is put at 15 miles per hour. There are also two lower speeds of 6 and 9 miles per hour, the lowest speed only being used for starting or working an exceptionally heavy gradient.

Engines.—The engines are of the four cylinder "Otto" cycle type with cylinders $4\frac{1}{2}''$ diameter × $5\frac{1}{2}''$ stroke capable of giving continuous power, under working conditions at 1,000 revolutions per minute, of 30 H.P. with petrol fuel. The engine crank and cam gear are enclosed in an oil-tight and dust-proof case, and lubricated under pressure. The cylinders are cooled by water circulation, operated by a pump of the rotary type, and of ample capacity.

Each cylinder has an explosion every fourth stroke:—

(1) In the first or suction stroke the chamber and cylinder are filled with the proper proportion of petrol vapour and air.

(2) In the second stroke the mixture is compressed to about one-seventh the original bulk, giving a pressure of nearly seven atmospheres or about 102.9 lbs. per square inch.

(3) In the third stroke the explosion takes place, the

expansion of the gases giving a pressure on the cylinder piston of from 200 to 250 lbs. per square inch.

(4) In the fourth stroke the products of combustion are forced from the cylinder through the exhaust pipe into the silencer, where they are partly condensed.

As there are 1,000 revolutions per minute and each of the four cylinders has one explosion every two revolutions, every cylinder is fired 500 times per minute.

As a general rule these explosion engines are timed for much higher speed,—1,200, 1,500 and even 2,000 revolutions per minute being not uncommon.

In the engine as designed for this car the cylinders are made of a comparatively large diameter and stroke, so as to reduce the number of revolutions as much as possible and keep within a certain limit of weight.

The valves are all mechanically operated, and the full speed and power of the engines can be taken up by the gearing either in mounting a steep gradient at the speed of 6 or 9 miles per hour, or by taking the full speed of 15 miles per hour along an easy level track.

The speed of the reverse is 6 miles per hour, to be used only in cases of emergency.

The cubic contents of the working part of each cylinder would be	87.4736	cubic ins.
The compression chamber usually about one-sixth or	14.5789	,,
Making a total volume of . .	102.0525	,,

When the first or suction stroke begins, the compression chamber is filled with air at atmospheric pressure, and it may contain some of the products of combustion of the last stroke. These gases will be mixed with the air and petrol vapour of the next stroke, and should any petrol vapour have been unexploded at the last stroke it may now be exploded along with the new mixture.

The proportion of the mixture in the cylinder, if just enough of air has been drawn in to make a perfect explosive mixture, would be $C_7 H_{16}$ 11 (O_2) 41.4 (N_2).

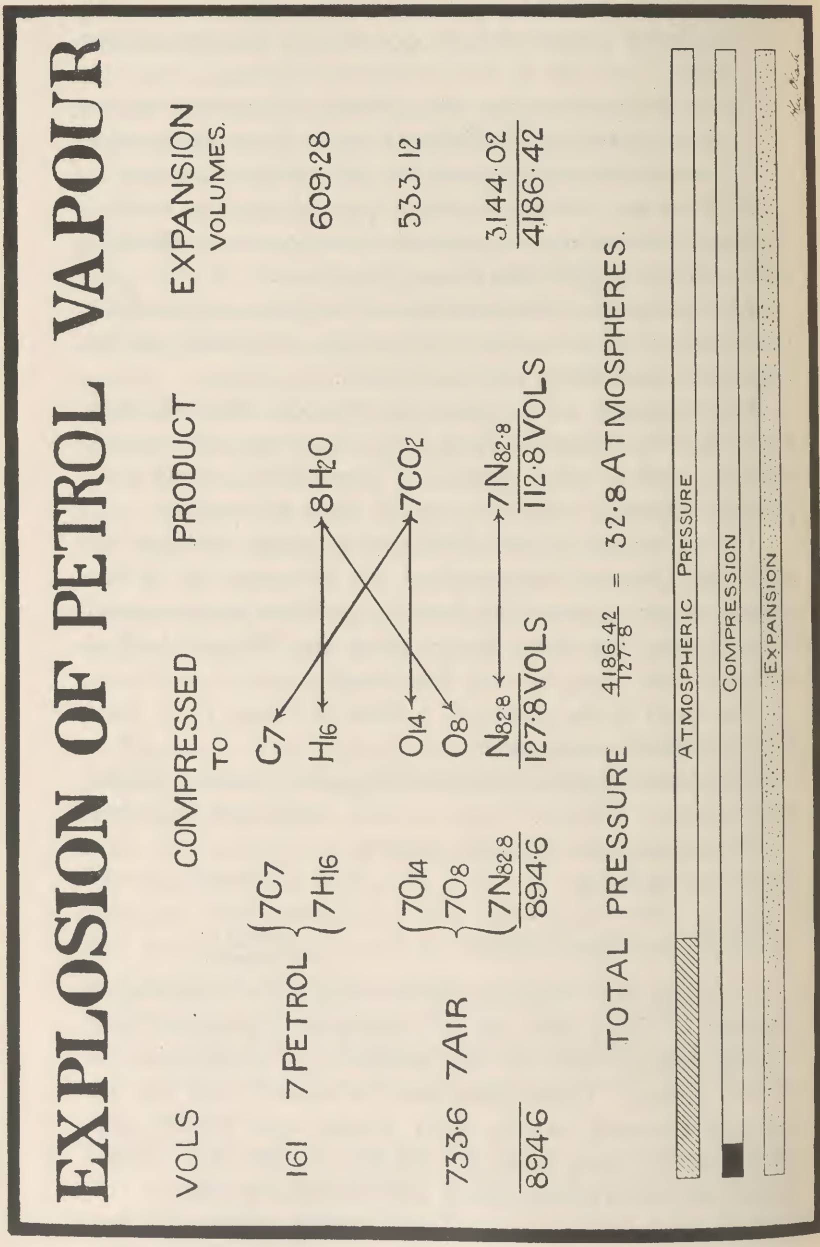

EXPLOSION OF PETROL VAPOUR
VOLS
7 PETROL
7 AIR
COMPRESSED TO
PRODUCT
EXPANSION VOLUMES.
161
733·6
894·6
7C7
7H16
7O14
7O8
7N82·8
894·6
C7
H16
O14
O8
N82·8
127·8 VOLS
8H2O
7CO2
7N82·8
112·8 VOLS
609·28
533·12
3144·02
4186·42
TOTAL PRESSURE 4186·42 / 127·8 = 32·8 ATMOSPHERES.
ATMOSPHERIC PRESSURE
COMPRESSION
EXPANSION

FIG. 8.

At 1,000 revolutions per minute 1 gallon of petrol would run for twenty-five minutes.

At 6 miles per hour :—		2.50 miles per gallon of petrol.			
„ 9	„	3.75	„	„	„
„ 15	„	6.25	„	„	„

From this calculation it would appear that if a journey of 40 miles could be done continuously at the rate of 15 miles per hour, the petrol required would be 6.4 gallons, whereas if an average of only 9 miles could be kept up, an amount of 10.66 gallons would be required.

It is important to observe, however, that in a road of 40 miles there would probably be many parts level and downhill, besides some portions with very easy rising gradients where the full explosive stroke would not be required, and on all these lessened strokes a considerable saving of fuel would be affected. This theoretical calculation would therefore be modified to a large extent by taking all the gradients and calculating for each separate value.

We have now further to consider the temperature of the gas as drawn from the carburettor into the cylinder. The calculations as given are on the supposition of the vapour being at 60° Fahr., but we shall find on enquiry that the gas is supplied at a much higher temperature, that it is therefore less dense and a smaller quantity is required than has been allowed.

In the first instance, however, the turning of the petrol into vapour reduces the temperature. The quantity of heat required for vaporisation is almost in the inverse ratio of the atomic weight ; thus :—

$$C_7 H_{16} = 100. \quad H_2O = 18. \quad \text{Latent heat of water.} = 966 \text{ Fahr.}$$
$$\therefore 100 : 18 :: 966 = 173.88 \text{ heat units.}$$

Instead, however, of allowing the temperature of the walls of the carburettor to be reduced to an extent indicated by the above calculation, the exhaust gases from the engine are used to heat the chamber by passing into a jacketting space round the carburettor. The petrol vapour is also further heated by mixing with the exhaust gases in the compression chamber, by the hot cylinder and ports, and by the throttling process in the intake.

The vapour along with the air thus drawn into the cylinder may be brought up to 300° Fahr., or even higher, before the compression stroke of the engine begins. This temperature varies considerably from time to time, but the aim is, by the best possible adjustments to keep it at as regular a temperature as possible.

On the return stroke of the piston, the inlet valve being closed, the gas is compressed into about one-seventh of its original volume, and the heat developed by this pressure may be 395° Fahr. beyond the ordinary temperature of the atmosphere. It is during this stroke that may be there is a danger of pre-ignition, and if this takes place it is liable to spoil the effect of the compression, and may possibly do serious damage. It is therefore of the greatest consequence that the compression stroke should be fully completed before the ignition spark acts. This is supposed to be perfectly regulated by the ignition gear, and is entirely dependent for its regulation upon the same gearing which actuates the piston and the valves. It is timed for a small fraction of a second after the beginning of the explosion stroke.

It is of considerable importance to have the fullest compression that is possible. A little reflection will show that —(1) It gives extra power in a smaller space; (2) a higher working pressure is provided; (3) the particles of the gas are brought closer together and there is greater rapidity of explosion; (4) there is also a smaller amount of cylinder wall to absorb the heat; and (5) it is found from experience that there is an economy in fuel, as a poorer quality of mixture can be got to fire owing to the compression and consequent heat which is developed.

In the explosion which takes place the union of the carbon and hydrogen with the oxygen of the atmosphere produces a very high temperature, at the moment of explosion reaching possibly 2,730° Fahr. or even more, and the increase of the pressure due to this temperature gives the impetus to the piston.

In the explosion in the cylinder we have assumed that we find—

7	volumes	carbonic acid gas	CO_2 =	volumes	14
8	"	steam	H_2O =	"	16
41.4	"	nitrogen	N_2 =	"	82.8
					112.8

These gases originally occupied 127.8 volumes, but were compressed into 18.2 volumes.

Pressure $= \frac{2730^\circ - 60^\circ}{491^\circ} = 5.44$ atmospheres, but allowance must be made in expansion for three volumes of original carbon and oxygen condensing to two volumes and also for formation of H_2O.

This will therefore reduce the pressure to:—

$$127.8 : 112.8 :: 5.44 = 4.80 \text{ atmospheres.}$$

Pressure at beginning of working stroke $= 4.8 \times 7 \times 14.7 = 493.92$ lbs. per sq. in.; above atmosphere, or 508.62 lbs. per sq. in. (absolute).

Average forward pressure $= \frac{508.62}{2} = 254.31$ lb. per sq. in.

$$\text{Mean effective pressure} = \text{Average forward pressure} - \left\{ \text{Average pressure during compression stroke.} \right.$$

Mean effective pressure $= 254.31 - 52.905$

" " $= 201.405$, say 200 lbs. per sq. in.

The duration of the stroke on the piston would be approximately: — one-third of stroke before explosion developed the full force, say .7 of stroke available.

$$\text{H.P.} = \frac{\overset{\text{Square in.}}{15.9043} \times \overset{\text{lbs.}}{200} \times \overset{\text{Ratio.}}{.7} \times \overset{\text{ft. per min.}}{916}}{33{,}000} = 61.83$$

This is the full development of power by the ideal engine. Every improvement that is made tends to realise a larger portion of the possibilities.

Ignition.—In these high-speed engines making a 1,000 revolutions per minute, which is roughly 16 revolutions per second, it is absolutely necessary that the time of firing should be mechanically operated (see Fig. 9). There are

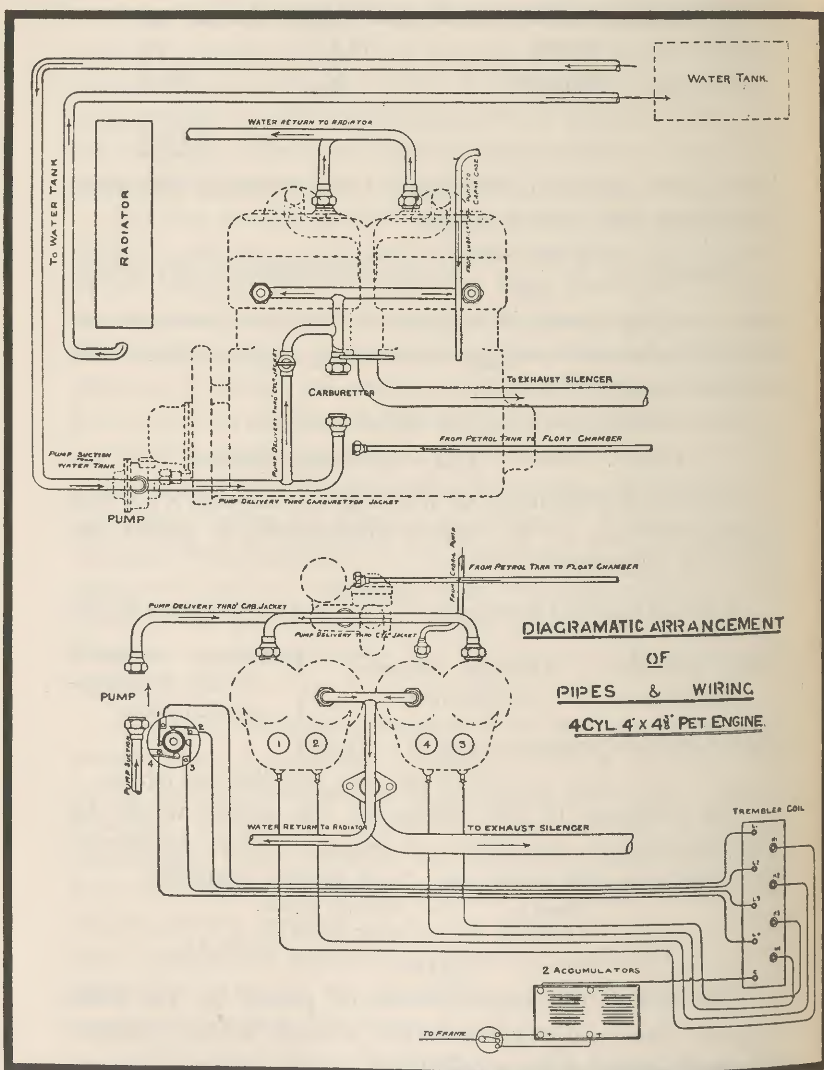

WATER TANK.
To WATER TANK
RADIATOR
WATER RETURN TO RADIATOR
CARBURETTOR
To EXHAUST SILENCER
FROM PETROL TANK TO FLOAT CHAMBER
PUMP SUCTION FROM WATER TANK
PUMP DELIVERY THRO' CARBURETTOR JACKET
PUMP
FROM PETROL TANK TO FLOAT CHAMBER
PUMP DELIVERY THRO' CAB. JACKET
PUMP DELIVERY THRO CYL. JACKET
DIAGRAMATIC ARRANGEMENT
OF
PIPES & WIRING
4CYL. 4" x 4⅛" PET. ENGINE.
PUMP
PUMP SUCTION
WATER RETURN TO RADIATOR
TO EXHAUST SILENCER
TREMBLER COIL
2 ACCUMULATORS
TO FRAME

FIG. 9.

four explosions to be accounted for at every two revolutions of the crank. This represents 2,000 explosions per minute, or a little over 32 per second. It is of the utmost importance therefore, that there should be no miss-fire, and various systems of ignition arrangements have their advocates founded on experience.

All agree that the roughness of the roads have a great deal to do with the efficiency of the ignition gear. In the case of a tramcar there should be no difficulty in keeping a fairly uniform and regular spark. For some reasons the accumulator method is preferred as being less liable to derangement and as being more easily replaced by charging at an electric station if it gives out, but we trust never to have the experience when we are travelling of having to wait till the driver goes to the station to get his battery re-charged. He would probably return, however, within twelve hours if he were lucky in getting a new charge. There is really no difficulty in selecting a reliable system at the present time.

Silencer.—A close box with tubes and cross partitions to deaden the noise of the high-pressure escaping gas, is provided and closely connected with the exhaust pipes from the cylinders. For engines of the size we have been considering—the cubic content is about $\frac{1}{2}$ cubic feet for 20 horse-power developed. As before mentioned, the carburettor absorbs a certain amount of heat from the exhaust gases to warm up the petrol as it is being vapourised, and before it has passed into the engine cylinders. The principal portion of the exhaust gases, however, are either partly condensed in the silencer or pass out to the open air at a very low pressure.

Radiator. — This is a contrivance consisting of a great number of small tubes set in parallel rows, either horizontally or vertically, and separated from one another by light armoured plates fixed to the outer surface of the tubes so as to give as much surface as possible for the radiation of the heat from them. The arrangement is for circulating the water through the cylinder jackets, the motion being kept up between the water tank, cylinder jackets and the radiator by a force pump of the rotary type. A cooling surface of 4 sup. feet per horse-power is generally considered sufficient for keeping the heat of the circulating water at a working temperature. This is one of the points in the petrol engine which still requires a good deal of improvement. A much larger quantity of heat is produced than can be utilised, and water requires to be carried for cooling and for preventing the breaking up of the substance of the materials of which the cylinders, etc., are composed. When it is considered that the melting point of cast iron is 2,200° and of wrought iron 3,000° and that the temperature developed by the explosion of the gases in the cylinder is 2,730°, it is evident that the substance of the materials must rapidly deteriorate by being exposed to such high temperatures, as of course a large amount of this heat is absorbed by the walls of the cylinders. If it could be all turned to good account the performance of the engine would be more than doubled. Even in its present imperfect condition its efficiency is higher than the steam-engine as now known. This deficiency in the steam-engine is largely owing to the defects of the steam boiler, but these are gradually being reduced in the newer forms, and if the boiler could be *half* perfected the steam engine would take precedence of the petrol engine in its present form.

It has taken a very long period to develop the steam-engine, but manufacturers are now waking up to the possibilities of further improvement, stimulated, no doubt, by the performance of the petrol engine.

Tanks.—A water tank to contain about 3 cubic feet, or, say, 20 gallons, would be sufficient to supply water for cooling purposes, and a petrol tank to carry about 12 gallons would supply the necessary fuel for a journey of 100 miles. It was shown by calculation that a gallon of petrol would run about 6.25 miles at full power and speed, but, as a rule, fully one-half would be easy work, either on the level or down hill, when very little fuel would be required. In these cases the exhaust can be left open so that the compression stroke will not act as a brake on the motion of the car, also the petrol supply can be cut down to a limit of about $\frac{1}{32}$nd part of the full stroke. An average of a gallon per 8 miles will therefore be amply sufficient.

Resistance, Tractive Force and Adhesion.—The total weight of a tramcar built as described would be nearly $4\frac{1}{2}$ tons. Add for weight of load, $3\frac{1}{2}$ tons. Representing a total load of 8 tons.

The resistance of this on the level at 15 miles per hour (V) would be—

$$R = 6 + .009V^2$$
$$= 6 + .009 \times 15 \times 15 = 8.025 \text{ lbs. per ton.}$$

Add to this for extreme gradient 1 in 16. $\frac{2{,}240 \text{ lbs.}}{16 \text{ lbs.}}$ or 330 lbs. per ton.

Therefore:—

Total tractive force per ton . . .		$= 8.025 + 330$
" " " " . . .		$= 338.025$ lbs.
" " "	for loaded car (8 tons)	$= 338.025 \times 8$
" " "	" "	$= 2704.2$ lbs.

The pressure on the engine piston was found to be over 200 lbs. per square inch upon a piston of 15.9 square inches, and we also found we had a gearing of 1 in 6 ratio at full speed. If, then, we consider only half of this power developed, we would have 100 lbs. × 15.9 sq. ins. × 6 = 9,540 lbs. of tractive force available to meet the 2,704 lbs. required to take the car up a gradient of 1 in 16 at the speed of 15 miles per hour. Further, we have the lower gearing of the ratios of 10.4 and 15.6 for 9 and 6 miles per hour, which are always available if required, and which would greatly increase the tractive force.

There still remains the question of adhesion. This is a varying quantity. With the rails in good condition

600 lbs. per ton could be reckoned on; but in ordinary British weather, which includes a good deal of all sorts, a more reliable figure would be 450 lbs. per ton, or 3,600 lbs. per car of 8 tons. Should matters come to the worst, the usual application of dried sand is available until something better is invented.

Petrol Car for 3′-6″ Gauge.—The observations made so far refer to the construction of a tramcar for a gauge of 4′-8½″. When we come to the details of a car for a 3′-6″ gauge some alterations may be made, if considered necessary or advisable. This is merely a matter, however,

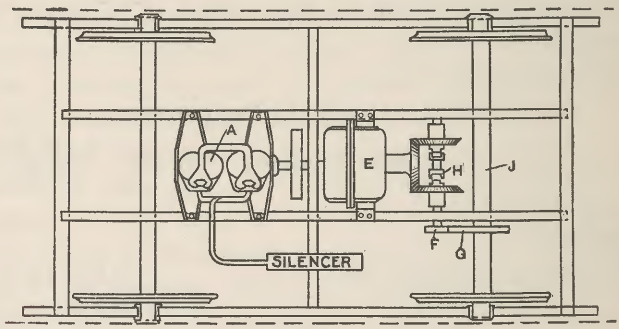


FIG. 10.

of the adaptation of the existing engines and gearing for the work. If the arrangement already described for the wider gauge be preferred, there is no difficulty in adapting it also to the narrower gauge, but an alternative system may be briefly described, which may find favour in the eyes of some under certain conditions. The most important differences from the car just described are:—

(1) The engines are placed longitudinally and not transversely; they are also in the centre of the car instead of being under the side seats (see Fig. 10).

(2) The drive from the main shaft is still continuous, but being longitudinal it necessitates the intervention of a set of three bevel wheels in order to change the direction to that of the axles of the car.

(3) The two shafts of a pair of these bevel wheels, which are exactly in the middle of the car, and are driven from the central bevel wheel in opposite directions, carrying also two chain pinions which are fixed exactly opposite two chain wheels mounted on the axles of the car. The two axles of the car are thus driven alternately from the chain pinions according as they are connected by the respective clutches to the cross shafts before described.

(4) The arrangement of the seating in the interior of the car is also altered, owing to the change in the position of the engines. In this case there are four single seats which take the form of chairs, and one central seat of double width on which there is accommodation for sixteen passengers (eight on each side). This arrangement provides for twenty passengers inside. The outside arrangement is for thirty passengers, as in the case of the wider gauge car.

(5) Owing to this alteration in the inside seating the doors are placed in the centre as usual, and the stair to the top of the car turns to the right hand instead of to the left. The passengers, therefore, all pass between the conductor's box and the car entrances.

(6) A portion of the end of the central seat is made portable for access to the engines, but there is also a considerable space under the car which may render the removal of any part of the seat seldom, if ever, necessary.

Steam Tramcar.—A steam tramcar can be produced in which the working machinery is disposed so as not to affect the main portions of the vehicle as we now know it, to any appreciable extent (see Fig. 11, Plan of lower frame of Steam Tramcar). To follow out similar power and dimensions to that which we have been considering :—the boiler would be placed under one of the stairs, and as all its operations are automatic, it would require no attention beyond the first raising of steam and the setting of the automatic regulators. It (the boiler) consists of a cylindrical shell of steel plates about 1′ 8″ diameter and 1′ 8″ high, having about 512 fire tubes $\frac{9}{16}''$ diameter placed vertically, and developing a working pressure of 250 lbs. per square inch. The fuel used is ordinary paraffin oil, which is vapourised by passing through heated tubes, and burned in a specially constructed burner. It is automatically regulated by the steam in the boiler, so that if the pressure exceeds 250 to 300 lbs. the supply of paraffin is curtailed, and the flame lowered. There is an arrangement also for superheating the steam. The water is used many times over as it is condensed in a cooling coil or in the radiator, and pumped back again to the supply tank to be re-used again for feeding the boiler. Sometimes it is preferable not to pass the steam from the exhaust directly back again for use in the boiler, as, for instance, in climbing a steep hill, or in certain cases

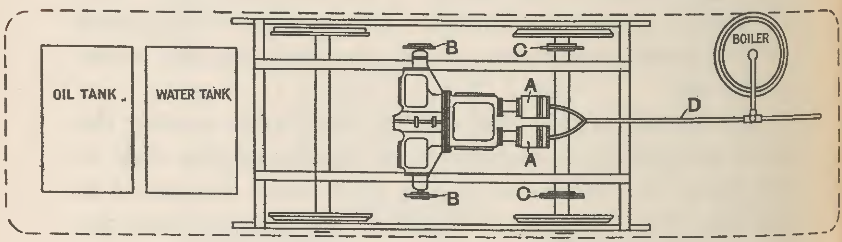


FIG. 11.

where the steam has to be economised. In these instances the condensed steam is, for the time being, pumped into a separate tank to be re-used again at a more suitable time for the boiler. This economy of steam gives the engines a considerable reserve of power when it comes to any situation where their full strength has to be put forth.

The boilers are tested to a hydraulic pressure of 700 lbs. per square inch before being used.

Engines.—The engine constructed to work the steam carriage with the boiler described has two cylinders 4″ diameter × 4″ stroke, and the main cranks make 277.2 revolutions per minute in developing a speed on the road of 14 miles per hour, the driving wheels being 2′ 10″

diameter, and the gearing between the main cranks and the driving axle being 1 : $1\frac{1}{2}$. If allowance be made for a $\frac{3}{8}$th cut-off stroke, which reduces the average pressure in the cylinders to 150 lbs., and also for loss and the proportion of time working when the full boiler pressure is not developed, the average pressure would be, say, 100 lbs. per square inch, and the piston speed—

277.2 rev. per min. $\times \frac{4}{12}$ ft. stroke $\times 2 = 184.8$ ft. per min.

Area of each cylinder 12.5664 sq. ins.

Total pressure on each piston $= 100 \times 12.5664 = 1256.64$ lbs.

$$\frac{1{,}256.64 \text{ lbs.} \times 184.8 \times 2}{33{,}000.} = 14.062 \text{ H.P.}$$

This is nominally a 12-H.P. engine, and it has abundance of reserve to work far beyond this power. We have not noted the additional gain from the gearing which would increase the power by one-half.

Pumps.—There are four pumps used :— (1) To supply the feed water to the boiler from the main tanks; (2) to supply the paraffin oil for the burner into the oil pressure tank; (3) to circulate the lubricating oil to all the bearings. In connection with this matter there is a very simple and beautiful arrangement whereby the oil is forced into each bearing in turn through a system of tubes connected with a central cistern; (4) pump for continuing the circulation of the water from the condenser back again to the main supply tanks.

Tanks.—The supply of water for a steam-engine is sometimes looked upon as a real difficulty to be reckoned with. In the case of this engine it is a very small matter indeed. If the engine be not condensing, about $1\frac{1}{2}$ gallons or 15 lbs. of water per mile has been used, but the condensing plant has been so satisfactory, that a tank of 34 gallons is found sufficient for 100 miles of an average road.

The paraffin used has worked out to about $\frac{1}{6}$ of a gallon per car mile, so that a tank of 17 gallons would be a sufficient supply for a run of 100 miles. At the very worst parts of the road $\frac{1}{4}$ gallon per mile was enough.

There are many other ingenious points in connection with this new development of the steam tramcar which, did time permit, would form interesting topics, but these we have already pointed out will show how completely the whole mechanism has been designed. In fact, the details have been so successfully worked out that they can be applied at any moment in the construction of a tramcar as soon as the car is required.

The New Light Railway Carriage.—Before proceeding to the question of comparison between the tramcars of the present time and those we have been describing in the matter of cost, we would call your attention briefly to a new design for a light railway carriage (see Fig. 12). There are a great many short branch lines of railway in this country which would be better served by one, or at the outside, two carriages every half-hour or so instead of the heavy locomotives with their trains of carriages, numbering from five to twelve, as occasion may suggest, and running only two or three times daily. If the Railway Companies were to do away with or dispose somehow of most of their old stock which they keep running on these branch lines, and invest in a few new motor carriages suited to the needs of the present time, they would save their expense to an enormous degree, they would greatly increase their traffic, and they would accommodate the public. In a great many cases, a single carriage to accommodate fifty passengers would be quite sufficient if run every fifteen or thirty minutes; there would be no necessity for keeping station-masters and porters at all these roadside stations, as the tickets would all be sold and collected on board the carriage, and in these places where platforms and the extensive machinery of station-houses with all their adjuncts are not yet erected there could be immense reductions in the expense of these appliances. The steam engines for working this carriage are similar to those just described for the tramcar. One of these engines would be quite sufficient to work the carriage

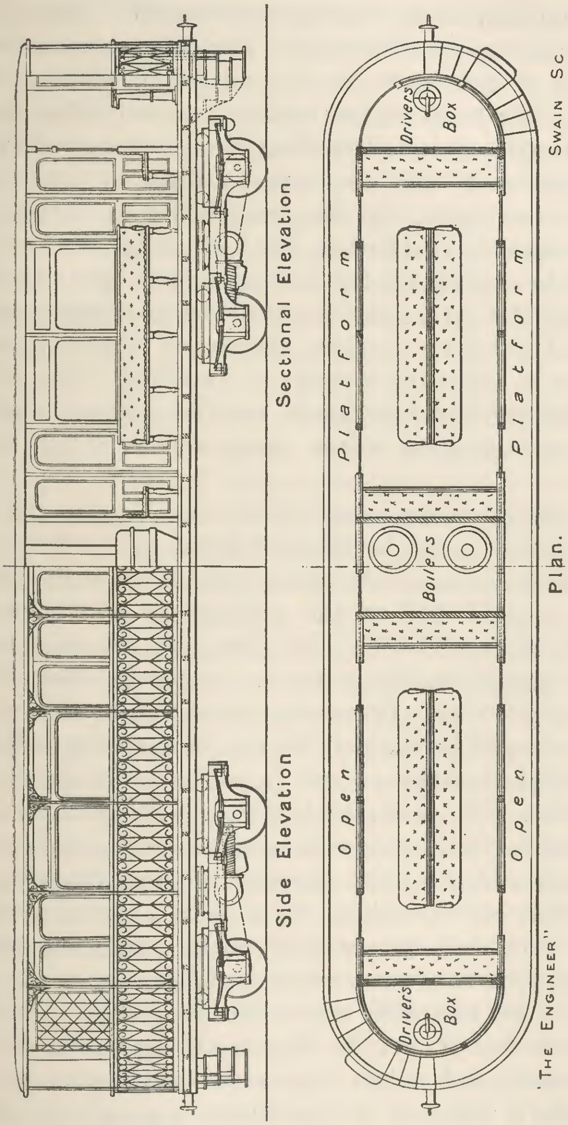

Sectional Elevation
Side Elevation
Drivers Box
Platform
Platform
Boilers
Open
Open
Driver's Box
Plan.
Swain Sc
"The Engineer"

FIG. 12.

at the speed, say, of 20 or 30 miles per hour, and the second engine could be utilised as necessity arose.

In the plan of the seating, a verandah is shown going completely round the carriage. This verandah is approached by steps at both ends, so that no station platform is required. The body of the vehicle has two compartments which would accommodate about twenty-four or twenty-six passengers each, and one side platform, at least, would always be available. In the centre of the car is the boiler-room containing two boilers, which would be attended to by a stoker to regulate the fuel as described for the steam tram-car; and the driver has a semi-circular compartment at each end which he occupies alternately, according to the direction in which the carriage is travelling. One of these compartments could always be used for luggage, when the driver was using the other compartment in front of the train.

A change such as the use of a carriage of this kind would involve, could be brought about gradually. In the construction of any new lines, if such are still contemplated, a great deal of the preliminary cost at stations could be dispensed with. In a line, say, 20 miles long, a single carriage would make six single or three double journeys per day. In twelve hours, twenty-four double journeys would be made at the rate of one every half-hour, so that eight carriages would be sufficient for the working of the line. Of course, the half-hour division might not be so suitable as having trains running closer at certain periods of the day and at longer intervals at other times, but this could soon be ascertained by a little experience of the traffic. Any deduction made from the traffic as conducted on most lines at present would be fallacious, as the trains are not in the meantime run to suit the public. The tramway traffic has shown the Railway Companies what they may expect, and unless they make some effort to meet the traffic it will soon be found that a great part of their occupation is gone.

In the course of time some of the older branch lines will come to be renewed, and in all renewals the works could be simplified and cheapened, and in the extra traffic which would come to the railways from the increased facilities, combined with the reduced cost of the mileage, they would earn dividends which they have not hitherto dreamed of.

The goods traffic may also be included in the new system. The motor railway waggon is quite as much within the range of practical work as the motor carriage and the motor steam crane as an old friend could be rehabilitated in the newest garb. At many small road-side stations where the old stationary cranes hold the field, the motor crane would do the work at far less cost, and might serve several stations owing to convenience and portability.

The New Service Road Car of the Future.—We have still a few remarks to make on the New Public Service Road Cars. Although these have been at work for some time in certain districts, they have not yet come to be recognised or appreciated at their proper value. They have taken several different forms according as they are required to act as the city tramcar, the bus to convey passengers to or from the railway stations (when they are expected to carry considerable cargoes of luggage), or the mail coach travelling through the country with the triple responsibility of carrying the mails, including the parcel post, the passengers bound for the outer boundaries of civilisation, and their goods and chattels. That there are many districts where the motor car in some of its forms can be put to some of these uses need not be demonstrated. In many parts of London, for instance, the traffic is so congested that, although conveyances are much required, it is impossible to lay down rails in the streets or to run tramcars on them. In these cases the motor car has taken the form of the old London horse bus with or without the top seats. In Fig. 13 a view of a car with top seats, made to carry thirty-three passengers is shown. This car is driven by a steam-engine with a boiler, both being such as already described. Besides congested places, such as London, there are these places where, with a few miles of road between two small towns, it would not pay to lay down tramway rails, and in such places the motor road bus is the best solution of the problem.

In comparing a motor tramcar with a motor road car,

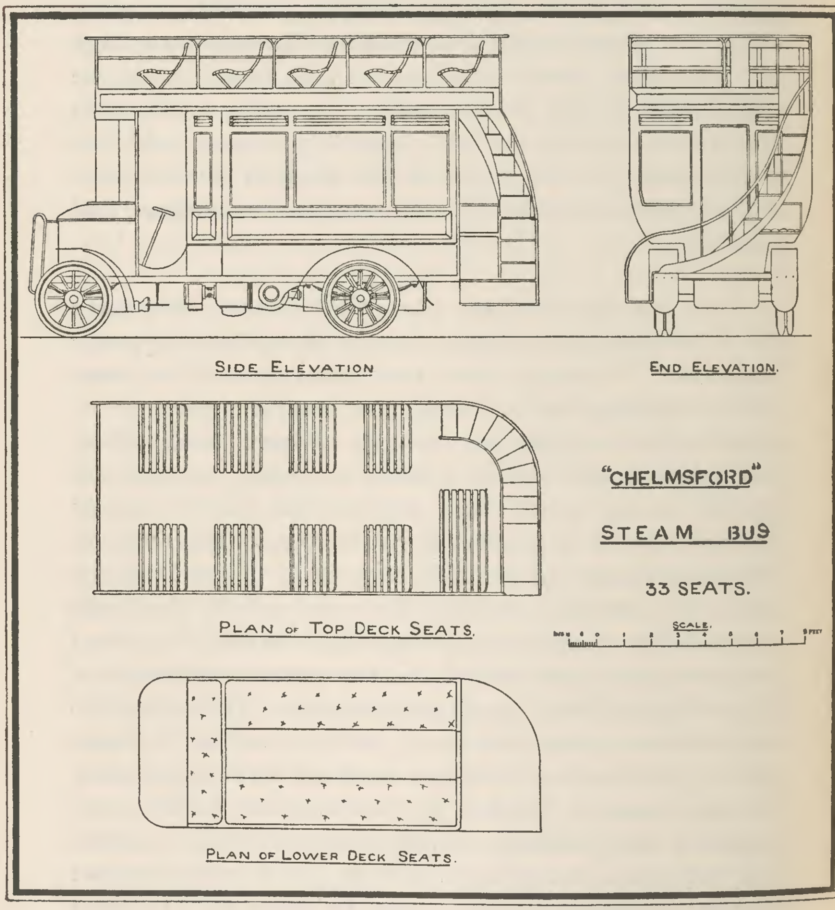


FIG. 13.

it has to be borne in mind that the traction on rails is approximately in the ratio of one on rails to ten or twelve on macadamised roads. According to this value, we should only require a pull of about 10 lbs. to draw a weight on rails equal to that which on a road requires a pull of from

100 to 120 lbs. We never, however, seem to get the full benefit of this ratio in tramway work. A tramcar weighing about 8 tons loaded will require about a 12-H.P. engine. An engine of the same power will be considered ample for a road car weighing 40 to 45 cwts. loaded. The tramcar will accommodate fifty passengers,—the road car will take sixteen passengers. The tramcar will be four times the weight, and the passengers three times the number. So far, then, the advantage is with the tramcar, which carries three times the number of passengers for the same horse-power of engine. But the expense of providing and laying the tramway must be paid for out of this saving, also the line must be kept up and the depreciation paid for.

For the rest, the road car is at a disadvantage with regard to its wheel tyres, it has a more complicated gearing to keep up, and beside being more flexible in itself it has a rougher road to travel on and is more liable to sudden jars, and also to collisions.

Further, the smaller-sized road car has not the capacity to take a large extra number of passengers at the busy times of the day, while the more capacious tramcar may make up a decent average for the day by getting its space fully filled up at the special times when passengers are most plentiful. The average number of passengers conveyed by the larger car may be much less than the capacity of the smaller car, but the latter car never recovers the loss from the small averages of the less busy seasons. No doubt the car runs more easily and lightly during these slack seasons, and the heavier car has a greater weight to carry per passenger at all times, but especially when the proportions of passengers are at the lowest ebb.

When we come to calculate the costs of the various systems we shall enquire whether the saving in the providing of the tramway is a full compensation for the disadvantages of the road car.

Besides the road cars which we have been discussing, and which are almost exclusively for passengers, there is the bus which is half a lorry or a carriage and a baggage mule combined. It is sometimes loaded on the top like an overburdened growler, and sometimes like a waggonette half filled with goods and half with travellers.

Then there is the lorry itself wholly devoted to goods.

Lastly, we have the Royal Mail Coach, char-a-banc style, with accommodation for passengers, luggage, and mails. This coach is specially designed for lightness to carry a few passengers and a considerable weight of mails and goods.

All these cars, coaches, buses, or by whatsoever name they are called, can be constructed to be worked either by petrol or steam power. There are innumerable little differences, but the same general principles of construction run through the whole and have already been described.

We pass on now to the comparison of the cost of working and construction with the systems now in use.

In the first part of this paper an allusion was made to the vast sums of money spent on tramways, and to the continual expenditure still going on in the varied extensions through the country. The electrical overhead system has, for the time being, taken possession of the arena, and we have begun to accustom ourselves (not in Edinburgh, but in most places) to the pillars in the streets, either with or without lights on them, and to the overhead wire entanglement which so many people at the beginning of these electric times so strongly objected to, and with which they prophesied the public would never be satisfied. We are now trying to persuade ourselves that they are no obstruction nor even an eyesore, that in fact we rather like them than otherwise, and we shall no doubt be prepared before long to declare that we could never do without them. We don't really care for them, but somehow they seem to be a necessity or a method of warding off greater evils in the shape of street grooves or street studs, or the heavy accumulator systems with their enormous car-loads to carry, and all the extra expenses attendant thereon.

It will, no doubt, be admitted almost at the beginning that if we have succeeded in showing that a tramcar can be constructed and run, such as has been described, it will be more economical both in construction and working than any other system which meantime holds the field.

If we analyse the costs of some of the electrical systems on the table on p. 244 we shall be able to see what are the elements which combine to make up the outlays, the revenue, and the cost of working.

Taking the town of Nottingham as an example, we have 30 miles of single tramway, costing £558,838, or an average of £18,661 per mile. But this does not include the expense of the electric station, and as one-half of the whole electric power of the station is consumed in working the tramways it is only fair that this proportion of the cost of the station should be added to the capital spent on tramways. This half comes to £200,000, which being added to the cost of the 30 miles of tramway is equal to a mileage addition of £6,667 per mile, making the total cost £25,328 per mile.

			Per car mile
For the year ending 31st March 1904, the receipts from traffic amounted to . .		£128,202	or 12.25d.
Expenses . .	£71,259		
Interest . . .	15,333		
		86,592	
Leaving for Renewals and Sinking Fund . . .		£41,610	
There is no exact amount given of what the renewals cost, but it may be taken at the amount reserved for the year, which is . . .		13,482	
		£28,128	
Out of this a sum was devoted to the relief of rates amounting to		£13,000	
Leaving for Sinking Fund		£15,128	

TABLE OF COSTS OF ELECTRIC TRAMWAYS.

	Route Miles	Capital Total	Capital per Mile	Receipts	Expenses	Interest etc.	Renewals & Depreciation		Relief of Rates
							Total	Per Cent. on Capital	
Aberdeen . .	12	£324,597	£27,050	£50,986	£26,381	£7,667	£16,938	5.47	
Dundee . .	12.3	309,634	25,174	42,005	27,126	8,446	6,433	2.08	
Dover . . .	3.5	65,450	18,700	11,636	8,479	1,184	1,973	3.00	
Glasgow . .	65.25	2,372,789	36,365	656,572	304,315	66,131	261,126	11.00	£25,000
Liverpool . .	71.22	2,363,485	33,185	544,720	341,463	53,454	117,722	4.98	32,081
Nottingham . .	17.0	758,838	44,637	128,202	71,259	15,333	28,610	3.77	13,000

PROPOSED NEW MOTOR TRAMWAY.

Double Track .	5	95,000	19,000	32,120	18,980	3,325	9,815	10.33	

The question comes to be—what percentage should be allowed for depreciation? Considering that the greater part of this expenditure is for machinery and rolling stock, or its equivalent, an allowance of 5 per cent per annum is not too large an amount.

Depreciation at 5 per cent on capital .	£37,941
So that the Sinking Fund of . .	15,128
Leaves a loss in value of . . .	£22,813

and there was really no money over to apply to the relief of rates although £13,000 was actually paid. The amount actually set aside for Sinking Fund was a little under 2 per cent.

Dover Tramways.—If we examine similarly the returns of the accounts of Dover for the year ending 31st March 1903, being the last year for which we have accounts, it runs thus:—

Expenditure on Permanent Way Plant, etc.	£39,450
One-fourth of Generating Station . .	26,000
TOTAL Capital	£65,450

Being for $3\frac{1}{2}$ miles of route:—£18,700 per mile.

			Per car mile.
		Receipts £11,636 =	10.23d.
Expenses . . .	£8,479	=	7.45d.
Interest	1,184		
Sinking Fund and unappropriated Balance	1,973		
		£11,636	

The depreciation on £65,450 being the total amount of Capital	£3,272
But Sinking Fund and Balance only .	1,973
There is, therefore, a deficiency of . .	£1,299

besides the fact that nothing is put down as charged for renewals.

	Per cent.
The amount of Sinking Fund being only .	1.45
and the unappropriated Balance . .	1.55
TOTAL	3.00

Glasgow Tramways.—In the Glasgow accounts up to 31st December 1903.

The total capital expenditure is £2,372,789, being per mile of route, £36,365. The electric power is included in this return, and, as most of the track is double, it may be taken as £18,182 per mile of single line.

The receipts for traffic for the year .			£656,572
Expenses . .	£304,315		
Interest . .	66,131		
		£370,446	
Under the heading of Depreciation Sinking Fund, Depreciation *special* and general reserve the amount is put down at		261,126	
Common Good . .		25,000	
			656,572

Taking Depreciation as before at 5 per cent. on the total Capital of	. £2,372,789	118,639
But in this case the amount set aside is 11 per cent. for Renewals, Sinking Fund, and Reserve		261,126
Or an excess of		£142,487

Liverpool Tramways.—71.22 miles.

Capital	£1,863,485		
Power Installation (one-third) . . .	500,000		Per car mile.
		2,363,485	or £33,185

Abstract of Revenue—

Expenses .	£341,463		
Interest .	. 53,454		
Sinking Fund	. 53,560		
Depreciation	. 64,162		
Relief of Rates	. 32,081		Per car mile.
		£544,720	or 11.15d.

The Depreciation as before at 5 per cent.	.£118,174
And an amount for Sinking Fund and Depreciation has been laid aside of .	117,722
which is within . . .	.£ 452

of the amount calculated upon.

Dundee Tramways, 15th May 1903.

Capital Expenditure . . .	.£256,634
Power Installation (one-third) .	. 53,000
	£309,634

Being £25,174 per mile.

			Per car mile.
Receipts for year . . .		£42,005	or 11.09d.
Expenses .	£27,126		
Interest . .	6,246		
Accident and paid Company .	2,200		
Sinking Fund and Depreciation .	6,433		
		42,005	

The depreciation at 5 per cent. on Capital	£15,482
But the Sinking Fund, etc., only	6,433
Being deficiency of . . .	£ 9,049

The depreciation fund in this case is only 2.08 per cent.

Aberdeen Tramways.

	To 15th May 1903.
Capital Expenditure	.£259,597
Power Installation (one-third) . .	65,000
	£324,597

Being £27,050 per mile.

			Per car mile.
Receipts for year . .		£50,986 or	12.66d.
Expenses .	£26,381		6.55
Interest. . .	7,667		
Sinking Fund and Depreciation .	16,938		
		50,986	

The Depreciation at 5 per cent. on Capital . . .	£16,229
And the Sinking Fund, etc. .	16,938
Leaving a surplus of . .	£ 709

The London County Council are proposing meantime to lay down tram lines on the Thames Embankment for a length of $1\frac{5}{8}$ miles, at a cost of £146,600. If they are fortunate enough in earning 2 d. per car mile, after paying all expenses, they will have to run a car every minute both ways on the track for every day in the year, and for sixteen hours a day, in order to pay 3 per cent. interest on the money, and 5 per cent. depreciation on the plant :—

5 per cent. + 3 per cent. = 8 per cent.

8 per cent. on £146,600 = £ 11,728 per annum.

= 2,814,720 pence.

365 days × 16 hours × 60 mins. × $3\frac{1}{4}$ miles = 1,138,800 miles.

$$\frac{2{,}814{,}720 \text{ pence}}{1{,}138{,}800 \text{ miles}} = 2.56\text{d. profit per car mile.}$$

Almost anything is possible in London in the way of traffic, but we contend that this extraordinary expense is unnecessary, and we wish to show that there is a method of doing the whole of the work in a simpler and easier way.

If we now take as an example an ordinary tramway with rails, say, 84 lbs. per yard laid with a double line, and all points, crossings, etc. required, and 5 miles long.

Say, 10 miles single track @ £6,000 or	£60,000
Add for car sheds and sundries . .	10,000
	£70,000
25 cars complete @ £1,000 . . .	25,000
CAPITAL	£95,000

Car service every day 16 hours (5 minutes)
16 hours × 12 per hour × 10 miles = 1,920 miles daily.

1,920 miles daily × 365 days = 700,805 miles yearly.

Pay back £9,000 annually, being whole capital in ten years

$$\frac{£9{,}500}{700{,}805} = 3.250\text{d. per car mile.}$$

Working Expenses—

			One car for one day.
Two drivers (eight hours each)	@ 6s.	.	£0 12 0
Two conductors do.	@ 4s.	.	0 8 0
Fuel 100 miles	@	$1\frac{1}{2}$d.	0 12 6
Lubricating oil, 100 miles	@	$\frac{1}{4}$d.	0 2 1
Cleaners, waste, etc. . . .		.	0 7 0
Repairs and renewals . . .		.	0 2 0
General expenses, office, etc. . .		.	0 10 0
			£2 13 7

$$\frac{£2\ 13\ \ 7 \text{ per day}}{100 \text{ miles}} = 6.43\text{d. say, } 6\tfrac{1}{2}\text{d. per car mile.}$$

Receipts may be estimated at 11d. per car mile.

	Per car mile.	Per day.	Per annum.
Abstract receipts	11d.	£88	£32,120
Expenses	6.50d.	52	18,980
	$4\frac{1}{2}$d.	36	13,140
Deduct depreciation	$3\frac{1}{4}$d.	26	9,490
	$1\frac{1}{4}$d.	£10	£3,650
Interest on Capital $3\frac{1}{2}$ per cent.			3,325
BALANCE			£ 325

If we compare the result of a similar double line 5 miles long constructed on the overhead electric system, the result will work out something like the following:—

10 miles of single track, including cars, car-sheds, generating stations, etc. at £18,000 per mile, or a total of £180,000.

If this amount were to be paid up under the same conditions as have already been calculated for the motor car tramway, the depreciation would be £18,000 per annum,—and working this out for the same mileage

$$\frac{18{,}000}{700{,}805 \text{ miles}} = 6.16\text{d. per car mile.}$$

This is a loss of about 3d. per car mile.

With regard to the ordinary working expenses it is evident that the cost of the men in the generating station will be all additional, and that extra men will be required on the permanent way to attend to the wires, both underground and overhead. This could not be estimated at less than 2d. per car mile.

Taking these two items of extra expense, we have a yearly loss on a 5 mile double route of:—

700,805 miles at 5d. or £14,600 2s. 1d.

In placing these figures of comparative cost before you, we would observe that so far as regards the motor tramcar they are amply sufficient for the purpose, in working out the scheme a good many savings could be effected—but it was thought better to make ample provision for every cost, instead of looking forward to increased expenditure in the shape of extra works which should have been included at the beginning. Of course, it is quite possible to meet with exceptional circumstances which really form no part of the tramway scheme, but these would be evident at the commencement of the work, and would be allowed for in the probable estimate.

In the case of the cost of the electric system, special care has been taken to put these down at a minimum amount, as it was considered better rather to understate than to overstate the difference between the two systems.

We have not discussed the question of the objectionable overhead wires as they are a feature we have grown accustomed to since it came to be thought there was no other feasible way of working a tramway but by their use.

We cannot, however, so readily forgive them when they represent a system which is not only not the best, but is more than double the cost of the best as known at the present time. The working of the conduit system in London has not so far given satisfaction. It has cost originally over £25,000 per mile of single track, being over £50,000 per mile of route, and the cost of keeping it up is so great that no other city or town in this country could afford to keep it in order and proper repair.

To such towns or districts as have already embarked in tramway schemes and have laid down rails, the motor tramcar will come as an enormous saving; but to such places as have not yet so occupied the roads so as to interfere with the traffic, the motor road car must successfully appeal. After all that can be said in favour of tramways it must be admitted that they sadly interfere with the road traffic, and where it is possible to avoid this it is always most satisfactory to do so. The motor petrol or steam car can travel quite as fast as a tramcar, and as it is not confined to rails it may change its route at any time to suit public convenience.

The introduction or proposed introduction of the light railway has never been a success in this country, as in nearly all cases the cost of carrying it out has been about equal to the expense of a main line. In the suggestion we have endeavoured to give them there is a considerable departure from established custom to meet the wants of the times and suit the public convenience by having a light railway in truth and reality. Very much lighter railways can be used, the large expense of stations will be virtually done away with, the transit and delivery of goods will be accomplished at a much cheaper rate and the convenience of the public will be served in many ways that the present systems cannot accomplish in any satisfactory or rational manner.

The main trunk lines of railways would in many ways be greatly benefited by the intercommunication on the cross roads by systems of tramways and road cars, and when these are made to work conveniently together, hundreds of small towns and villages will be brought into such close contact that it will be possible to live at some distance from the towns and still attend to business every day.

The great question of the overcrowding of cities is becoming every day a more important one, and every improvement that can be made in locomotion goes some way towards the solution of the problem.

There is every year a greater need for workmen travelling long distances to the factory, the workshop or the warehouse, and these varying needs can only be satisfied by a flexible system which can accommodate itself to the ever-changing requirements of the time.

But the electric tramway is in no way suited to meet the case. It is costly and cumbrous—whereas we now require something which is more flexible in itself and more capable of being adapted to the varying needs of the community. Such a system we have in the motor tramcars and the motor road cars which we have laid before you. In themselves they are complete units not depending upon the working of machinery some miles distant, and the successful keeping up of communication with a central power. We therefore submit that this system claims the first consideration at the hands of municipal authorities or others engaged in projecting extended schemes of locomotion throughout the country.

*Improvements in Kitchen Ranges.** By THOMAS OMIT.
(With Illustrations.)

THE improvements consist of a Ventilating Fire Door, Rising Bottom Grate, and Cold Air Excluder, by the combined use of which a kitchen range may be made slow combustion, thereby saving a considerable amount of fuel.

In consequence of the many complaints which have been made for some years, and which are still being made, about the great amount of fuel consumed in the ordinary kitchen range, many individuals and firms have been considering how the very apparent waste of fuel might be avoided.

The result is that many appliances to accomplish this end have been put on the market.

Prominent among these are the Rising Bottom, False Bottom, etc., in present use.

While these contrivances have certainly accomplished one end, viz., the reduction of the size of the fire, it does not necessarily follow that there will be a corresponding reduction in the amount of fuel consumed.

For example, take a kitchen range with a rising bottom and a 12-inch fire—a very common size of fire—the width and depth measure about 12 inches × 10 inches, giving 120 square inches of front.

When the bottom is at its lowest point or natural position, and when the fire door is open, cold air will be passing through these 120 square inches, causing the fire to burn brightly.

When the bottom is raised to its highest point, reducing the size of the fire-box to nearly one-half, the same amount of cold air is still going in to burn up the smaller fire, thus bringing about a more vigorous combustion.

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* Read and illustrated before the Society on 16th January 1905.

Not only is this so, but fully one-half of the air passes in *under* the bottom grate, thus causing the fire to burn away more quickly.

As a natural result, the smaller fire burns away more

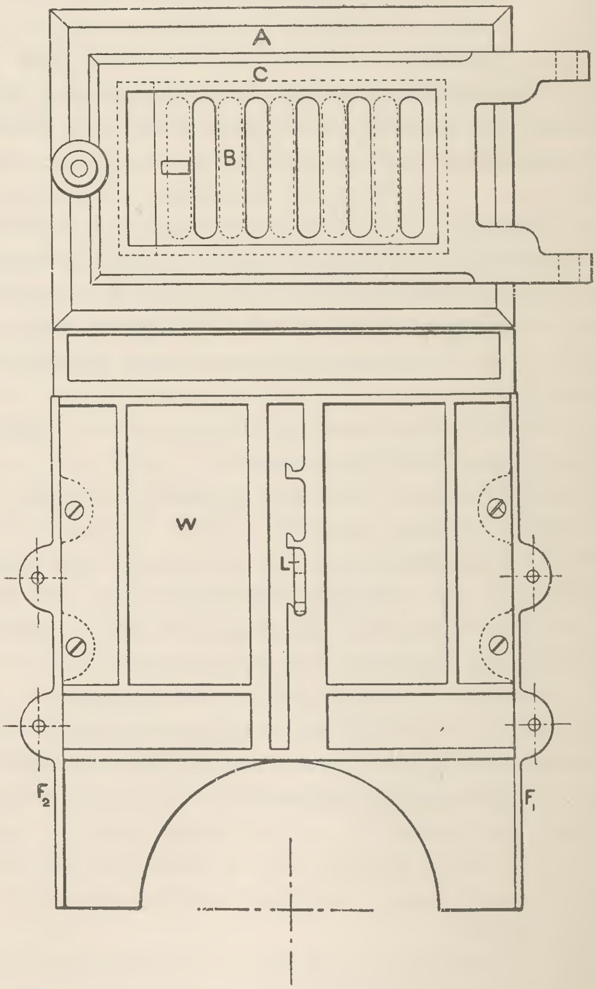

Fig. 1.

rapidly than the larger, and has to be replenished more frequently.

The author is inclined to think that instead of saving fuel, as much, if not more, is burned when the bottom grate is raised or when a false bottom is used, as when the bottom is at its lowest point.

Not only so, but in many instances when the bottom grate is raised the cold air passes under the false bottom

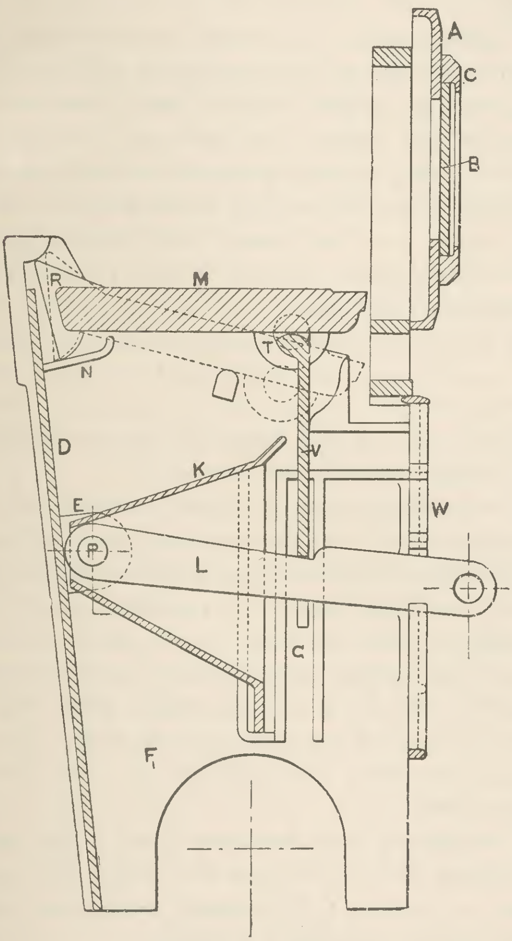

FIG. 2.

and goes directly up the boiler flue, cooling it to such an extent that hot water cannot be obtained.

Notices appear frequently in the Press of large bodies such as the Admiralty, shipping companies, railway companies and large firms experimenting with the object of reducing the consumption of fuel, this being one of the heaviest items of expenditure.

The author can see no reason why a saving should not be effected in private houses as well as in large companies.

The author's firm has been experimenting with the object of bringing out a range which will lessen the consumption of fuel, without at the same time reducing the efficiency of the range, and has lately brought out and patented a rising bottom grate and cold air excluder, also a ventilating fire door by the combined use of which a kitchen range can be made slow combustion, thereby saving a considerable amount of fuel, the average saving being about 40 per cent.

This is the simplest and most effective range on the market, which can be called, and actually is, a slow combustion range.

A front view of the range is shown in Fig. 1, and a cross section in Fig. 2.

The ventilating door is made in three parts. There is a cast iron plate (A) forming the door itself, extending the full width of the fire and to the depth of the poker bar. In this plate there are cut slots exactly opposite the openings in the fire bars. In front of the above plate there is a second cast iron plate (B), slotted like the first, and fixed to (A) by a cast iron frame (C). The plate (B) can slide in front of the plate (A), thus forming a sliding ventilator by means of which the fire can be forced or checked at will.

On comparing this door with that which has been in use for some years, it will be found that the "new" door measures 12 inches × $8\frac{1}{2}$ inches, while the "old" door measures only 12 inches × 6 inches.

The "old" door admits cold air to the fire when the door is shut, through the space under the door measuring 12 inches × 4 inches, while the "new" door admits air through a space measuring 12 inches × $1\frac{1}{2}$ inches, or just about *one-third* of what the "old" door admits.

Not only so, but the "new" door purifies the smoke, thus keeping the flues and chimney very much cleaner.

Although the author makes no claim that it is a smoke-curing apparatus, it has been known to cure smoky chimneys where other appliances have failed.

Rising Bottom, etc.—D is the back plate of what may be called the fire-box section. On this plate there are cast two ears (E), through which a pin (P) passes for holding a lever (L) and a plate (K) in position. F_1, F_2 are side plates (right and left hand). On these plates are cast small brackets and strips, the brackets holding the bottom in position while the cold air excluder works in grooves (G) formed by the strips.

On the back of the plate (K) is cast a bracket; this bracket is carried to the back plate and held in position by the pin (P), which passes through the ears on the back plate (D).

The use of this plate will be more clearly seen later.

The bottom grate is shown at (M); on each side of the grate and at the back is cast a projection (R) which rests on the brackets (N) cast on the side plates. The use of these projections being to throw the bottom forward when raised, thus leaving a space of about $\frac{3}{4}$ inches between the back of the bottom and the back plate, sufficient to allow dust or ashes to fall into the ashpan, so keeping the fire much cleaner. (The dotted lines show the bottom grate in its lowest position.) On the front of the bottom and at each side is cast an ear (T), from which is hung a cast iron plate (V) sliding in the grooves (G) on the side plates. The lever (L) is for the purpose of raising the bottom and plate attached thereto. This is held in position by a pin passing through the ears on the back plate as already described.

The front of the range is formed by a plate (W), in which is cut a slot provided on one side with a series of notches. On these notches the lever rests when the bottom is raised.

The object of the plate (K) is to exclude the cold air. It being bevelled on the top edge prevents any air getting up between it and the plate (V) hung from the bottom, as these plates rest against each other when the bottom grate is raised.

The cold air being drawn through the ashpan has the effect of causing the fire to burn brightly from the bottom of the fire-box, and so burning up almost everything, leaving only a fine powder at the end of the day, with very few cinders.

Everything being now in position, suppose there is a large fire wanted for some purpose or other. The rising bottom would of course be at its lowest point, the ventilator in front of the fire door open, and also the damper in the ashpan, thus admitting as much cold air as possible.

With a fire such as this hot water at a very high temperature can be had in a very short space of time, while the ovens can be heated up to 510 degrees Fahr. When it is found that the large fire is no longer required, the bottom could be raised, the dampers closed, and also the ventilator in front of the fire door, when the heat would be retained, there being no air getting into the fire.

Thus a slow combustion fire can be obtained, which without further attention would burn for hours.

One point the author thinks is in favour of this rising bottom, viz., its simplicity, there being no intricate parts to get out of order. Should any of the fire parts require repair, that can be done without taking down any part of the range.

In conclusion the author states that this range has been very severely tested, when it was acknowledged to be a decided success.

*Electrical Hoisting Machinery.** By John Ritchie, C.E.
(With Illustrations.)

In the year 1892, the author had the privilege of submitting to the Society a Paper on the application of electricity to hoisting machinery.

At that time the use of electrical driving for such a purpose was distinctly novel, and the appliances for electrical transmission were not quite perfect.

Great improvements have since been made in the design and construction of both dynamos and motors, but even then the great possibilities of their application were apparent, and the results have amply justified their use. Electric motors are now applied to every description of hoisting and lifting machinery.

The mechanical portions of the machinery described in this Paper have all been designed and constructed at the author's own works in Edinburgh.

As every one now is more or less familiar with the construction of dynamos and motors, and as they have been described in several Papers which have come under the notice of the Society, our remarks will be confined principally to a description of the forms of electro motors, which are generally used for cranes, hoists, etc., but before doing so, it is necessary to enter briefly into several comparatively elementary matters in connection with electricity.

Electrical Transmission may be divided into two systems.

First.—Direct or Continuous Current. That is the current passes continuously in the same direction from the dynamo to the motor, and then back to the dynamo.

Second.—Alternating Current, in which the current is

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* Read and illustrated before the Society on 16th January 1905.

continually alternating between a positive and negative maximum.

Of the two systems, in this country at least, continuous current, up till now, has been the favourite means of transmission. It lends itself to a wide and economical speed regulation, and as by far the largest number of generating stations are continuous current, it necessarily follows that the use of this class of motor is also more extensive than alternating current machines.

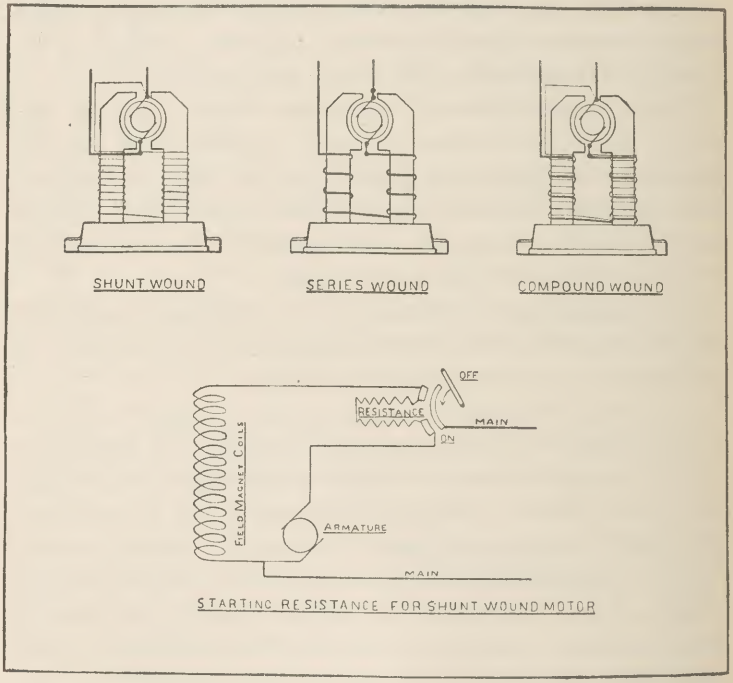

FIG. 1.

Continuous Current Motors.—These may be divided into three classes. Each class derives its name from the form of the winding of the wire on the field magnets.

(1) *Shunt Wound Motors.*—The magnets of dynamos and motors are excited by coils of copper wire receiving their current from the machine itself.

In the shunt wound machine, the field magnet coils consist of a large number of turns of fine wire, connected in parallel with, or as a shunt to the external circuit, and only a small portion of the current is used to excite the field magnets.

As a motor, this arrangement maintains a fairly constant speed, with a varying load, but it does not start well against a heavy load, and it is necessary to use a starting resistance in the armature circuit, so that the field magnet may be excited before much current passes round the armature.

(2) *Series Wound Motors.* — In a series wound machine, the armature coils, field magnet coils, and two external circuits, are in series with one another, forming a simple circuit, so that the whole current passes through the field magnet coils. As a motor of this kind has its greatest torque or pulling power at starting, when the current is at its minimum, it is specially suitable for severe changes of load.

It is not self-regulating as to speed, for, as the demand for current increases, the speed decreases, and *vice versâ*. It is specially suitable for cranes, where the motor is started, stopped, and reversed, with the load hanging in the hook.

(3) *Compound Wound Motors.*—The compound wound machine is a combination of the shunt and series machines. As a motor, it has considerable starting torque, due to the series winding. It is capable of maintaining a heavy load at a constant speed, and its shunt winding prevents a dangerous rise of speed with light loads.

The efficiency of motors may be taken as 90 per cent. at full load, to 85 per cent. at half load, but this varies with the size of the motor.

In applying a motor to a crane, the form of winding adopted on the motor depends a good deal on the kind of work the crane has to do.

(4) *Alternating Current Motors.*—The action of these may be better understood from the following diagram (Fig. 2).

The current first rises, as it were, in the positive direction from zero to maximum, then falls in the same direction passing through the mean line, and reaching zero again. It changes to the negative side, increasing to the negative maximum, returning to the mean line in zero again, and so on.

The time within which the current makes this double alternation is called a period. Currents may be arranged of different periods, but a common one is a "Frequency" or periodicity of 50 per second. The above is called Single Phase Current.

Single phase motors being difficult to start, caused

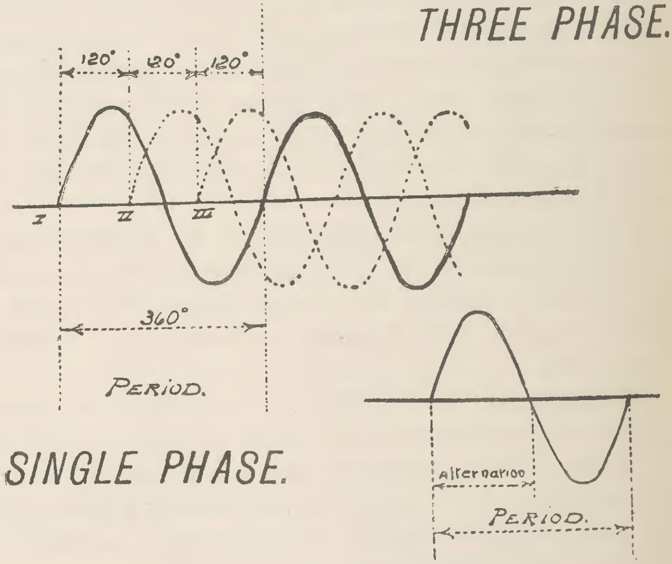

FIG. 2.

the introduction of Three Phase Current, the action of which will be more clearly understood from the diagram.

The three phase current usually employed is obtained from a combination of three alternating currents of equal periodicity, but which are inclined to each other, at an angle of 120 degrees.

The action of single and three phase current may be best understood by comparing a single crank steam-engine, with a three crank one. The single crank engine has a dead centre, and is difficult to start, whereas the three crank engine may be started whatever the position of the cranks, and has a more equal turning action.

The construction of the three phase motor is radically different from the continuous current one. It has fewer parts, and no commutator or brushes. It has been largely adopted on the Continent for transmission plant, and its use in this country is also on the increase.

If the crane or hoist is fitted with one motor only, and all the various motions are worked from it, it is advisable to have the motor running at a fairly constant speed, and a shunt or compound machine is adopted. If, however, the direction of rotation in the motor must be reversed, or the load is to be started at a low speed, and afterwards increase that speed, then a series wound motor must be used.

The most severe test for a motor is to start the load when hanging in the hook, as it is then that the rush of current is greatest, and this phase of the work to be done illustrates the beautifully automatic arrangement in an electric motor. If we could imagine a steam crane to automatically turn on more steam, when the load came on, without the aid of the driver, this is exactly what happens with a series wound motor.

Suppose a constant potential is maintained at the terminals of the motor, the strength of the field magnets is also constant, because the current through the coils will always be the same, but the speed of rotation regulates the current through the armature; when, therefore, a heavy load comes on the crane rope, and thence through the gearing to the armature, the tendency is to reduce the speed of the latter. This allows a stronger current to pass through it, by reducing the counter electromotive force, thus giving the power to overcome the load, when it is most wanted. With a light load, however, the tendency is for the speed to increase. The counter electromotive force rises also, allowing less current to pass through the armature, and less expenditure of electric power takes place.

It will thus be seen that the machine automatically regulates itself, and takes only the power required to do the work. It also enables light loads to be raised at an increased speed without any change of gear, which every one will recognise as being a very valuable property.

The motors for cranes are now invariably of the enclosed type, and they have a great resemblance to one another. The larger sizes are generally multipolar.

It is taken for granted that the electricity supplied to crane motors is generated in the first instance by steam, gas, or other power. This being the case, it was only natural that they would be first adopted in those works or factories which possessed an electric plant for lighting purposes. With an existing plant, it became a comparatively easy matter to apply part of the current to drive cranes and other machinery.

For comparatively small works, now that corporations and electric companies are offering electric power at such low rates, it is possible to buy the current at a much cheaper rate than it can be generated by the user.

It is somewhat difficult to say at what power the line must be drawn between buying current and making it, as it depends so much on the economical working of the boilers and engines, driving the generating plant, but the fact that there are individual users in this city taking considerably over 100 H.P. from the Corporation Mains, proves that they consider it is cheaper to buy the current than to generate it.

The total H.P. taken from the Edinburgh Mains is about 6420, and it is increasing at a rapid rate. This is not to be wondered at. The ordinary boiler and steam-engine, if non-condensing, and more especially, if under 50 H.P., uses from 5 to 10, and boiler insurance inspectors say, as much as 20 lbs. of coal per H.P. per hour, whereas the average consumption in a well-designed electric station does not exceed 2 lbs. of coal per H.P. per hour. You will at once see there is a great margin to work on—then a large dynamo or generator is more efficient than a small one. The cost for attendance and incidental charges are all less on a large than on a small scale, and this accounts

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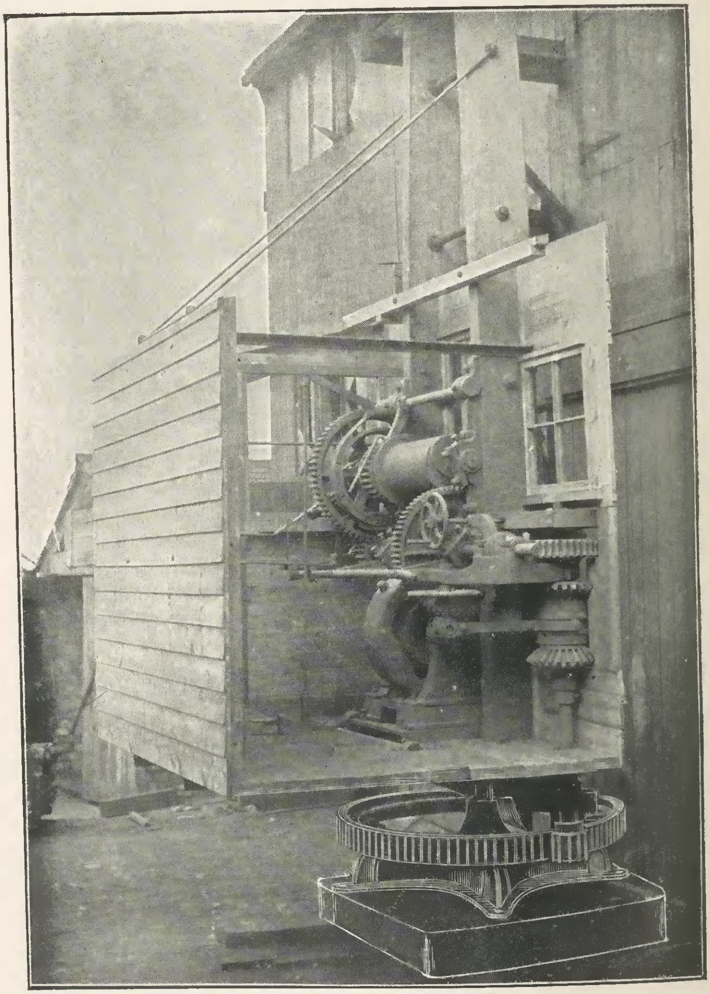

FIG. 3.—Mast of a 3-ton Electric Derrick Crane (side of cabin removed to show gearing).

for the fact that the Edinburgh Corporation can sell current at 1¼d. per unit, or less than a penny per H.P. per hour, and still make a profit.

The Application of Motors to Cranes.—Steam Derrick cranes are familiar objects wherever building operations are going on. There are many situations, however, where the use of electrically driven cranes are possible, and might with much profit supplant steam cranes.

The arrangement of the gearing in an electric derrick crane differs very little from that of the steam one. This combination of gearing in a steam crane, and which is retained in the electric crane, is the result of many years' experience, and has been found to answer admirably for the purpose. Fig. 3 shows the mast of a 3-ton Electric Derrick crane, with the side of cabin removed to show gearing.

The engine crank shaft is replaced by a straight one, and as the speed of the motor is generally 500 to 700 revolutions per minute, or four times the speed of the engine shaft in a steam crane, it is necessary to use gearing between the motor and the first motion shaft. This is invariable machine cut gearing, consisting either of a gun metal or raw hide pinion on the motor spindle, and a cast iron or steel wheel on the first motion shaft.

Derrick cranes are usually fitted with one motor only, although in very heavy cranes it is usual now to have a separate motor for slewing, or turning the crane. The motor is series wound, and is reversible.

The reversing of the direction of rotation in a motor is not effected by any change in the motor itself, but is done by simply changing the direction of the flow of current through the motor by means of what is called a controller. This is a combination of contact points, connected to variable resistances in the main circuit of continuous current motors.

These controllers have been brought to great perfection, and the arrangement of the resistance allows a variation in speed of the finest gradation, so that the hoisting or lowering of a load may be done to a small fraction of an inch, and the crane is under more perfect control than a steam crane. The illustration (Fig. 4) shows the standard crane controller of the British Thomson Houston Co. Ltd.

Fig. 5 is another form of reversing apparatus, known as a liquid controller, by Messrs Scott & Mountain, Ltd.

This apparatus consists of a cast iron tank, partly filled with water, in which a quantity of soda has been dissolved. To the tank is fitted a lever and electrical connections.

When the lever is in the central position, the carbon contact plates which are attached to it are clear of the water in the tank. When the lever is pushed to one side or the other contact is made with the water, and to the positive or negative side of the motor, and the motor may be stopped, started, or reversed as required. This design permits of a fine graduation in the strength of the current in proportion to the immersion of the carbon plates.

It is only natural that a comparison should be desired between a steam crane and an electric one, both as to efficiency and cost.

Users of cranes know what a steam crane can do, what it costs per day for fuel, oil, attendance, repairs, etc. We hear so much in a general way of the great advantages of electric driving that it is necessary to come to facts, to satisfy the practical man.

Take the case of an ordinary 2-ton builder's steam crane, doing a fair day's work, the consumption of coal is about 5 cwt. per day, or, say, 25s. per week. Then there is the time occupied in taking coals, water, etc., removing ashes, as well as the man's time, firing and attending to the water supply, cleaning fires, etc., on all which it is difficult to put a definite value.

With the electric crane, the whole of the man's time is available for working the crane. Assuming the crane to make a lift every five minutes and swing round with it, the average load being 1 ton raised at the rate of 40 feet per minute; this takes theoretically 3 H.P., and adding 50 per cent. to this for crane friction, including wire ropes, the consumption of current for one minute's lift would be ·056 units.

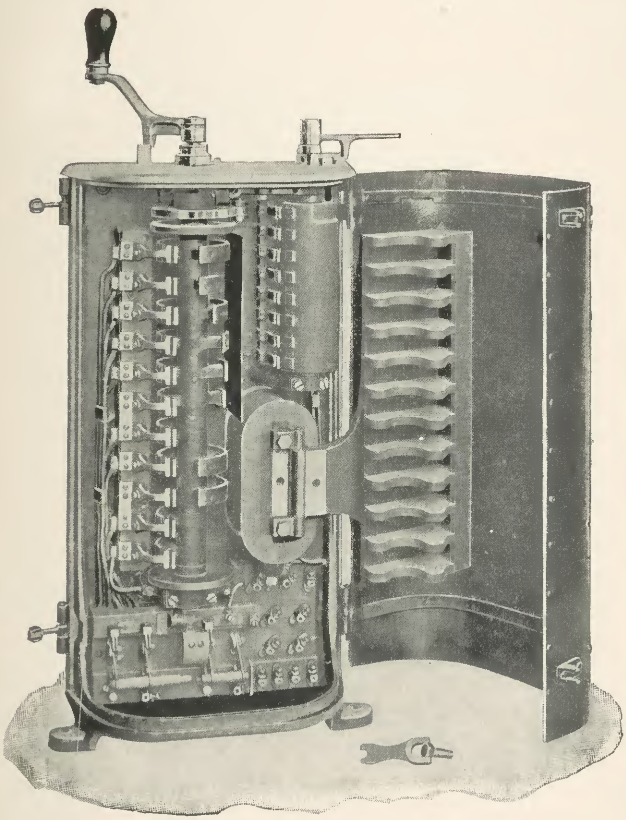

Fig. 4.—Crane Controller. Metallic Contact Type.

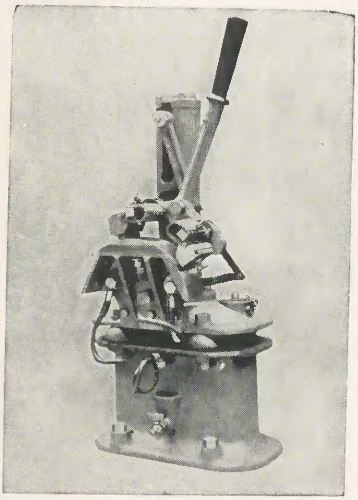

Fig. 5.—Crane Controller. Liquid Type.

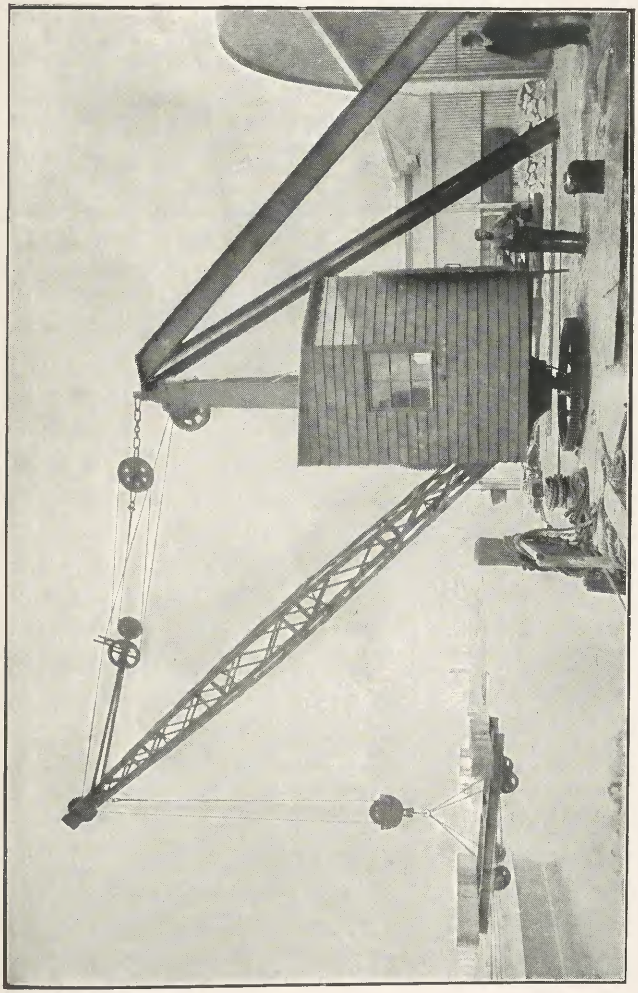

Fig. 6.—10-ton Electric Derrick Crane.

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Allow two minutes at half the above power for slewing, derricking, etc., or .056 units again, and we have a total consumption of .112 units every five minutes during nine hours, or an average of 12 lifts per hour. The consumption of current is equal to 12 units, or 1s. 3d. per day. The total cost per week for current at the rate of 1¼d. per unit is only 8s. 4d. for over 600 tons, lifted 40 feet. This is exceptional. The average work does not exceed one half of this.

Another instance may be given of a 3-ton electric crane employed for the last three years in the erection of some large buildings in the west end of Edinburgh which has been run on an average at a cost of 4s. per week—the work being of a less continuous character than stated above.

Allowing the crane driver's wages to be the same as for a steam crane, this shows a very considerable saving, without taking into account the benefit from the absence of smoke.

In a large yard in this city a 3-ton electric crane has been at work for over three years. This crane is in constant use all day. It serves thirty-five masons, several stone saws and planes, and the proprietor states that two steam cranes would be necessary to do the same work, owing to the driver of the electric crane being able to give his whole attention to the work to be done, which is not possible with steam cranes.

As the cables to the crane are not on a separate meter, it is not possible to say to a fraction what it costs for current per week, but it is calculated that it does not exceed 20s.

Steam cranes to do the same work would cost at least 50s. for coal and water, and the wages of an extra driver 30s.—or, say, 80s. in all, as against 20s., to say nothing of the interest on first cost—extra wear and tear, etc.

The first cost of an electric crane is a little more than a steam crane, but the wear and tear and consequent cost of repairs are less.

Fig. 6 shows a 10-ton electric derrick crane, recently erected in a large barge building and repairing yard on the Thames. It lifts a barge or boat clean out of the river, and sets it on a trolley, by which it is conveyed to any part of the works. Steam cranes have hitherto been used for this work. Steam had always to be kept up, because they never knew when they were to have a lift, and a man had to be kept in constant attendance, and some days they may not have half a dozen lifts. At other times there may be 20 to 30 per day of various loads.

From observations and tests made as to the cost of current for working, three loads of 10 tons were lifted 30 feet, slewed and lowered at a cost of 2.8d. each, and 6 loads of 5 tons each for 1.6d., or a total cost of 1s. 6d. The current was taken from the engines and dynamos which drove the works.

In setting forth the advantages of an electric derrick crane over a steam driven one, both in cost of working and maintenance, this does not necessarily apply to every steam crane. There are special situations in which an individual unit, like a steam crane, is the only one that could be adopted, as until public generating plant becomes more general it would not pay to put down a special plant at a small contract for one crane only.

Having considered the application of electricity to derrick cranes, we will now notice some other forms of cranes to which it is peculiarly applicable.

Locomotive Cranes.—Fig. 7 shows a 2-ton locomotive crane made by the author for the Corporation Gas Works, Birmingham. It lifts coal from a barge, runs with it 100 yards, and delivers it into a shoot. The current is conveyed by an overhead wire, and returned by the rail; 300 tons are dealt with per day.

Fig. 8 shows a 3-ton locomotive crane, made for the General Electric Co., Witton, near Birmingham. It does all the shunting and marshalling of railway waggons on the sidings, lifts and travels with material on the lines of rails all over the works, and is a generally handy tool.

Fig. 9 shows a 5-ton locomotive crane built for contractors' work in Mexico, and is an illustration of the application of three phase alternating current, which is

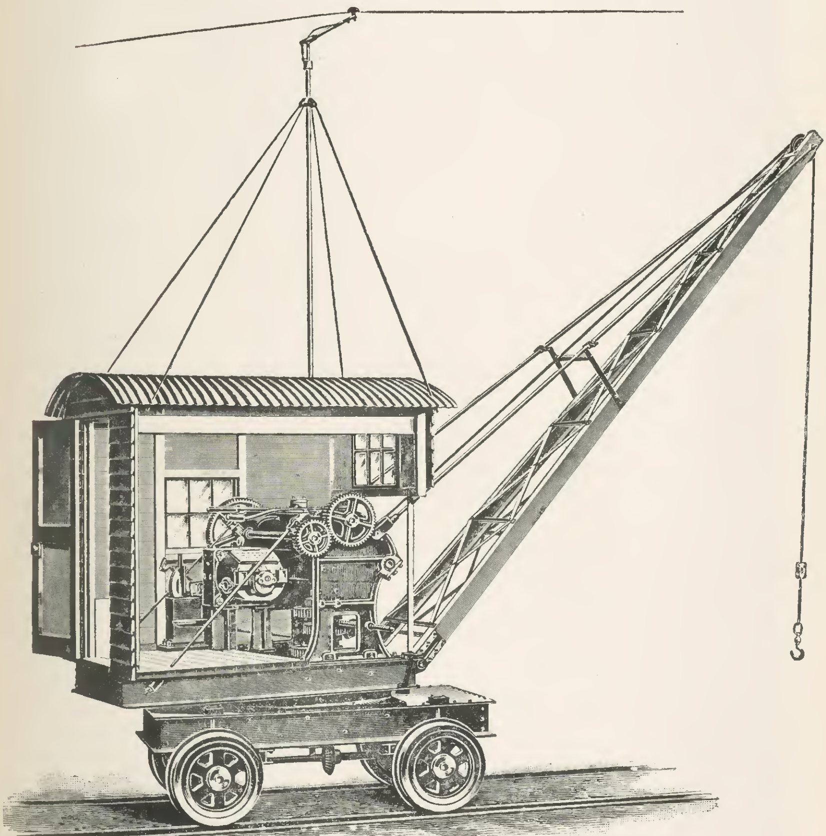

Fig. 7.—3-ton Electric Locomotive Crane. Side of cabin removed to show gearing.

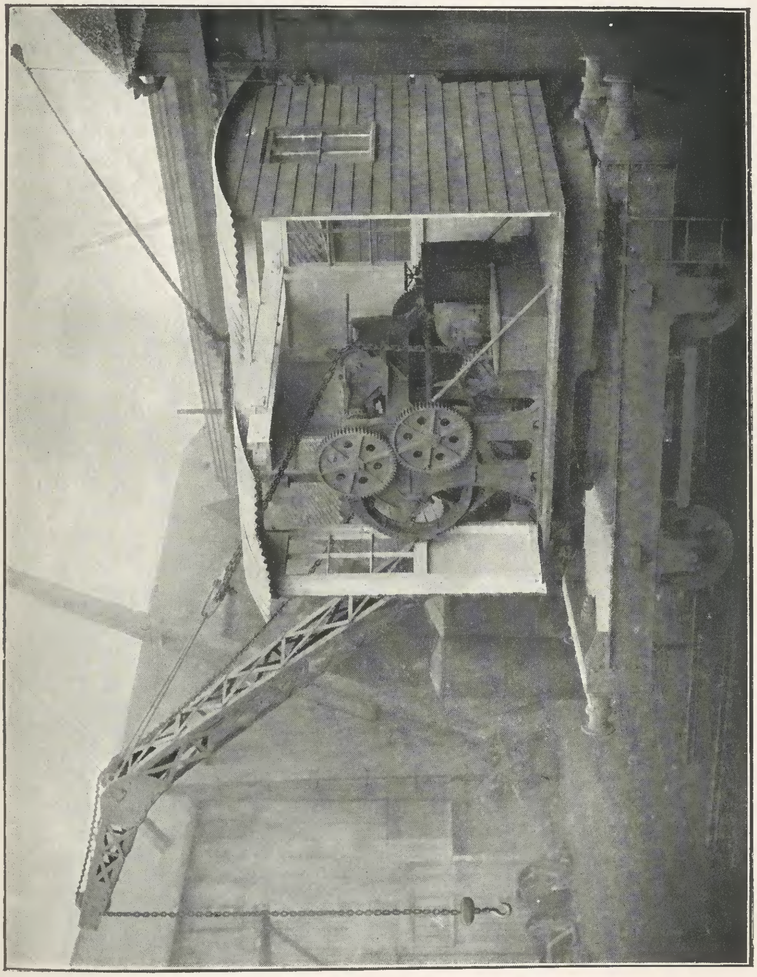

FIG. 8.—3-ton Electric Locomotive Crane.

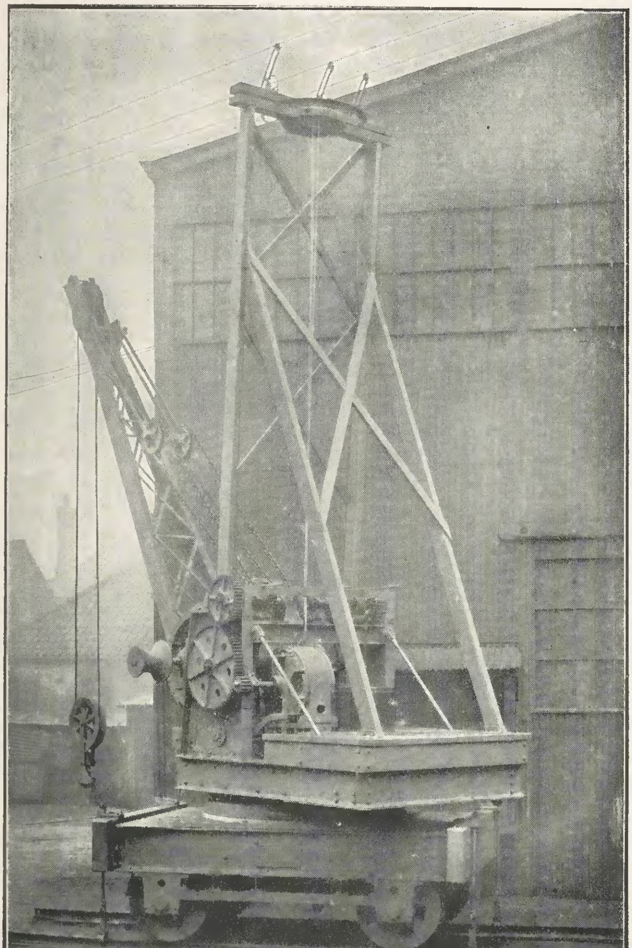

Fig. 9.—5-ton Locomotive Crane.

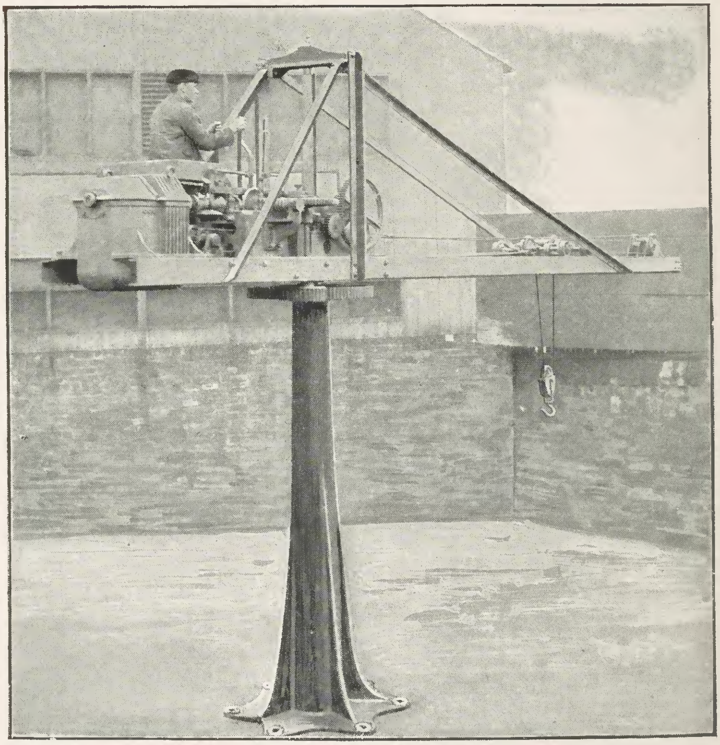

FIG. 10.—Fixed Pivot Crane.

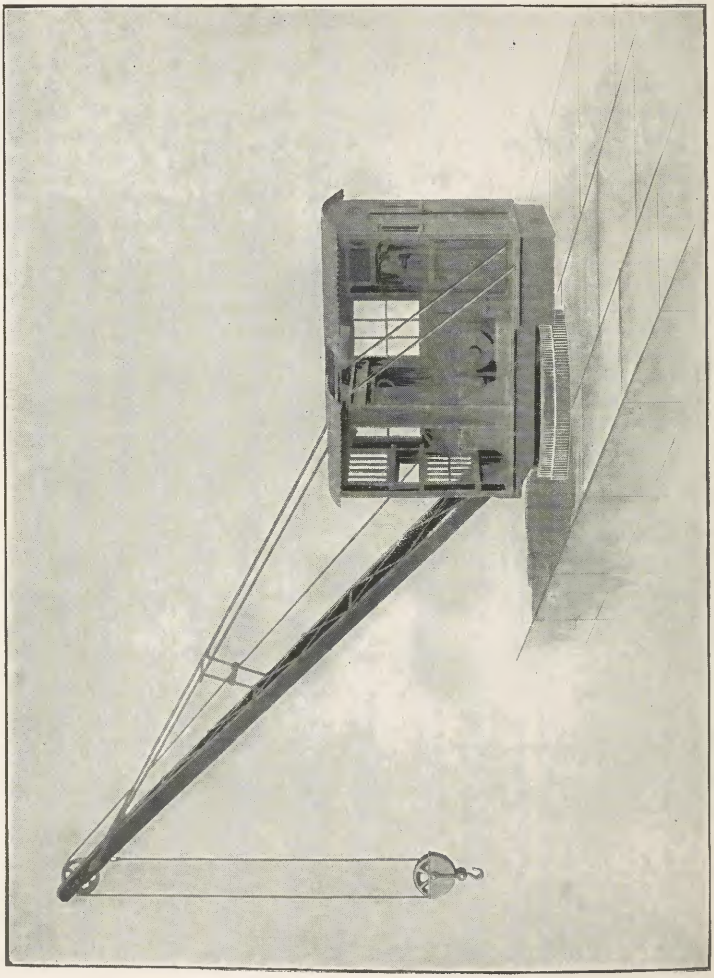

FIG. 110.—5-ton fixed Electric Pivot Crane.

conveyed to the motor by three overhead wires, and returned by the rails.

The three overhead wires on a crane of this type present some difficulty in the arrangement of the electrical collectors, as they must permit the crane to turn completely round without putting a twisting strain on the overhead wires. This is effected by three circular brass rings, fitted with brushes, the whole being pivoted on a small platform carried on timber uprights. This timber frame is boarded over so as to form a cabin to protect the machinery and driver.

The framing of the crane and under carriage is of steel, and the whole machine is made extra strong for contractors' work.

Fig. 10 shows a very useful type of fixed pivot crane. The whole machine is mounted on a central pillar, and turns right round. It is fitted with a single motor, and has three motions:—hoisting, running the load out and in on the jib, and slewing.

Electric cranes are now being adopted in the British Navy. Naturally conservative in adopting anything new, little progress was made until quite recently. Fig. 11 shows a 5-ton crane, one of three recently fitted on store ships or floating workshops, but equally adapted for use on shore. These cranes were fitted up on the iron decks of the ships, and have a radius of about 30 feet, so that they can reach over the ship's side into a barge or lighter. As the construction of the decks prevented the crane post being carried down through the upper deck, a complete arrangement of balancing had to be adopted, so as to relieve the deck as far as possible of bending strains. For that purpose each crane was fitted with a large balance tank filled with metal punchings.

The motors are of 25 H.P., series wound, and reversible by metallic controller. The gearing is machine cut.

Overhead Travelling Cranes.—Power overhead travelling cranes have hitherto either been driven by steam direct, by an endless high speed rope, or by a line of square shafting.

The steam overhead travelling crane can only be used for outside work, as the smoke and fumes under a roof make it prohibitive. In the other two forms a large proportion of the power is consumed in merely driving the rope or shaft.

Take the case of a 10-ton rope driven crane, in a shop, 200 feet long. The rope is driven about 4000 feet per minute. From actual tests, the power required to drive the rope and overcome the friction of the guide pulleys, and resistance to the air, etc., is 10 H.P.

This consumption of power is constant whether the crane is in use or not, and as the actual proportionate time that a travelling crane is at work, even in a very busy workshop, is not more than 15 to 20 per cent. of the total time, the loss that is continually going on can be imagined.

The same applies to shaft driven cranes. The power required to keep in motion at 150 revolutions per minute, 200 feet of $2\frac{1}{2}$-inch square shafting, with tumbling bearings, etc., including the side shafts of the crane, is 7 H.P. In fact, the power required to drive the rope or shafting often exceeds that required to raise the average load on the crane. From what we have said, it will be seen that overhead cranes are peculiarly adapted for electric driving. They may be divided into two classes:—

First.—Those with a single motor, which is kept constantly running as long as there is work to be done, and the various motions of hoisting, travelling, and traversing operated by a set of friction clutches and bevel gearing.

Second.—Those having three motors, one for each movement in the crane. Each type has its advantages in certain situations, but generally the three motor crane is the most useful.

Fig. 12 shows a 5-ton single motor overhead travelling crane, with a span of 40 feet, and is one of four made for the Bristol Waggon Company. The motor

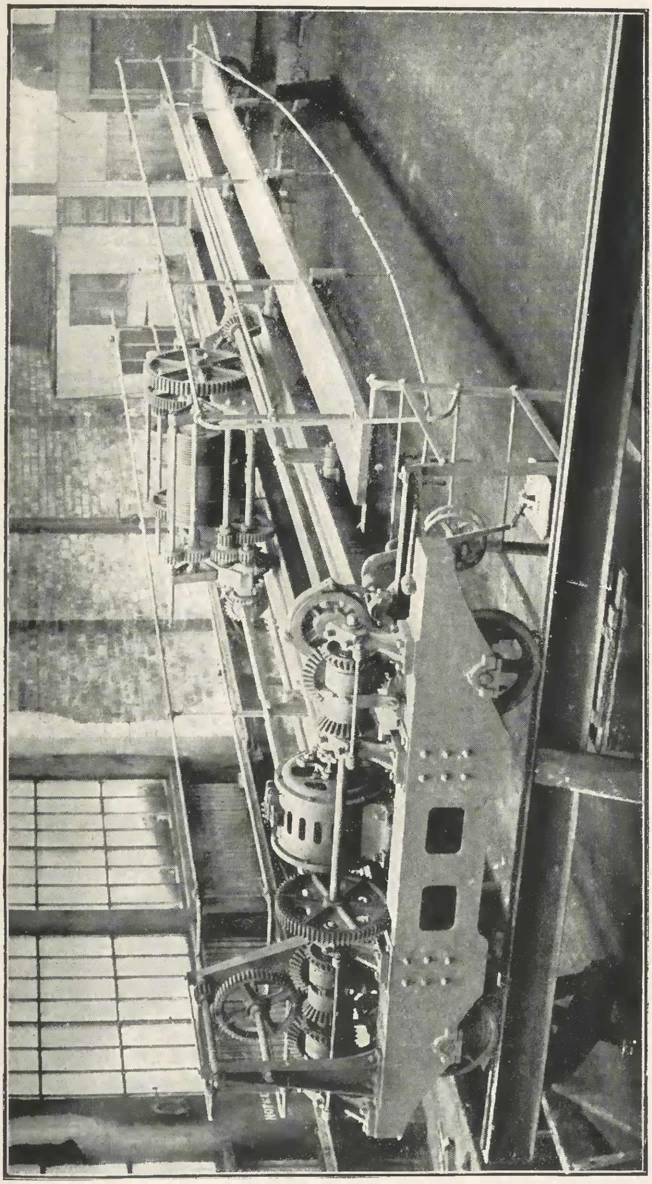

Fig. 12—5-ton Single Motor Electric Overhead Travelling Crane.

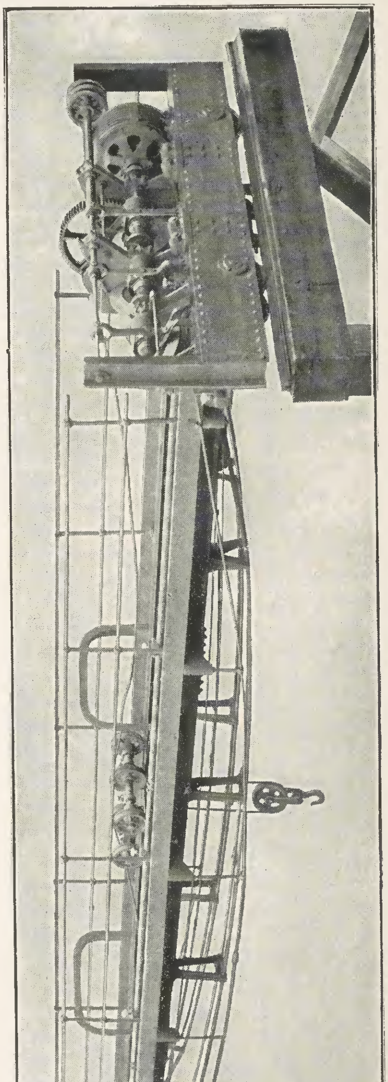

Fig. 13.—3-ton Single Motor Electric Overhead Travelling Crane.

is carried on one of the end carriages of the crane, and is geared in the proportion of 4 to 1 by machine cut gearing to a shaft running the whole length of the end carriage. Three sets of friction clutches are fitted to this shaft; these clutches being operated from the driver's cage by levers.

The motor is kept running as long as there is work to be done by the crane, and all three motions of hoisting, traversing the crab, and travelling the main carriage along the workshop may be carried on at the same time.

The hoisting gear is transmitted to the crab, which travels on rails fitted to the main carriage, by a square shaft supported by tumbling bearings. The motion for traversing the crab is transmitted in the same way, and the travelling motion for the main carriage is connected to a shaft which extends right across the crane, and is geared to the axles at either end.

The crab is fitted with two speeds of hoisting, and all the gearing is machine cut. The barrel has a right and left hand spiral cut upon it to receive the rope, thus assuring a perfectly vertical lift, whatever position the hook may be in. This arrangement of gearing has proved a very effective and durable one, where moderate speeds of lifting only are required.

This crane is also fitted with hand gearing, so that the various motions may be operated when no current was available.

Fig. 13 shows another type of single motor overhead crane. This is a 3-ton crane, with a span of 50 feet. The motor and all the gearing are concentrated at one end, and a small truck or jenny is moved backwards and forwards on the beams to carry the rope blocks.

The various motions are driven by frictional bevel gearing, the pinions being of compressed paper, and the wheels or discs of cast iron. This crane is designed for a high speed of both lifting and travelling.

The end carriages are of steel plates. The beams are composed of steel rolled joists suitably trussed with steel rods. A platform is fitted at either side of the crane, and this being latticed horizontally by iron bars gives great lateral stiffness when travelling at high speeds. Additional stiffness is also obtained by angle iron bows fitted to the main beams. The motor is connected direct on to a shaft running parallel with the end carriages, and the various motions are transmitted by the frictional bevel gearing.

For long span cranes, this arrangement of single motor crane is preferable to the type shown in Fig. 12, as the side shafts which transmit the power to the movable crane travelling on the top of the beams are not necessary, and a small truck carrying the rope blocks is all that is required. The truck is pulled to and fro on the top of the beams by endless ropes wound round turned grooved barrels. This arrangement works with great smoothness.

The motors of single motor cranes not being required to reverse are generally made compound, and the speed is only slightly variable, a starting switch and resistance only are required.

Single motor cranes are fitted with automatic mechanical brakes, so that when the friction clutch is taken out of gear, and the hoisting stops, the load will not run down. Lowering is effected by the driver easing off the brake as required.

Three Motor Cranes. — While single motor cranes have their uses under certain conditions, there can be no doubt that a travelling crane with a separate motor for each of the motions, of hoisting, traversing, and travelling, or what is known as a three motor crane, is preferable in every respect.

We now give several illustrations of these. Fig. 14 shows a 10-ton three motor crane in the foundry of Messrs Miller and Co., Edinburgh.

The span of the crane is 40 feet. The main carriage of the crane is built up of steel plates and angles, the rail wheels of steel. The end carriages are of special construction, and are formed in such a way that the rail wheels and axles can be removed for examination or repairs

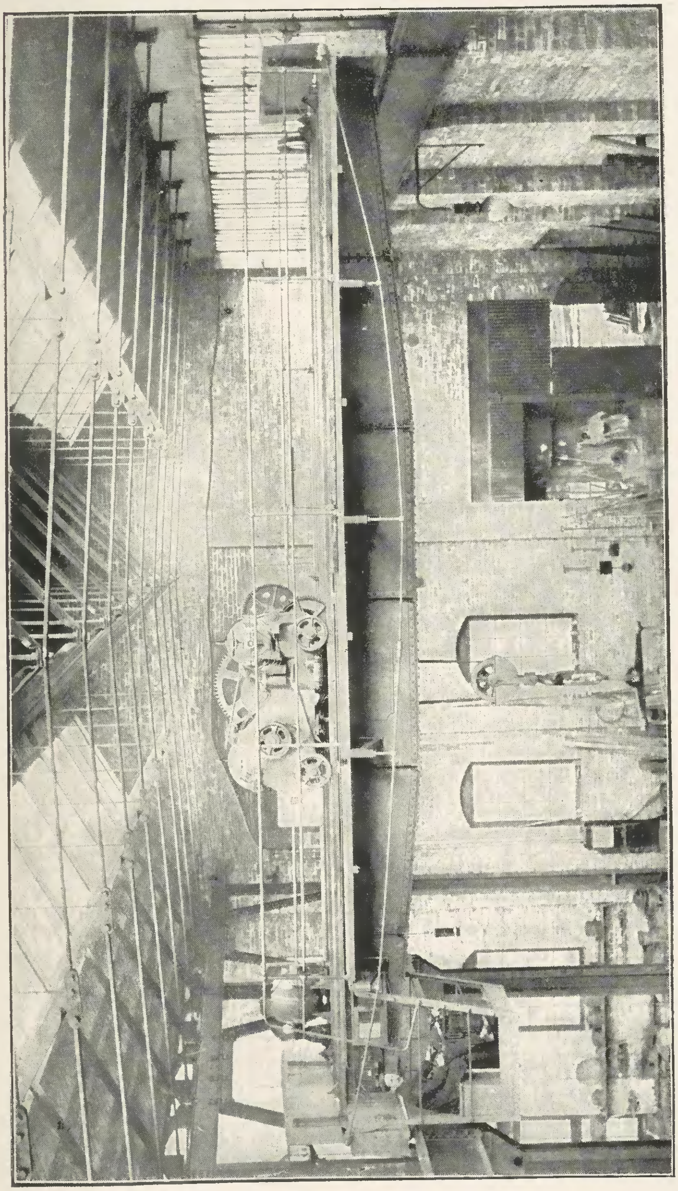

Fig. 14.—10-ton Three Motor Crane.

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without lifting the crane. The axles at each end are connected through gearing with hollow steel cross shafts, which ensures a perfectly parallel motion while travelling.

The crab cheeks are of cast iron, all bearings for the shafts being fitted with caps, so that any shaft can be removed in a few minutes for examination or repair. A platform is fitted at each side of the crane.

The barrel is cut with a double spiral groove to receive the steel wire rope, thus ensuring a perfectly vertical lift at all heights. The first and second trains of gearing are machine cut.

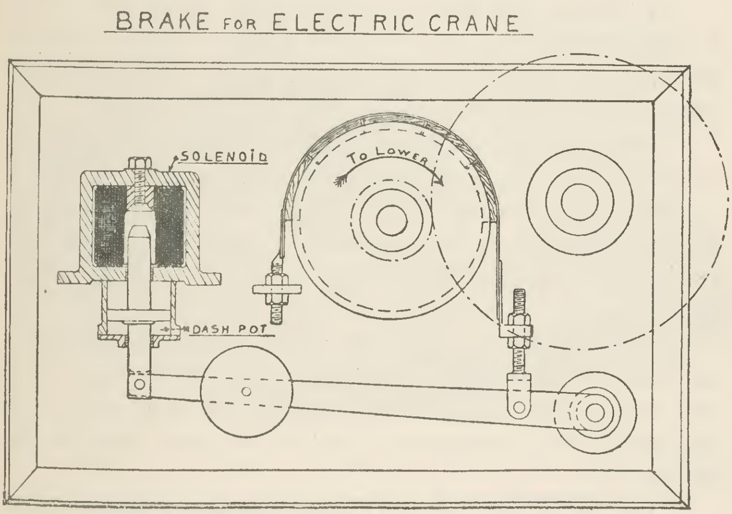

FIG. 15.

A special feature of three motor cranes is the electric brake. This is worked by a solenoid or magnet in circuit with the main current through the hoisting motor.

Fig 15 is an illustration of an electric brake. As long as the load is being lifted, the magnet being energised by the current pulls up the plunger, and raises the brake lever, leaving the strap clear of the brake pulley. When the hoisting motor stops, the magnet releases the brake lever, and the weight on the lever tightens the brake strap. To prevent the brake going on too suddenly the plunger is fitted with a piston and dash pot. The air below the piston escaping through a small hole, allows the tightening of the brake strap to take place gradually and without a jerk.

The reversing controllers, one for each motor are, of the metallic type, and are fitted in the driver's cage, which is suspended from the beams at one end of the crane.

The main conductors are placed one along each side of the building, and the collecting gear consists of brass pulleys carried on movable arms, the bare conducting wires lying on porcelain insulators. They are $\frac{1}{4}$ inch diameter, and are strained tight by screws at the ends.

By having the main conductors on each side of the building, there is no possibility of a short circuit between them, as there would be if placed close together on the same side of the building.

The cross conducting wires from the controllers to the motors are placed close to the inside of the crane beams.

Fig. 16 illustrates a 5-ton three motor crane, span 40 feet. The main carriage consists of steel joists with truss rods. The end carriages are composed of steel plates and angles.

The motor for travelling the main carriage is supported on one end of the end carriages, and connected to the axles by a cross shaft. This shaft is of steel tube, so as to reduce the overhanging weight on the side of the beams.

The electric outfit on this crane is made by Messrs Ernest Scott and Mountain, Limited, of Newcastle-on-Tyne. The motors are equal to 100 per cent. overload, and run at 500 revolutions with full load, being series wound and capable of being run up to 1000 revolutions per minute with light loads. The speed of cross travel is 70 feet per minute. Longitudinal travel 250 feet per minute, up to 350 feet per minute with light loads. Speed of lift 10 feet per minute with full load up to 20 feet per minute with light loads.

The transmission wires are stretched overhead, collectors being fixed to the crab for connection to the motors.

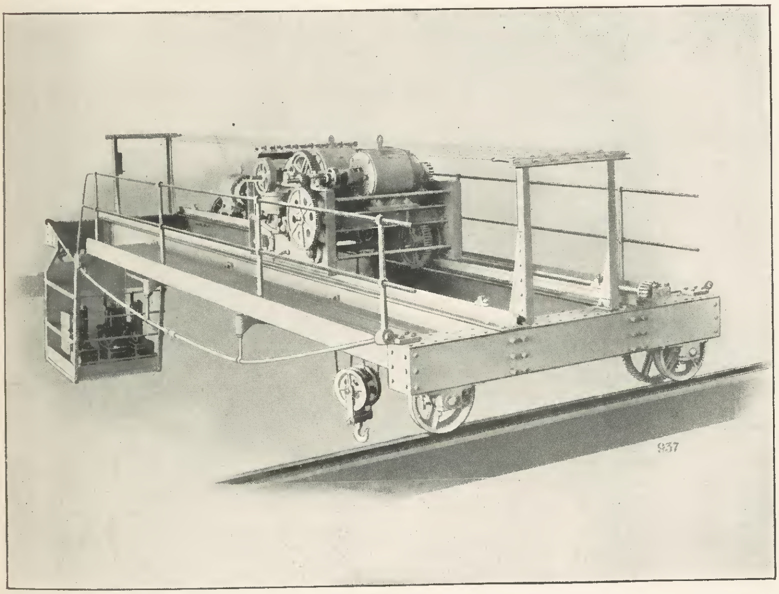

FIG. 16.—5-ton Three Motor Crane.

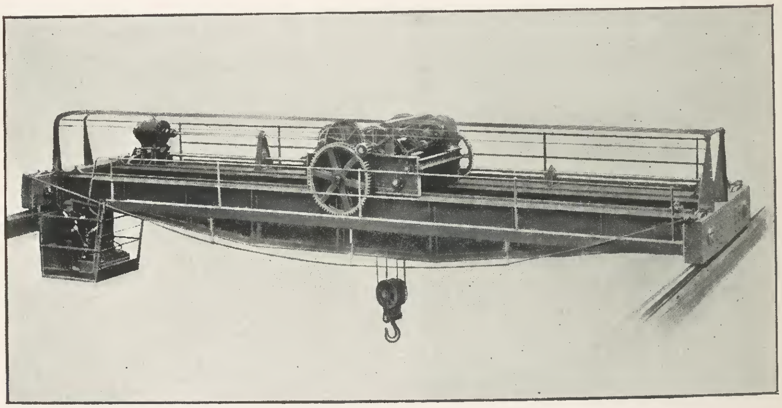

FIG. 17.—20-ton Three Motor Crane.

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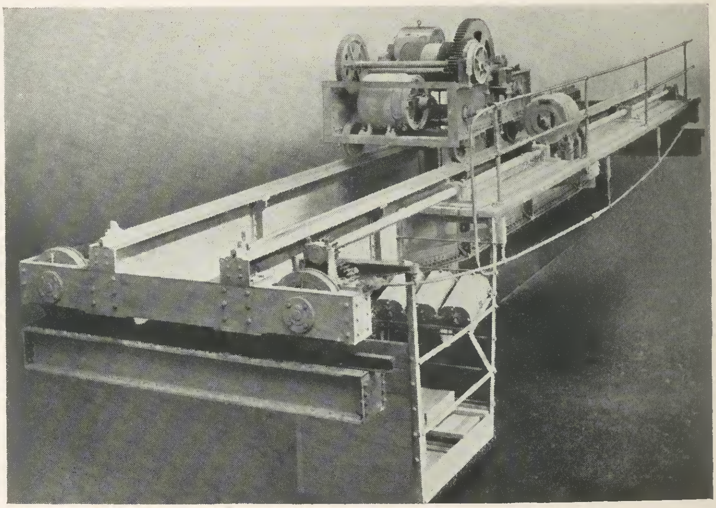

Fig. 18.—10-ton Three Motor Electric Overhead Travelling Crane.

The controllers, which are placed in the driver's cage, are of the liquid type, already described. See Fig. 5.

Fig. 17 shows a 20-ton three motor overhead travelling crane, with a span of 55 feet. The main beams are of box-section, and deepened in the centre, and the end carriages and also the outer ends of the beams are made extra deep to prevent any pendulous action in the beams when travelling at high speeds. The crab is fitted with two sets of speed gear, besides the acceleration due to varying speed of the motor.

Owing to the long span, the longitudinal travelling motor is not connected direct to the cross shaft at one end as usual, but an extension of the motor shaft is carried to the centre of the crane, where it is geared to the main cross shaft, which is connected by gearing with the axles.

By thus applying the power at the centre of the cross shaft, all liability of one end of the crane to travel in advance of the other due to any tendency of the shaft to twist is avoided.

The conducting wires in this crane are also put overhead.

Fig. 18 shows a 10-ton crane with a span of 50 feet. The main carriage of this crane is made specially rigid for travelling at high speeds. The ends of the main beams being stepped on to the end carriages. All the gearing is machine cut from solid steel forged rings put on to cast iron centres—the pinions being of nickel steel. The rail wheels have steel tyres.

All the speeds are extra high, maximum load 15 feet per minute, light loads 30 feet per minute, traversing 100 feet per minute, travelling 300 to 350 feet per minute.

Both electric and mechanical brakes are fitted, also a brake on the travelling gear of the main carriage.

The conducting wires are inside the crane beams. The controllers are of the metallic multiple contact type, and are fitted in the driver's cage.

The travelling motor is placed in the centre of the crane, and is geared to the main travelling shaft, thus ensuring an equal torsional strain on this shaft.

All the bearings are bushed with gun-metal, and wherever possible, are fitted with movable caps, so that any shaft may be removed for examination or repair with the minimum expenditure of time and labour.

The electric outfit is by the Sunderland Forge and Engineering Co., Ltd.

A special feature of these cranes is the use of spur gear throughout, instead of worm gearing, so extensively used in Continental practice. The use of steel cut gearing ensures the highest efficiency and durability.

All lifting is done by wire ropes on spiral grooved barrels, instead of the pin and link chain so commonly used in Continental work.

The author has constructed overhead cranes up to 40 tons, on the same lines as these already illustrated.

The principal advantages of a three motor crane over a single one may be summed up as follows:—

Each motor being at work only when the particular movement is required, there is less wear and tear. The absence of friction clutches, bevel gear, etc., with their attendant tear and wear. Greater variation in speed. All motions of the cranes may be controlled from any portion of the workshop by an arrangement of switches.

The electrical parts subject to wear are small and unimportant, and may be renewed at a small cost.

Electric Winches and Hoists.—Electricity is now largely applied to drive fixed hoisting gear, such as winches for general purposes, of which Fig. 19 is a good example.

This winch lifts 5 tons at a speed of 25 feet per minute, is exceedingly compact; the space taken up is only about half of that occupied by a steam winch.

These winches may be mounted on trolleys and made portable for general hauling purposes.

The barrel is driven through two trains of machine cut gearing, and the second motion shaft is fitted either with a foot or an electric brake.

The great advantage of an electric winch is, that it may be placed at any distance from the source of power, and there is no loss from condensation in steam pipes, etc., as in a steam winch.

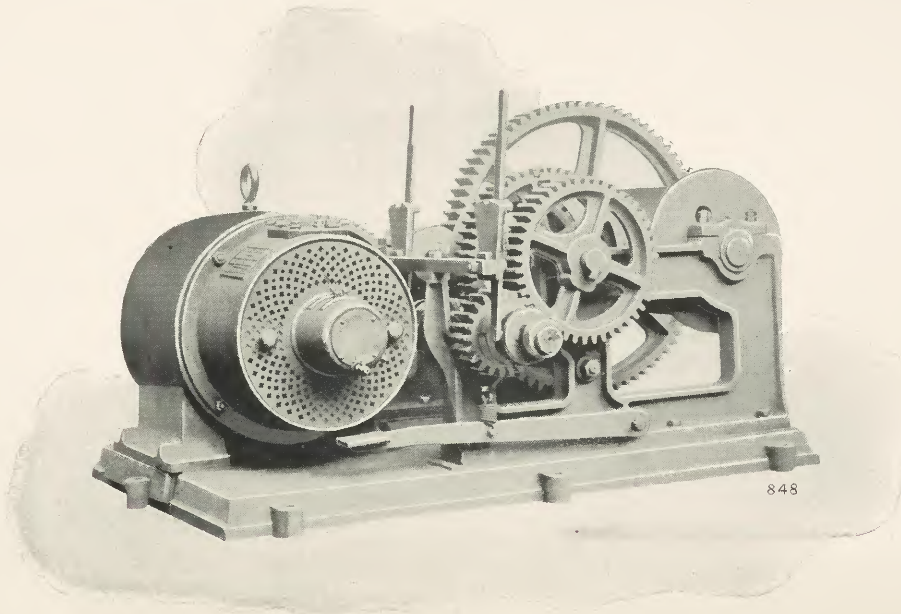

Fig. 19.

Mr John Ritchie, C.E.

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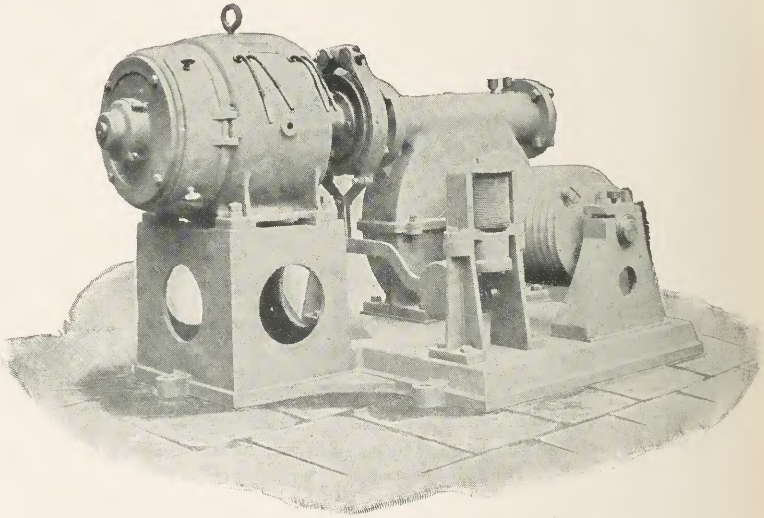


Fig. 20.—Worm Geared Electric Hoist.

The motor is series wound and reversible, but the load can be lowered on the brake, if necessary.

Fig. 20 shows another type of electric winch, in which the motion is transmitted to the hoisting barrel by a worm and wheel.

The motor is carried on one end of the bedplate, and is coupled to a hardened steel worm, gearing into a phosphor bronze wheel which revolves in an oil bath, thus ensuring perfect lubrication.

An electric brake is applied to the motor shaft.

This design of winch is that usually employed for hoists or lifts, when, in addition to the ordinary starting switch and resistance, there is fitted an automatic reversing gear, connected by stops operated by the cage or the lift. The resistance is also fitted with an automatic cut out, which allows of the motor starting at a comparatively slow speed, and gradually increasing its motion as the cage gets underway, thus preventing any sudden rush of current through the armature.

Two years ago, a hoist working on this principle was fitted up in a bonded warehouse in Leith. It replaced a hoist driven by a gas engine, and a comparison of the cost of working an electric hoist with one worked by a gas engine is interesting.

	PER ANNUM
The cost when using the gas engine was	£18 0 0
The cost of current for the electric hoist is under	4 0 0

This, of course, is largely due to the fact that the gas engine being difficult to start was allowed to run on for hours practically doing nothing, whereas the motor only takes current when there is work to be done.

Electric Cable Conveyors.—In the year 1884, the late Professor Fleeming Jenkin read a Paper before this Society on a new method of conveying goods by electricity, and to which he gave the name of "Telferage."

This was the principle of electric traction on a single rail or rope, the motor forming part of the train or carriage carrying the load.

For a good many years not much headway was made, but during the past five years or so, the system has come rapidly to the front, many of the difficulties having been overcome by persevering effort, and one of the latest developments is a new form of a cableway conveyor.

One of the leading features of this invention is the method of stretching the rope on which the conveyor travels. Quite a number of these machines are in use for harbour work in the south of England and other places.

One of the principal drawbacks to the majority of the various systems of cable conveyors hitherto brought out, is the absence of provision for ensuring a perfectly taut cable throughout its entire length.

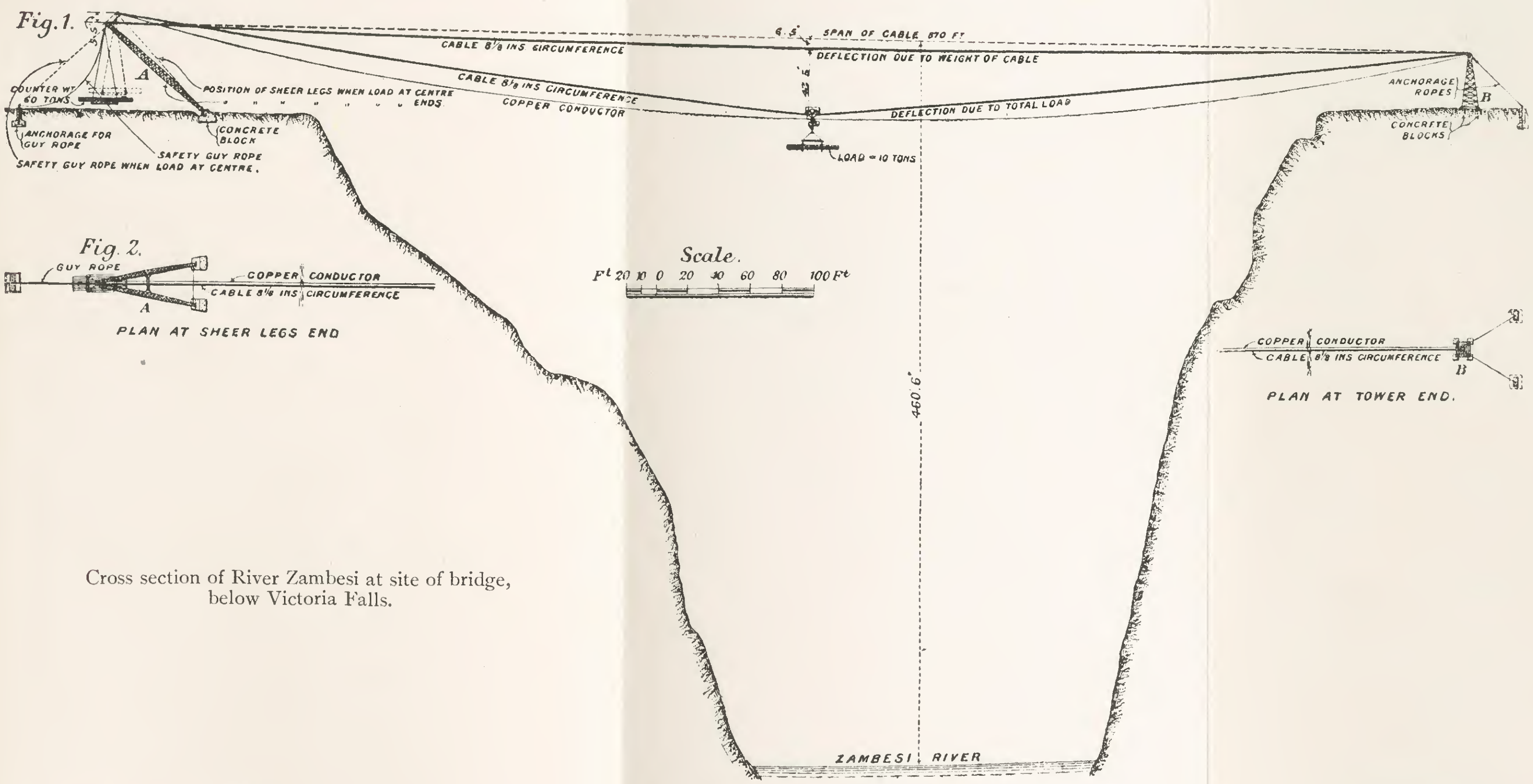
The elimination of this weak point is one of the features of a new system which has been introduced by Mr Poole of Westminster, in conjunction with Messrs Ernest Scott & Mountain of Newcastle.

It consists in anchoring the cable at one end, passing it over a tower, and at the other end it is fixed to a set of oscillating shear legs, to which are attached counter-weights. By the action of these shears the deflection is increased with the load, but as the load decreases the strain on the cable is maintained, owing to the shears settling back and thereby taking up the sag. The shears are set at an angle of 45 degrees.

When the Cape to Cairo Railway was decided on, it was necessary to cross the River Zambesi, and for reasons which it is not necessary to mention here, it was decided by the engineers that the river should be crossed at the great gorge a short distance below the falls. The river here is 650 feet wide between the banks, which are 400 feet high above the water level.

Under these circumstances it was manifestly impossible to use scaffolding, and it was decided to construct an arched bridge built out from either side, and to use an electric cableway to transport the material.

Fig. 21 shows a section of the gorge with the conveyor in position.



Cross section of River Zambesi at site of bridge, below Victoria Falls.

Mr John Ritchie, C.E.

Fig. 21.

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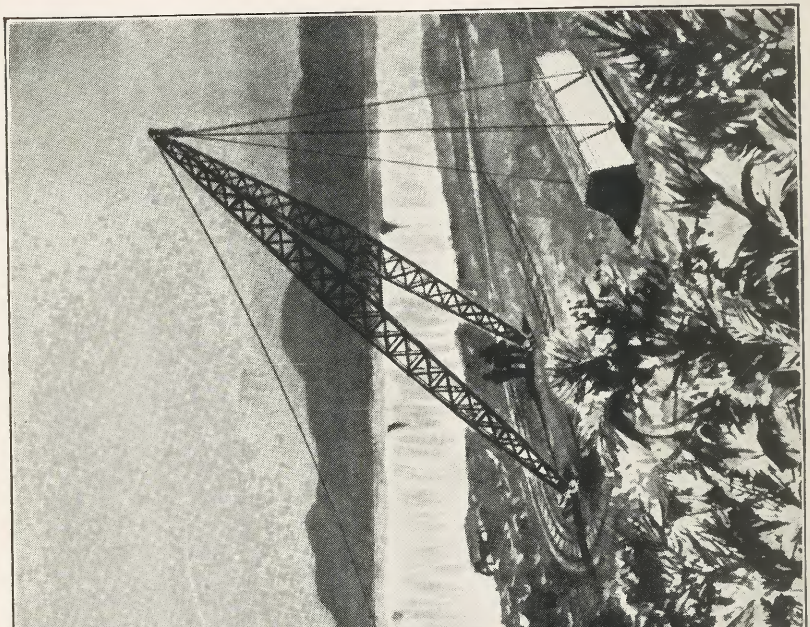

Fig. 22.

Mr John Ritchie, C.E.

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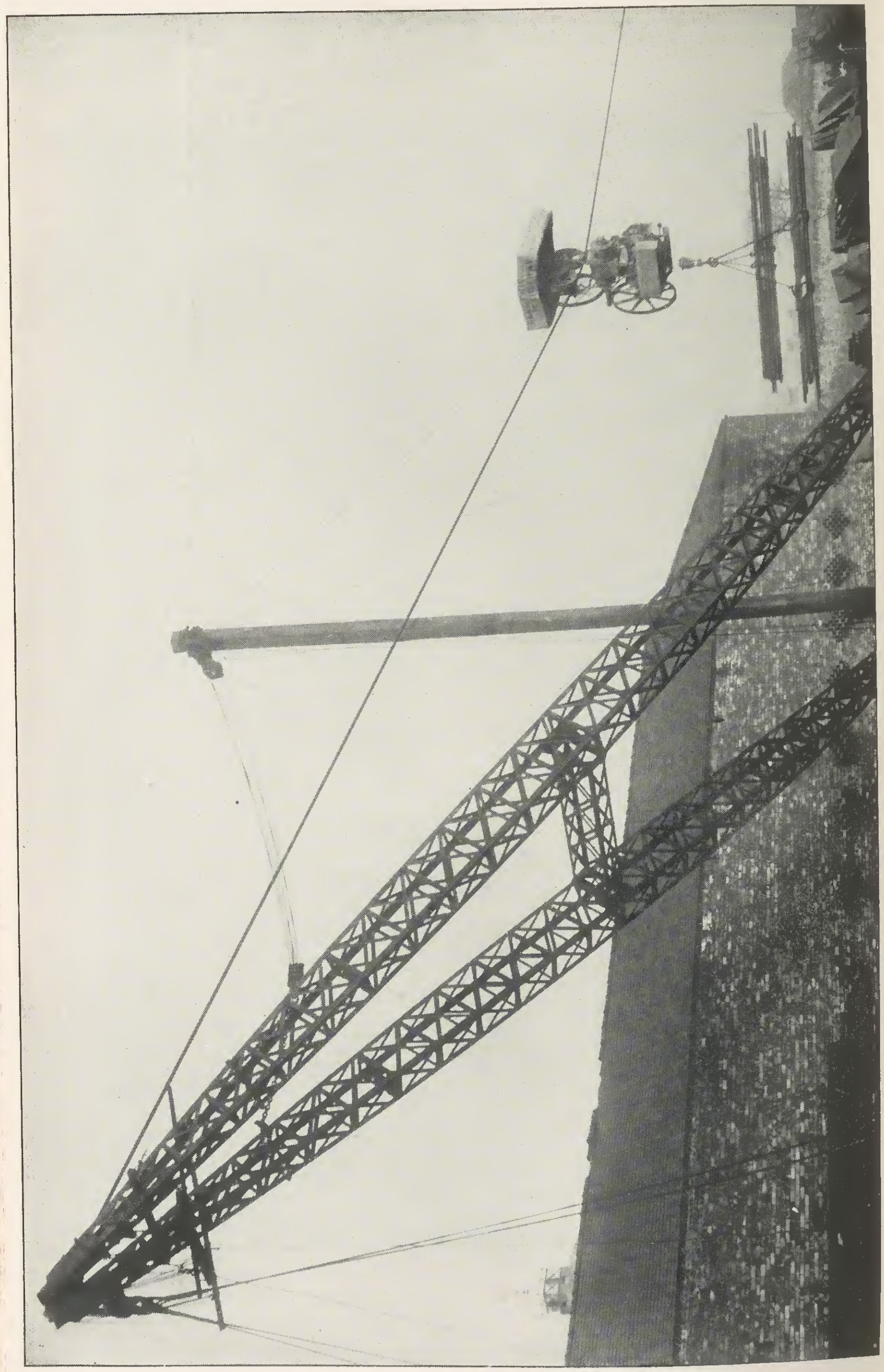


Fig. 23.

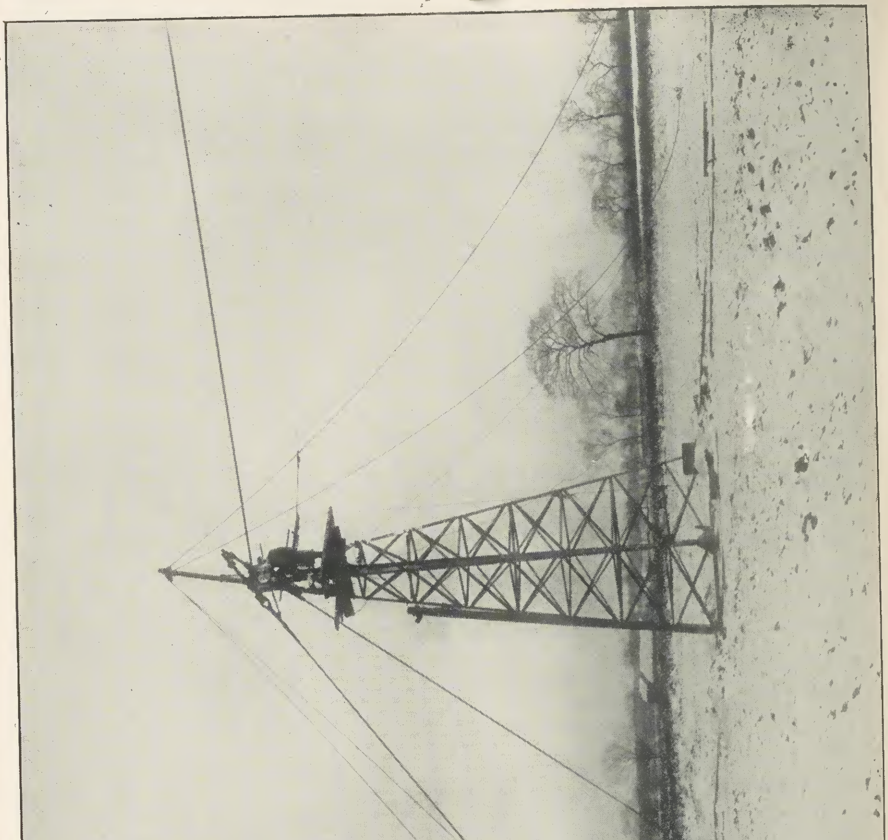


Fig. 24.

Mr John Ritchie, C.E.

[*To face page* 279.

Fig. 25.

The Cleveland Bridge & Engineering Company of Darlington obtained the order for the bridge.

Fig. 22 is a perspective view of the cableway and conveyor.

Up to this time the heaviest conveyor on this principle was constructed to carry 4 tons, but owing to the enormous quantity of material to be carried across the river, something like 40,000 tons, it was decided to make one for a load of 10 tons.

The author was entrusted with the modification of the design, to adapt it for a 10-ton conveyor, and the construction of the mechanical portion of the hoisting and travelling apparatus.

Fig. 23 shows the oscillating shears, with the conveyor loaded with 10 tons approaching the end of its journey, when being tested.

Fig. 24 shows the fixed tower at the opposite end of the cable.

The electrical conveyor is in some respects similar to the usual type, but the necessity for using runway ropes, fall rope carriers, etc., as a means of hauling the load from one end of the cable to the other, are done away with, and the special self-contained hoisting conveyor only requires a copper trolley wire to convey the current to it from the generating station on the bank.

Fig. 25 shows the travelling portion of the conveyor.

The whole hoisting and travelling apparatus is suspended on two travelling wheels running on the rope. On a frame which hangs down from the wheels are carried an electric motor, a seat for the driver, and two drums on which the hoisting ropes are wound.

As originally made, the power was transmitted from the motor by friction, the large driving pulleys being of wood, but it was considered advisable, owing to the climate to substitute steel gear.

The end of the motor shaft carries a forged steel pinion which can be made to engage either of the spur wheels on one side of the carriage; one of the spur wheels operates the travelling gear, and the other the hoisting gear, consisting of two double drums.

These drums can be worked independently, and all the different motions are actuated by levers under the control of the driver.

The current is supplied to the motor by a copper wire which runs parallel with the main cable. The contact is made by a collector pulley. The return current is taken by the main cable.

The motor is 30 H.P.—the normal speed being 500 revolutions per minute, but with light loads the motor, which is series wound, can be run up to 1000 revolutions per minute.

The speed of hoisting 10 tons is at the rate of 15 feet per minute, loads of 5 tons at 20 feet per minute, and 3 tons at 30 feet per minute. The rate of travelling with 10 tons is 300 feet per minute loaded, and with light loads up to 450 feet per minute, and when travelling down the rope to the centre without current, 600 feet per minute.

Automatic electric brakes are fitted both on the hoisting and travelling gear.

The cable is $2\frac{9}{16}$ inches diameter, and the sag in the centre of the span, which is 870 feet, is 43 feet 6 inches, with a 10-ton load.

Great care was taken in the design to reduce the weight to a minimum, and the travelling part of the conveyor weighs 5 tons only.

General Conclusions.—In comparing the relative cost of raising weights by hand, or animal power, steam, compressed air, or hydraulic pressure with electricity, we have carefully to consider the conditions under which the various hoisting operations are carried out.

If the work is of a temporary nature and very intermittent, and the load small, it is probably cheaper to apply manual labour, costly as it is.

We have seen that a steam crane, when there is sufficient work for it to do, is thirty times cheaper than hand labour.

When describing steam cranes, we have proved that the advantage is on the side of electric driving to the extent of 30 to 50 per cent.

Compressed air has been extensively used for hoisting purposes, principally in mines, but is also used for cranes, lifts, etc. Its efficiency, however, is not on an average more than 30 per cent. of the power expended in compressing the air. While it may be useful in some special situations, it cannot be compared with electric transmission.

In hydraulic transmission electricity has a more worthy competitor, but even this system is giving way. For instance, the number of hydraulic lifts now being erected is comparatively small in proportion to electrical ones.

In order to prove to their satisfaction the superiority of electric compared with hydraulic cranes, a most elaborate series of tests was made last year by the North Eastern Railway Company at their Middleboro' Docks. A set of newly-installed electric cranes were pitted against a set of hydraulic ones, doing exactly the same work, the same number of lifts per hour, with the same weights. The steam, water, and coal consumption was noted in each case, and the result proved a saving of 25 per cent. in favour of the electric cranes. The load factor on the electric cranes was only 7.3 per cent., as against 14.4 per cent. on the hydraulic cranes, and had these been equal, the saving would have been nearly 60 per cent. This did not take into account the relative cost for repairs, which are greater in the case of the hydraulic cranes. In ordinary work the electric cranes do 50 per cent. more work than the hydraulic cranes. The electric cranes can be moved 30 feet along the rails, and refixed ready for starting work in the new position in three minutes. It took 6 men 15 minutes to move and fix the hydraulic cranes.

Those desirous of examining these results in detail, will find them in "Engineering" of 24th June 1904.

The best proof, however, is the large number of cranes that are being converted to electric driving, or replaced entirely by electric cranes.

On Roads. By The Right Hon. SIR J. H. A. MACDONALD, K.C.B., LL.D., F.R.SS. (L. & E.), M.I.E.E., Lord Justice-Clerk of Scotland.*

It is by no means a creditable feature of the history of our race that we should have been so long blind to the value of good roads as a source of civilisation and material prosperity, apart altogether from the also important question of comfort and amenity. In very early times Man realised the great gain to be obtained by the use of water as a way for commerce, and an aid to the combat for supremacy. As regards our own country, we know of the far-off Phœnician having found his way to our coasts to make merchandise of the mineral wealth of Cornwall, long before conquering Rome had touched our shores. How early did the Greeks and Romans use the water as a means of developing their power both in peace and in war, while the hardy men of the North Sea made their way over the waves to great conquests, which have left their mark on many parts of this land, and of the north of France. The great *trirèmes* fought at Salamis, and the merchant faced the perils of the sea for gain long before system was thought of for land transport. Does not Horace tell us how the seaman, who had suffered from the perils of the deep, rebuilt and repaired his shattered barques that he might find prosperity.

> "Mox reficit rates quassas,
> indocilis pauperiem pati."

> "Soon doth he build again his shattered fleet,
> Untaught in patience poverty to meet."

Thus early and vigorously did man make his way by water.

Yet transit by land was for ages left to work itself out

* Read before the Society on 30th January 1905.

by the seeking of a possible path, and its gradual hardening by the foot of man and beast, not a thought being given to the making and improving of a roadway, otherwise than by the accident of wear and smoothing out by traffic, just as in our own later experience, it was thought to be a sensible mode of mending a road for man and beast to cover it several inches deep with hard angular flints, and to force the traffic on to the sharp loose metal by setting up logs as obstructions wherever the road was still good for traffic. This barbarous mode was in full operation on the principal roads out of Edinburgh within the last thirty years.

Only now is the truth coming to be recognised that roads should be made good for the traffic, and not by it. So it was that, at the beginning of the last century, there was no such thing as a road in any true sense in Europe, except those that had been left by the Romans. As we know, that conquering race thought not of social or commercial ends in making roads; their sole ends and aims were military. Of this we see an excellent example in Scotland, for the Roman roads were made not to open up the country, but to shut off one part of it from another. They built walls against their enemies, and they made roads parallel with these walls, so that they could move troops, chariots, and munitions of war across country to any point at which they were required, and keep up communication along their line of camps, by which they held the frontier of what they had conquered. But there is no trace of their having done anything to establish useful roads by which the agriculture and the commerce of the country could be developed.

From that time down to the beginning of the nineteenth century there was no development of invention or skill in the laying out or the making of roads. Legislation was not directed to the formation of a permanent way. To quote an old Statute, the law commanded that "when any highway is worn deep and incommodious another shall be laid out alongside." What this led to is described in sufficiently pithy language in Young's

Six Months' Tour in the North of England, published in 1770, thus:

"I know not in the whole range of language words to describe this infernal road. Let me seriously caution all travellers who may accidentally propose to travel this terrible country to avoid it as they would the devil. They will here meet with ruts, which I measured, actually 4 feet deep, and floating with mud only from a wet summer. What, therefore, must it be after a winter? The only mending it receives is the tumbling in of some loose stones, which serve no other purpose than jolting a carriage in the most intolerable manner. These are not merely opinions, but facts; for I actually passed three carts broken down in these 18 miles of execrable memory."

Such was the state of things on the chief roads in the latter part of the eighteenth century. And, again, as in the past, the first great step of progress was brought about by military considerations. Napoleon the great, with that combination of indomitable will, and farseeing imagination, which might, if well directed, have been so valuable to the best interests of man, but from his military instincts and insatiable ambition were so sadly perverted to the sinister ends of lust of power and conquest;—I say—Napoleon early perceived the transcendent military advantages which must accrue to a country in war, if it could be intersected by great and well-formed roads. The benefits to France to this day are enormous from the skilfully engineered and well-laid highways which were constructed as part of Bonaparte's great military schemes. It has often been a cause of wonder how the poor peasants of France have a prosperity that seems to defy national disaster and impoverishment. Perhaps if it were investigated closely, it might be found that easy and cheap transit by good roads has more bearing upon rural prosperity than is generally supposed, and that France is a standing testimony to the truth of this idea. The reaching of a market quickly and cheaply is a very large factor in the cost of production, for it must always be remembered that in production is included the presence of what is produced at the place where there is a buyer, whether at home or abroad, and that the temptation of cheapness to the purchaser of a commodity can only be obtained by the article to be sold not being overweighted by heavy charges for conveyance, and thrown late or intermittently on the market by slow and uncertain transit on the road. We have seen lately how a thick fog obstructing locomotion in a city like London and the surrounding country, can cause the loss of hundreds of thousands of pounds sterling to those having goods to sell of a particular class connected with Christmas festivities, the season for which is short and the demand temporary, and how the same cause may make vast commercial adventures to stand still, from passage by road or water, and even by railway being difficult or, temporarily it may be, impossible.

There is no doubt that the road of to-day is a way of luxury compared to what that of by-gone times was. In the middle of the eighteenth century we learn from records that even then the use of wheeled vehicles for long distances was very meagre; and in those days blind prejudice was as great a hindrance to the development of practical improvement in locomotion as it often is now. Coaching was looked upon askance by the community, who declared—I quote—"that it would injure trade, ruin the breed of horses, and make men careless of good horsemanship." A project to establish a coach service between Edinburgh and Glasgow was thought too hazardous, and was ruminated upon for seven years. Being at last established in 1749, the journey of 42 miles was accomplished in two days! What does that witness to, as regards the state of the roads? So strong, however, was the prejudice against road vehicles, that a Statute was passed in England at the beginning of the eighteenth century "to restrain the excessive use of coaches," and those who rode in them were ridiculed by the wits and hooted by the mob. The Londoners, we are told by Evelyn, dubbed the coach "a Hell Cart," and at the end of fifteen years we find D'Avenant, a French resident in the Metropolis, saying—"Master Londoner, be not so hot against coaches." A Mr Cresswell, so late as 1662, wrote a tract in which he stated that the adoption of stage coaches would "entirely ruin the country," for by this rapid mode of travelling "gentlemen would come to London on the slightest pretext, which, but for these abominable coaches, they would not do but upon urgent necessity." It adds to the comicality of this diatribe to know that the "rapid" coaches this gentleman was denouncing took about three days to drive from London to Dover.

Things remained stagnant for a long time. It was only in 1820 that the cabriolet—now shortened into "cab"—was introduced from France, just as now France was the country which introduced the power carriage to us. Of these cabriolets it was written at the time—"They rush about the streets as rapid as fireflies," and the writer adds words which might well be held prophetic of the day of the autocar. "They lame few, they kill fewer, they sometimes overrun us, but their serious damage is not much."

Thus in the past, the fast-moving horse vehicle had to fight its way for many long years before the ordinary citizen could be persuaded to see what a boon it was to the whole community, and to cease to regard it as an engine of evil, a "Hell Cart," an expression of blind prejudice which has its counterpart in our own day, when a gentleman at a meeting suggests that owners of power cars should be boycotted, "for helping to ruin the country by encouraging this hideous traffic"; and a reverend rector of a parish, Mr Withered, speaks of motor cars as "accursed machines,"—"engines of Satan."

As the improved vehicles of the latter half of the last century made their way, there was an awakening in the national mind which had long been smothered into somnolence, and the thought arose that it would be well to provide good roads so as to obtain the best benefit from good carriages. Accordingly, the genius of Macadam and Telford, and of their contemporaries abroad, led to a complete transformation of the road, by which its value for passengers and goods traffic was increased in manifold degree, and incalculable contribution made to the national prosperity.

Then came the day of the railroad, an invention which brought increased social and commercial advantages, but had one great effect for evil, for it checked and indeed practically killed the progress of good road-making. The contrast in speed between the railway line and the road was so great that the railway, even for short distances, drained the roads of their traffic, and thus for a time a stagnation in road management and improvement set in, and with the exception of the slow introduction of road rolling—a not unmixed benefit as I shall show presently—nothing was done for fifty years to make the roads better, and in many instances deterioration instead of improvement was too manifest. The evil of this was great everywhere, and specially in those districts which were far from the railway lines.

There are signs now that the public mind is awakening once more to the fact that there is a great future for road traffic, and that good roads are a most valuable national asset. The rapid development of power traction, consequent on the invention of the explosion motor, has made it plain that in the immediate future, the distances which can be traversed conveniently and economically by road will be trebled or even quadrupled, that cheap and rapid access to markets by the highway will be greatly increased, and that pleasure driving will open up roads, and put a smiling face on desolate countrysides and revive the prosperity of the roadside inns, which the abolition of coaching was believed to have permanently ruined. Of course I do not expect every hearer to accept this. We have still the doubter and the objector to change among us, and we know quite well that there are many who—like our reverend friend, from whom I quoted—think they would be doing patriotic service if they could scotch and destroy every power vehicle, just as the mob of old shouted "Hell Cart" after the coach of 1750. But I prophesy because I know. You might as well try to stop an Atlantic liner, by rowing a cockle shell skiff across its bows, as to stop the progress of power traction. It is only two years ago that a correspondent of the *Scotsman*, writing about automobile vehicles, said: 'Nothing but absolute prohibition will satisfy our reasonable demands." Well, there are, and will always be such people, and I suppose they serve some useful purpose in the world. But in this particular matter, their position of obstruction is hopeless, and they will have our pity as they "dree their weird."

The revival of the use of the road which is upon us in the form of already 80,000 power vehicles the establishment of long-distance motor road-omnibuses in many cases by the railway companies themselves, and the now certain fact that the great omnibus companies of London have definitely determined to abandon horse haulage: these events—all of which are only the harbingers of the coming great change—have once more aroused interest in the road, as a possession which may no longer be neglected, but must have earnest thought directed to its improvement in many respects n which it is as unworthy of its duty, as would be a piece of coarse sacking placed as a carpet on a floor of a palace for a queen to tread on.

Will you come with me on a little run, starting from the General Post Office, and let us see what we have to encounter. Going along Princes Street we shall be on a good, level, and pleasant road. But what of the surface? It is made of wood with the grain upwards, and, as a consequence, the top is in wet weather soaking in filth, and in dry weather is having filth crushed into it by the wheels, with the consequence that it is a continuous nest and rapid hatchery for evil germs, which the wind blows in our faces, forces down our throats and into our nostrils, and lodges in our clothing, to be carried into our dwellings. And long before it can with reasonable economy be replaced, it will from variation in the quality of the blocks, become pitted all over with holes like a pock-marked face, forming basins for filthy water to rest in, soaking into and destroying the wood, and thus becoming a fecund source of evil emanations. Let any one who is in London look at some of the pavement there in the neighbourhood of Trafalgar Square, and which has been down for some time and he will see what I mean. After a certain stage about an inch of what has been rotted away scales off the surface in patches, showing a black decayed face, which is foul in wet weather, and spreads dangerous dust when it is dry.

If leaving Princes Street we ascend the Mound, we come on to a street of stone, with the same double line of railway as in Princes Street with three rails for each line, set upon a steep hill, and running up by narrow Bank Street. If to avoid the rails we turn up Lawnmarket, and go down by the back of the Castle, we come upon a piece of macadamised road, a plaster cast of which would make a good representation of the surface of a stormy sea. Only, when one goes along it, the waves being solid, the motion is not that which can be described as "walking the water like a thing of life," it is more like having the life shaken out of you. Coming round into Lothian Road, we again debouch upon a street railroad, and moving up to the end of Princes Street we enter a railway junction, on which enormous caravans, each big enough to hold two full-sized elephants monopolise the greater part of the road, and stop so as to cause as much inconvenience as they can to the other traffic. When you have passed this mixed-traffic Mugby Junction, and move on towards Haymarket, the course is along the street railway, the road being laid with granite sets. The slow carts occupy the railway when they can, thus keeping in the very centre of the road, and giving way to no one, until they are whistled off by the tramcar driver, when they slowly move aside and shut up the road, so that what with the car stopping a few yards ahead, and the cart slowly moving up to it, we shall have to wait time after time, blocking the other traffic coming behind us. The difficulty and danger are added to by the fact that passengers leaving the tramcars, or entering them, must cross from or into the middle of the road. Further, the rails are depressed by the heavy traffic, and the sides of the sets next the rails worn down, so that it is often very difficult and severely trying to wheels and springs to wrench the vehicle out of the rut, and get off the rails if once the tyres have dropped into the inch deep groove. If anyone will take the trouble to look at the tram lines on a wet day he will see that the difference of level is often so great that the rails are completely hid under the water, and if there is a slight gradient the road is draining itself along the line of the rails. This is a most dangerous state of things. Once I was myself, when driving a horse vehicle, caught in one of these grooves. The wrench to get out threw me from the driving seat, and had it been to the off instead of to the near side, I should most certainly have been thrown off and in all probability killed, as my box was a high one.

Well, we pass on to Corstorphine, and are once more on macadamised road, but as Corstorphine is now a fashionable suburb, and as no lady who lives in a villa can be expected to put her dainty feet into the mud of a road, Corstorphine is furnished with crossings made of stone sets, forming a hog back. The consequence is that we shall have to do a little steeplechasing. It is difficult to know whether to take your leaps fast or slow. Either mode strains the springs and frame of the vehicle, and racks the back of the rider. The sets being laid in a curve to let the crossing drain itself, and the traffic rolling off the curve on to the road, crushing its way down in the fall, produces a hollow. In this, the water draining off lodges and destroys the road surface, so that it sinks into puddles more and more. The consequence is that you are favoured with four successive bumps from your front and back wheels, which cause an exclamation, the character of which depends upon your temperament, and the degree of success of your parents in giving you early training in self-control. It is no better when the roadman sees that the state of things is getting too bad, for he comes and piles a quantity of stones on each side of the crossing, and as he knows that these will gradually go down, he sets them up above the level of the crossing, and so makes you jump up and over, instead of down and out. If we go on by the road to Kirkliston we come upon another crossing, this time a railway crossing of a line which no longer exists. The rails have long been removed from the ground on either side of the road, but for some inscrutable reason the causeway and rails are left in a neglected state for the road driver to hop over. Turning to the right as we reach Kirkliston, so as to make for the Queensferry Road, we come, after a short run, to one of those wonders of road-making, which are all too common, where the road—a narrow one—is taken sharp round a corner at a right angle, there being one of the steepest gradients to be faced that is to be found in the whole county. It is difficult to decide whether this is more cruel to those ascending or descending. To go round the corner the speed must be lowered to a minimum in either case, with the result that no momentum can be obtained to aid the ascent, and the descent, with the sudden turn at the bottom, calls for sound nerve and very skilful use of brakes. To horses in two-wheeled carts the descent must be extremely dangerous.

Turning towards Edinburgh we get the first really pleasant prospect of a broad good road of easy gradient, which, with the exception of a few more crossings that require careful negotiation, enables us to reach the town once again in comfort, unless rain has caused thick mud, or drought has produced a loose road, and consequent dust. But even in dry weather we may find thick, heavy mud, on those parts of the road near Barnton, where trees shut out the road from the sun, so that the lodged water cannot be quickly evaporated.

Of course, if we find our macadamised road in good order, we know that it has been consolidated by the modern road-roller, the only real improvement in road construction, that the last half of the nineteenth century has given us. But there is road-rolling and road-rolling, and sometimes if it is unskilfully done it had better not have been done at all. I said before that rolling was not always an unmixed benefit. There is a place I know well, where, by bad rolling, an otherwise good road has been made most objectionable, and although the worst I have seen, there are many that are not much better. The purpose of rolling is to produce a flat surface, but this can only be done if the material is in a proper state. In these cases which I speak of, the roller when applied to the road, has pushed up the material in front of it; has then mounted the ridge so made, and crushed its way over, going on to raise another ridge. The result is the whole road has a ruffled surface, causing a series of jolts to vehicles. After rain, and when the road is drying up, there is a sort of mackerel-skin appearance, the ridges being dry and the hollows damp, indicating the lodging of water, and exposing the road to serious deterioration, both from weather and from traffic.

Lastly, we come to the streets laid with large stone sets, where, if there has been an hour's rain, the surface is as freely marked by puddles as a leopard is by spots. If the sets have been down for some time the upper side of each is, by the action of heavy iron shoes, rounded like the top of a Scotch 4 lb. loaf, and in dry weather, if there is any gradient, it becomes a polished, slippery surface, putting great strain upon, and causing much danger to horses, and, as a consequence, to persons.

It will, I think, be admitted by every candid mind, that no one of the different classes of road described can be held to be satisfactory, unless it must be accepted as the best obtainable. No one of them fulfils the requirements of a really good road. For a good road should be smooth, easily kept clean, free from railway lines, durable, having a surface contributing as little as possible to noisiness, free from dust and mud, and last, but not least, it should be of such a make that it can be repaired piecemeal, so as to be kept in good repair at all times, and not as at present, only to be repaired either by compelling the vehicles to go over a bed of sharp hard stones, or by blocking the traffic for weeks at a time, and that most often in those places where a block is most likely and most inconvenient.

The improvement of our ways must be considered in two aspects: (1) Can we find modes of surfacing our roads according to the requirements of the traffic, which, if adopted, would give satisfactory results? and (2) If we cannot now say that any such road has been invented, how can we best, in the meantime, improve what we have, so as to minimise the disadvantages of our present systems?

It is proposed to take up the second division first, for even if good means are to be found it would be many years before they could become universal.

I take up then, first, wood pavement, and in spite of its excellence in quietness, which is its only recommendation, I think it must be condemned as decidedly insanitary, and further, not capable of any repair otherwise than by breaking it all up, which means, of course, that it must get to its worst before it is dealt with. To use a material which must fray and take a brush face, which face is liable to rot when soaked with water, and to use it in circumstances in which it must always have spread over it a film of insanitary filth like the butter on bread, to be rolled in by the wheels of vehicles, cannot be a sound device for making the roads which pass through places densely crowded with human beings. If anyone will go on a day in dry weather and look carefully at the roadway in Princes Street, he will see that the filth of the traffic is caked down and holding to the perishing surface, so that no sweeping will remove it, and it is thrown up in insanitary dust as the traffic loosens it in dry weather. And, of course, when the surface becomes, as it does in two or three years, depressed every here and there into saucer-like dimples, and ultimately exhibiting large patches where the softened top, rotted by moisture, has scaled off, the evil must become much greater from water lodging in these hollows, and causing increased decomposition. Then in winter, the most foolish spreading of gravel is made, which, when ground down, tends further to disintegrate the wood, especially if, as I have seen done in London, gravel of a large size is used. Here are specimens which I took out of the gravel pile in the Euston Road, laid down for use in slippery weather. What must be the state of the wood when such stones have been forced into it, or slowly broken up and ground to powder on its surface?

If it be asked what at present I would substitute for wood, I unhesitatingly say, Val de Travers asphalte. With it you get an absolutely smooth surface, capable of being kept free from all insanitary filth, and possessing the great advantages that repairs can be made bit by bit, and got ready for traffic in a few hours, where any need for repair arises, and that it is impervious to moisture, that insidious enemy of roads. It is a significant fact which speaks volumes for its advantages, that in no place where it has been laid down in London, so far as I know, has any other paving superseded it, although much of it was laid many years before the introduction of the present wood pavement. With such a surface the unpleasantnesses of the street are reduced to a minimum, There is no brush-like end wood to harbour damp and foul matters, deteriorating the roadway and fostering disease germs, and it can be kept absolutely clean, with little labour. Noise is reduced to a minimum, the only sound being the patter of the metal-shod hoofs, the iron shoe being itself a testimony to the badness of roads, for if roads were perfectly smooth, and of easy gradient, some elastic medium could be used for shoeing, just as the hobnailed and iron-heeled boot of the clodhopper is not worn by those whose walk is on smooth pavements.

It is also a great point in favour of the asphalte road that, as already mentioned, it can be repaired quickly and bit by bit. The surface being impenetrable in any degree to water, repair is only required on the upper skin, and a piece of any size can be cut out and a new lair fitted in, restoring the surface without destroying the continuity of the whole, and without stopping the traffic or temporarily deranging it for more than a few hours.

I think I hear someone exclaim—But what about the expense? Well, I shall have a word to say about that presently, as it is a general question applicable to all classes of roads. All I say just now is that it shall not be forgotten.

As regards the laying of streets with stone sets, I suppose this will continue for some time yet in those streets where municipal wisdom ordains that "not the best" is all we are to have, although it cannot be called an ideal mode of making a roadway. But is it done as well and as practically as it might be? I think there is strong reason for holding that it is not.

Time does not permit that I should go into detail on this matter. But there is one particular in which it may be suggested that a great improvement might be accomplished. In studying the subject I have been much impressed by the fact that sufficient care is not given to making sure that when the stones have been laid in their places, and the street formed, two conditions shall be satisfied: (1) That the stones are resting on an absolutely dry bed; and (2) That they shall be so set and packed as that no moisture, however slight, shall penetrate to the foundation in wet weather. It is the want of attention to these two points that is the most prevailing cause of the breakdown of our paved streets—their ceasing to be flat, and falling into holes, in which water lodges and works its way down between the stones into the bed of the road. Too great stress cannot be laid upon this desideratum. The failure to attend to it militates against the attainment of what is the true aim of a wise road-maker, and which I express in the words of an American writer, Mr Austin T. Byrne, whose treatise upon *Highway Construction* should be studied by every road surveyor, and every member of a road construction authority. He lays it down that the object is:

"(1) To secure a water-tight covering that will preserve the natural soil from the effects of moisture, and not, as commonly supposed, to support the vehicles, the weight of which and that of the covering material must be actually borne by the natural soil; (2) To furnish a smooth surface on which the force of traction will be reduced to the least possible amount, and over which vehicles may pass with safety at all seasons of the year."

For these reasons, the road must be impervious to be fully efficient, and it is vain to attempt to make it impervious, if by putting on an impervious surface on the top we imprison moisture which has been allowed to accumulate below it to begin with. Therefore, the foundation which is made for the road must be allowed to dry thoroughly, and the sand cushion which is to lie between the foundation and the sets must be dry also. If the road is to be a good road these requirements are an absolute necessity, and the neglect of them is a fruitful source of deterioration, by which the upper surface is thrown off the level, and the injurious action of penetrating water made unavoidable. The ramming down of the sets may be cleverly done so as to produce the appearance of a flat road, but this will be a delusion and a snare if there is water lodged—in however small quantity—in the bed and its sand cushion. For the purpose of ramming is not to depress each stone until it is at the same level as those next to it, but to bring every stone to a final and unyielding bearing. If it is a mere surfacing, then as Mr Young says, it will result in an "uneven roadway when the pressure of traffic is brought upon it."

Now what do we see constantly in our own streets;—sand full of moisture laid below the stones and into the interstices. It is not uncommon to see paving being proceeded with after sand laid down for use has been exposed to a night's rain, and the bed on which it is laid has more or less water on it. Instead of this dry sand only should be used, and so important is this, that if necessary it should be dried artificially, and the bed protected from moisture until the pavement is put down on it. All moisture below is deadly in its mischief, and the effect in a severe frost is fatal to the soundness of the road. And for this reason, not only should the bed and the sand cushion be dry at first, but they must be protected from the access of moisture from above passing down between the stones. And this can never be done by merely packing sand between them. For sand put between the stones is subjected to no pressure, and is not rammed down when the sets are struck by the rammer. The space between the stones is not altered by ramming, and so the sand loosely put in when the stone is set remains loose. It would be easy to try the experiment after a piece of pavement had been laid with sand only shovelled in by the scoop end of the paviour's hammer; the test would be to put some puddling as an edge round say a hundred stones, and pour water on the sets. It would be seen how much would disappear between the stones, and every drop would be a power for the destruction of the road. What is wanted for filling up the interstices is some combination of material which will exclude the moisture and will not be liable to crack so as to make openings for water to find its way in. For this purpose some solid pressure-resisting matter should be inserted, which will form an impediment to lateral movement of one stone towards or from another, and which shall be of such size as will permit of some water-resisting joint-filling material being poured into its interstices, binding the whole together. This purpose is best fulfilled by the system of inserting, instead of sand, such as is used for the cushion below, clean gravel of as large a size as will pass between the blocks and binding it with hot bituminous cement, the gravel and the cement being put in alternately, until the whole space is filled up, and the gravel being heated so as not to chill the cement, which might prevent its penetrating well down to the cushion. By this means a close joint is made, and the hard gravel resists and prevents lateral motion of the blocks, which might cause displacement of the cement. I venture to suggest that every one of these points deserves careful attention, for it is true of street making as regards its sins of omission, that he that offends in the least, is guilty of all. If we must have hard granite blocks, let us have them flat, and not, in a series of 2-inch deep puddles, plunging into which our springs and our bodies are racked, and our tempers tried. Again I shall be asked—"What about the expense?" and again I say, this question shall not be forgotten.

Finally, we come to the ordinary road of the country, that which we identify with the name of the great Macadam. What he did was to effect a revolutionary change, by which the old mere track road was superseded by the road we now have, which is to the highway of the eighteenth century what a gentleman's avenue is to a farm road running down the side of a field, if, indeed, the comparison is not much too favourable. What a chariot of luxury must the fast mail coach, which was made possible by Macadam, have been by comparison to the conveyance which it superseded, in which a journey of not more than 20 or 25 miles a day was possible, and the bones of the traveller were very sore even at that, and which could not possibly be run during the hours of night without serious risk of broken limbs as well as worn-out bodies.

But the macadam road, great improvement as it was, has shown itself to be by no means a perfect device. In moderate weather, neither too wet nor too dry, it gave a really good road, of which no one could reasonably complain. But whenever the weather became decidedly dry or decidedly wet, deterioration set in, making the traveller a sufferer, and causing the haulage animals to suffer also, and, as a consequence, causing commercial loss by the slowness of transit, and further loss by deterioration of horseflesh and of vehicles. Again, in the case of dry weather, the road broke up and became covered with loose stones, while layers of inch-deep dust lay upon it, to be thrown up by the traffic, and blown about by the wind. The dust nuisance is no new thing on frequented roads. It was only by the cessation of active traffic on the roads that it was abated. We read in *The Rivals* that on arriving at Bath from London Bob Acres shouts: "Warm work on the road, Jack! Odds whips and wheels! I've travelled like a comet with a tail of dust all the way as long as the Mall." And who has not seen the sporting pictures of mail coaches with clouds flying from their wheels? So keenly was the dust annoyance felt that in those early days on some of the roads frequented by the rich, elaborate arrangements for cure were made at great expense, as for example on the London and Bath Road, where the wayside pumps can be seen to this hour, by which daily and along the whole road the dust was laid, that the rich travelling in their chariots, and the ordinary travellers by the mail, might not be choked and loaded with the very fine dust into which the road metal was ground by the constant traffic from and to London. In the case of wet weather, of course, nothing could be done, if the dust instead of being taken off the road in the time of drought, was allowed to accumulate more and more, than to try to scrape it off when formed into mud. This, of course, could only take off what was soft upon the surface, but could not prevent the water from working into the road, the upper layer of which had already been brought into a pasty state by the scarifing action of the horse's hoofs, followed by the crushing action of the wheels. And the very scraping itself tended to present a scarified and broken surface to the action of the weather. This caused, when rain continued to fall, a series of longitudinal gutters where the wheels had gone down to the firm, and squeezed up the mud at either side of the wheel and thus formed troughs in which the water could rest and carry on its work of disintegration.

The action of traffic upon a macadam road is not generally understood. It may be interesting to consider what are the things that happen when such a road is put to use. In this way we shall be able most fully to appreciate what is good road construction and what is the reverse of good, and to see how best to keep the road in good condition after it has been formed.

There can be no doubt that the first cause of the deterioration of the road is the action of the draught animal. Every horse that has a heavy load to draw, and all horses that have to climb a gradient with a load behind them, attack the road by toe action, and in the case of heavy cart horses, by the iron projections at the heels as well. The first effect is to make a slight indentation in the road, and pull some of the surface out of it. Then comes the action of the wheels which crush down the sides of the little pit, loosening more material. Where the alternate action of shoe and wheel has taken place a few times, a hole is formed corresponding in curve to the line of the wheel circumference, and this hole, of course, fills with water when there is rain, softening the ground still more, so that its lower surface becomes a mud pool, the detritus in which will be disintegrated still more freely into small particles and develop dust, when dry weather returns. And all this destructive action has followed as a certain sequence from the first little dint made by the toe of a horse's shoe. For it is of course the horse that breaks the road and not the vehicle. If any one doubts this let him examine a farm road on which the vehicles all go in one line, and what will he find? In dry weather there will be a strip sunk down of about a foot broad in the middle, in which there will be formed a soft velvety bed of mixed dust and droppings, probably 3 or 4 inches deep, while the wheels will have made two deep ruts (unless prevented by stones), and the bottom of these ruts will present a hard close almost polished surface. This indicates the general tendency of the horseshoe to break up and sub-divide, and of the wheel where it is continuously applied to a surface untouched by hoofs, to tighten it and bring it to a smooth surface.

The aim of the road-maker is to lay upon a sound resisting foundation a skin which shall have three qualities — (1) all smoothness consistent with foothold, (2) impenetrability to water, and (3) reasonable durability. It will be confessed, even by those who have charge of our roads that we have not yet reached finality in our struggle towards these ends. The stagnation of road traffic consequent upon the rapid development of the railroad, caused a stagnation of inventive thought in this direction, and for more than a generation the general state of our country highways was deplorable. The mending of roads and their care was often scamped, the appointment of a road surveyor was too often the finding of a berth for some worthy man who had failed at everything else, while the roadman was very generally a decent old man, past his time, from whom little work and no brains were to be expected. But a change is certainly coming, and the revival of the use of the road will stimulate road authorities to activity.

Having looked into the matter with some care, I believe that a means has been found whereby our roads can be greatly improved, to the suppression of both mud and dust, and the consequent improvement of their durability, efficiency and amenity. I do not refer to the many sprinkling devices, by which the effort is made to suppress dust, although doubtless there is much benefit to be derived from them. But after all they are ameliorating only and not remedial. They veneer the surface, but they do not reach to the body of the road itself. But I think the credit must be accorded to Mr Hooley, the Road Surveyor of Nottinghamshire, of having devoted many years to the search for an efficient road material, and the study of road laying, and of having succeeded in finding what if not a final solution of the difficulties, is a present solution of great value, and which though it may be improved upon by himself and others, will have a permanent influence for the future.

I think I cannot do better than read to you what he says on the matter in a recent paper.

"The method adopted at the present time is to prepare the outside of the road to receive the covering; sometimes even the road is scarified. The new material is then carefully applied on the surface, and if possible the whole is then rolled until it is smooth. When this point is reached the process of binding is carried out. This is generally done by the thorough watering of the surface of the road, and binding the same with sharp road scrapings or finer-sized stones, which form a sticky mass; this sticky mass is then swept into all the crevices and the whole rolled again until consolidated.

"By this it will be seen that dirt and water are, as a rule, chiefly relied upon for 'binding.' It is obvious, of course, that no such method can possibly be expected to stand the rapid changes of weather peculiar to this country. A road surface so made cannot throw off the water for long, consequently the latter soaks in, and the surface is softened. The moment this happens and heavy traffic in the shape of traction engines, heavy waggons, and carts come on it, the wheels break the face up, and the wet soaks in further and further, until, if the spell of wet weather be prolonged, traffic on the road becomes almost impossible. Of course, if frost should happen to follow on the spell of wet before anything can be done to remedy the condition of the surface the results are even more disastrous.

Tar Macadam.

"It is obvious from the foregoing that no durable results can be expected from such road forming. The remedy is to find something that will last as a bind, and while not making a greasy or slippery surface will resist the effects of wet, give a good foothold and an impervious surface. Many materials have been tried, but none of them answer so well as tar as a binding and waterproofing material.

"But the use of tar alone will not even meet the difficulty unless it is applied in such a manner as to become one with the road material it is to bind. Granite and syenite do not answer, because tar will not soak into them, the coating soon wears off, and the result is little better than with the old method. Again, the amount of tar used is a most important factor, for if too much is used the heat of summer will affect it, and when melted disintegration will rapidly follow.

"The first thing to be done is to find a material which is hard enough to stand the wear and tear of traffic, but not too hard to absorb tar. Furnace slag has already been suggested as a useful material for roadmaking, and it will also be found reliable in combination with tar if carefully picked by hand from ironworks making a good class of residual slag."

"In order to make a system of tarred macadam a success the material must be absolutely dry before it is tarred, as otherwise it already contains within itself the factors of disintegration, and disappointment must follow. Naturally the cost of drying the material is heavy, but further there is all the labour required for constantly turning the material over and over again to ensure every stone getting its proper amount of tar.

"To minimise the cost the materials should be mixed and made in large quantities at some central point. The whole expense of drying and mixing by hand can be saved if the material is tarred when warm just as quickly as it is broken. The whole process can be regulated and manufactured reliably by machinery instead of being left to the tender mercies of the average roadman.

"A further advantage will appear as the material is delivered on the roads ready for laying, thus saving the labour of local mixing, while it will also be found that the number of men usually employed in a gang for macadamising a road can lay about double the quantity of tarred material in the same time.

"There is no reason why this process should be expensive, as it has been proved after exhaustive experiments that tarred macadam made of furnace slag can be used and laid at about the same or a less cost as untarred granite macadam in similar quantities.

"It has been ascertained that if the material is only properly impregnated with tar the absorption of moisture is reduced to a minimum, and consequently the chief danger to road surfaces overcome. It will also be found that by the use of a system of tarred slag macadam roads will last much longer, while the saving in maintenance will be great, practically no sweeping or watering. is required, dust and mud being reduced to a minimum, loose stones do not occur, and a surface is produced which will not be affected by ordinary traction engines.

"Much has been written, and a great deal more has been said about the motor traffic now so universal. The motor has come to stay, and the sooner roads are made in such a manner that the dust nuisance is abolished, the motorist realises that he does not skid and can pull up within a very short distance, the better for everyone who has anything to do with roads, either from the point of view of the user, maker, or ratepayer."

Following this up let me tell you what a lady friend, who is a great road-user, both with horses and motor-cars, writes to me. She tells me that the results of laying tarmac are most remarkable, that she always runs at speed over it, that the absence of dust or mud according to the weather conditions is quite marked; and she further says that friends who ride in her car, and who know nothing about the road, invariably remark on its excellence, and the great difference between it and the road which is run over before and after reaching it.*

This mode of road laying has also the great advantage that patching, so as to join up and keep the road impervious to water, is quite easy, and therefore there is not so much need for frequent general road repairs as under the present system. It is just possible that it may be found to be the best mode of street-laying in all those many streets which do not carry very heavy traffic, and which, but for the nuisances of dust and mud, might to this day, as they formerly were, be laid like a macadamised road, instead of with stone sets.

There are two matters to which I should like to refer before saying a few final words on the question of cost. They relate to the repair of the ordinary road. A great deal depends upon the selection and proper breaking of the road metal, for if it is unsuitable in quality, and not broken down sufficiently, the economy obtained by this is a false economy. The proper size is now well known, but unless the stone-breakers are well looked after, duty

* Some months after I received this report from my lady friend, I had an opportunity of driving over this road, and it was still in the same excellent condition.

and practice will not always go hand in hand. It is certain that if stones larger than a size suitable to be held in place by the ordinary width of wheel are used, evil must result. There is, of course, not so much need for a small size at the side of the road as in the middle, where the bulk of the traffic will pass. But is it defensible to use such stones as I now show you, and which I picked up from a road not many miles from Edinburgh? It is impossible that such stones can ever bind well. They will, when pressed by a wheel at one end, tilt at the other and so the cohesion of the road is destroyed. And as the horse digs his angle-fronted hoof into the ground to get a purchase they are soon dislodged, causing the road to break up.

The other point is that it is much too common on country roads to make up the middle of the road with new metal, and to leave the sides as they are. This is fatal, as it gives the road too great a camber, and induces all drivers in order to avoid the side strain caused by the wheels being on different levels, to keep as much as they can to the exact centre of the road, forming on it the three tracks which we see on a farm road. In these tracks water lodges in large quantity, tending to destroy the road and causes it to break up, particularly when frost has opportunity to attack it. The true camber of the road is a most important matter, and if neglected the worst results must follow.

I now fulfil my repeated promise to say something about cost. This necessarily divides itself into two heads —construction and maintenance. But it would be most erroneous to suppose that they are not closely related matters, and that they can be considered separately. For the cost of maintenance depends greatly upon the efficient character of the original construction, and the permanence of the road after construction depends in great measure upon the efficiency of the maintenance. Accordingly what may appear to be a very high charge for construction may be truly more economical than an inferior road, the book cost of which is much less, and what may have an attractive present cheapness, may prove to be the most dear in the long run.

The great difficulty in the financing of roads consists in this, that the business of roadmaking and maintenance being conducted on a hand-to-mouth principle, by which road rates are constantly fluctuating, the simple-minded ratepayer is angry when the rate rises, and pleased when it falls, regardless altogether of the true point at issue—Are the roads such, that putting rates and the outlay he has to make on horseflesh, maintenance of vehicles, and the like together, he is not paying more than he should for a good and sufficient and sanitary roadway for his needs?

Tested in this way, the street or road which is properly made and maintained, although at what in the statement of figures seems to be a very large sum, may nevertheless be much less burdensome to the citizen than a street made on a cheese-paring policy. It is the old story of losing the ship for a "haporth o' tar." But, indeed, it is a very interesting and important question whether as regards the main roads of the country, their construction and maintenance should be left entirely to local authorities. Good main roads are a matter of national concern for universal accommodation, for commercial prosperity, and for national defence. The question is whether the expense should not be defrayed by the national Exchequer, that the service provided by the main roads may be equally good whether they pass through wealthy or poor districts, so that the quality of the great highways may be the same from end to end. The faulty character of the present system is obvious, when it is considered that it is in connecting the richer districts across the poorer that the greatest expense has to be incurred. For it is in the hilly and therefore thinly-populated and low-rented districts, that the cost of the engineering and construction of good roads is the greatest.

To ask of a locality such as Shap or Beattock Summit that it shall at its own cost make the through road communication as good as it should be to join up the populous districts would be asking what was unreasonable in the highest degree. And, therefore, some general system and general authority is the only true solution of the road problem. And I make bold to say that it would be a very wise policy for the Government of the country to establish a Commission to examine our roads, and determine what improvements are called for, and to find the money liberally for making our road system more efficient than it is, thus enabling great work to be done promptly, and spreading the expense over a period of years. It would add greatly to the commercial prosperity of the country if a sum of five or six millions sterling was given out in loan for systematic road improvement. And I say of all road improvement, both in engineering, and in laying of streets and roads with the best road bottom and road surface that the circumstances in each case may make advantageous, it would be found to be true that what seemed expensive was the cheapest in the end.

The national mind has slumbered on the road question for two generations, foolishly dreaming that the establishment of railways made roads of little importance. But there is now an awakening. The road is once more to resume its place as one of the great factors in the national welfare. Every month that passes will see the road traffic, both for commerce and for pleasure, steadily increasing, and that road improvement may develop in corresponding proportion should be the wish of every good citizen, both for his own comfort and for the national prosperity.

Allow me in conclusion to express my thanks to Mr Hooley for his kindness in aiding me with information and specimens, and to Mr Wilson, the assistant secretary, for preparing the diagrams which have been so useful to me in illustrating the paper.

On Machines for Grinding Telescope Specula, and a Simple Addition to an Ordinary Lathe for that Purpose. By W. Forgan.* (With Illustration.)

The simple addition to an ordinary lathe for the purpose of grinding telescope specula has been of so much benefit to the Author, that it was thought, if made known through the medium of the Society of Arts, it might become useful to others interested. Up to about fifty years ago the whole of the specula of reflecting telescopes were made of what was termed speculum metal, a composition of copper and tin in the proportion of their chemical equivalents. This metal when highly polished is stated to reflect only about 65 per cent. of the incident light. Just about fifty years ago Liebig made known his method of reducing nitrate of silver to the metallic form by means of grape sugar. The silver thus thrown down is pure, and when polished, authorities state it reflects over 90 per cent. of the incident light. A mirror having upon it a film of pure silver will be seen to possess a very great advantage over one of speculum metal. A mirror made of speculum metal may in the course of time lose its lustre and polish, and require to be again polished: this may result in the original figure being destroyed and lost. When made of glass and silvered on the face by Liebig's process, the silver may, and no doubt does, become oxidised in course of time; but the silver has only to be dissolved off, and the mirror resilvered as often as may be necessary, without affecting in any way its original figure. The construction of mirrors made of glass very soon became general after Liebig's process was known. The first to make them was Dr Steinheil of Munich, in the year 1857, and about the same time Foucalt of Paris and Dr Draper of New York also made

* Read and illustrated before the Society on 13th February 1905.

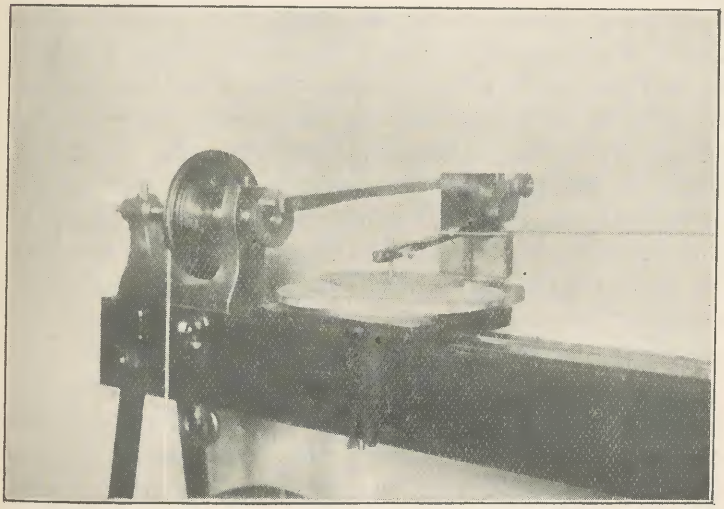
glass specula. The construction of glass specula has now become very general among amateur astronomers, and it is with the view of showing how very simple an addition to a lathe may be effective for that purpose that the present communication is made.

Before describing briefly the machines used in grinding mirrors, it may be well to indicate the first step of all. Take, for example, the tool necessary to construct a speculum whose diameter is 6½ inches, and focal length, say, 5 feet 6 inches. This is a size to which those beginning such work might do well to restrict themselves. The first thing is to make two grinding tools — a convex and a concave — each having a radius of curvature of 11 feet. A template must be struck by means of a long wooden rod, through the one end of which a nail or brad-awl is passed into the floor, and at the distance of 11 feet another nail or cutter of some sort makes a circular mark or cut upon a piece of zinc or brass 6½ inches broad, lying on the floor. When the metal is cleanly separated by clipping and filing at the mark, we have two templates—a convex and a concave. A piece of board is then placed on a lathe chuck and turned on its opposite faces to correspond to the above templates, and 6½ inches in diameter. Two castings are then obtained, either in iron, brass, or zinc, from this pattern, and worked upon each other, the convex surface of the one into the concave surface of the other, until either by turning, filing, or grinding they fit each other perfectly. The convex surface of the one is cut into squares with a file, the grooves so cut being about ½ inch apart — the depth of the grooves being immaterial. This is all the preparation necessary previous to beginning the operation of grinding. The most perfect system of grinding is that in which the whole operation is done by the hands alone. But hand-grinding is so laborious, slow, and fatiguing, that almost every one desires the assistance of a machine of some kind to lighten his labour. Now, it may be stated that no machine has ever been made, or can be made, to grind a perfect speculum by itself alone. Machines require constant alteration of the stroke during the process, and it is with the view of showing why this is necessary that reference to them requires to be made before describing the simple method devised by the Author. There are three essential things which require to be kept prominently in view to ensure success in grinding mirrors, either by hand or by a machine. The *first* is that in grinding, a true spherical surface must be got (Sir Howard Grubb states in one of his Articles that a true spherical surface is only got by chance); the *second* is the length of stroke used; while the *third* is the side-stroke. According to Sir John Herschel, the second and third seem to be essential. A beginner will have much difficulty with the first, less difficulty with the second, but the third is the most important of all. Reference is here only made to the case in which the tool is made to work over the speculum, either by strokes entirely straight, or partly straight and partly circular. While the speculum is slowly revolving on the machine, the grinder is caused to move across the speculum at a short distance from its centre; this movement constitutes the "side-stroke." If this were not done, and the centre of the grinder pass invariably across the centre of the speculum, a truly spherical curve could not be obtained, and the centre would be ground down much more than it ought to be.

Another point requires to be mentioned in reference to machine grinding. The motion of a machine is regular, and at certain times the strokes of the grinder recur oftener at certain places than at others, giving rise to nodes, and, of course, causing a circular groove or zone in the speculum at these points. There may be one or more of these zones. Thus, if the machine causes its strokes to meet with regularity at a definite point, there will be a depression at that zone all round the mirror, and instead of a circular curve there will be a wavy form; a speculum with such a surface will naturally be of no use. It is difficult to see these defects until the mirror is partly polished, when they are at once detected by reflected light. By a skilful and judicious use of the side-stroke, a mirror can be made without any zones. The first machine we know of for grinding specula is that used by Sir William Herschel in the year 1788, when he constructed his large 4-foot mirror of 40 feet focus. From 1774, when he began to make mirrors, up to 1778, he used hand-grinding only. A diagram or plan of the machine is given in Sir John's book, published in 1861, and we are led to believe from Professor Holden's life of Sir William, that that is a representation of the machine he used. It gave, apparently, a straight stroke with a side stroke, brought about by means of a rather complicated system of levers and toothed wheels. The next machine is that of Lord Rosse. In this machine a crank operated a straight rod, which passed through a fixed aperture; the end of the rod away from the crank had a side motion given to it by a wheel. The final motion thus obtained was of a pear-shaped form, but it had the drawback of making the grinder pass too much over the centre of the speculum—the side-stroke being of a very limited character. The next machine in point of date was that of Dr Draper of New York. He states in his Memoir, published in the "Smithsonian Contributions to Knowledge," vol. xiv., that he tried a machine similar to that of Lord Rosse, but could make nothing of it. He made altogether seven machines. The one he illustrates gives a perfectly straight stroke across the centre of the mirror. He had, however, a slot cut in the rod, which moved the grinder so that he could move the grinder a greater or less quantity away from the centre of the mirror. This was not a proper side-stroke. Dr Draper made three 15½-inch mirrors, and with one of them he was able to separate the two stars of Gamma 2 Andromeda, which were then somewhat wider apart than they are now. The next machine is that devised by the Rev. Mr Cooper Key, and which, it is understood, was identical in form with that used by the late Mr George H. With of Hereford, who was celebrated for the excellence of his mirrors. Mr Cooper Key's machine is described by him in vol. xxiii. of the Monthly Notices of the R.A.S. on 10th April 1863, p. 199. The body of the machine was essentially the same as that of Lord Rosse, but the movement of the grinder was different. The side motion or stroke was given by means of an oval wheel which had the effect of carrying the grinder more to the sides than the circular one of Lord Rosse. The side motion eccentric made $5\frac{1}{2}$ revolutions for each one of the speculum wheel. The best results were got by the stroke being equal to $\frac{1}{3}$ the diameter of the speculum, which is just what Sir John Herschel recommended.

The next machines to be noticed were both on the same principle, and were used by Sir Howard Grubb and Dr Cameron. In both of these machines there were two cranks geared together by toothed wheels and connected to the speculum by rods. The resulting motion was a rather peculiar one, but unless the positions of the cranks were constantly altered, a machine like this would give rise to zones. The next machine is that used by Mr Ritchey, the Assistant Professor of Practical Astronomy in the Yerkes Observatory at Chicago. His machine is profusely illustrated in a Memoir by him published in vol. xxxiv. of the "Smithsonian Contributions to Knowledge," copies of which reached Edinburgh on 25th January last. Mr Ritchey's machine is essentially the same in character as that of Mr Cooper Key's, with this very important difference that Mr Ritchey gets his side-stroke by means of a transverse screw motion by which he moves the grinding tool sideways off the centre of the speculum a certain distance at every 8 or 9 revolutions of the speculum. There are many other ingenious points in his Memoir which ought to be read by every one interested. No reference has been made to Mr Lassell's machine, constructed for him by Mr James Nasmyth. The stroke was a circular one, and Mr Lassell admitted that it gave zones. An attempt was made by Dr De la Rue to obviate this by causing a mechanical movement to shift the speculum. It will be seen from the above that in almost every case an attempt has been made to obtain what Sir John Herschel stated as seemed to be essential, viz., the side-stroke. Mr Ritchey in his Memoir seems to have overcome the difficulty about the zones in a surprising degree, but only by the constant shifting of the grinder to the side.

It occurred some months ago to the Author that this difficulty of the side-stroke could be got rid of in the case of small specula up to, say, $8\frac{1}{2}$ or 10 inches in diameter by using jointly the lathe and the hand motions, and he



believes that he has been successful. The photograph of the simple addition to a lathe is subjoined. It will be seen to consist of a board 1 inch thick, 8 inches broad, and 15 inches long, firmly bolted down to the lathe bed. A short upright piece is attached to the off-end by two strong iron hinges which allow it to swing forwards and backwards through the action of a wooden rod attached to a crank-pin fixed to a chuck on the lathe mandrel. The other side of this upright piece has a wooden rod which engages with a pin on the back of the grinding tool. A cord passes from the small groove on the lathe wheel, which is 1 foot in diameter, to a 5-inch wheel in the mandrel, and when the lathe is worked the grinding tool is made to move across the speculum by means of the two wooden arms. The crank is set so as to produce a motion of $\frac{1}{3}$ the diameter of the speculum, which rests upon a piece of thin wood somewhat larger than its diameter; and while the motion of the lathe continues, this piece of wood is turned round more or less by the left hand, either backwards or forwards, thus giving an irregular motion of the very best kind, superior in every way to a mechanical one. Now, if this were all, any number of zones would be the result, and this has been found to be so in actual practice. These are got rid of in a very simple way. A piece of string is hooked on to a nail in the middle of the wooden rod which drives the grinder, while the other end is attached to some fixed point. The string allows the centre of the grinder to pass over the centre of the speculum, but to get the side stroke the pointer finger of the right hand is pressed on the string more or less, and the grinder in this way can be moved, while the lathe is running, to the necessary extent off the centre of the speculum and thus obtain the necessary side-stroke in the very simplest possible way. The stroke is a straight one, but notwithstanding this, the motions given by the action of the two hands entirely eliminate the zones, and the result is a nearly spherical surface, if indeed it is not as true a one as can be desired. Two specula, each of $6\frac{1}{2}$ inches diameter, have been ground in this way, and the results given by them are exceedingly good. They are still unsilvered, and of course reflect somewhat under 5 per cent. of the incident light, but they undoubtedly show both by trial on stars, on the moon, and Jupiter, that the movement forms a means of obtaining a nearer approach to the spherical surface than can be obtained in any other way. It may be thought that too much has been said about obtaining a spherical curve, but it seems to be the foundation, and the correct one, for getting the necessary parabolic one. The difference between a spherical and a parabolic surface is so small that it is assumed by most that the conversion to the parabolic form is got in the polishing. Mr Ritchey gives in his Memoir the difference in regard to some mirrors, and these are in decimals of an inch:

(1) His own 2-foot, of 93 inches focus . .0004
(2) Lord Rosse's 6-foot, of 60 feet focus . .0001
(3) The Yerkes' 5-foot mirror of 25 feet focus 0006

It will be seen from these figures that in the first one the difference is only $\frac{4}{10000}$ of an inch, an amount which it seems could without difficulty be removed in the polishing after a true spherical surface has been obtained.

The lathe runs so easily with the grinder and acts so rapidly with the motion that when it is making 120 strokes a minute, a $6\frac{1}{2}$-inch polished speculum can be put on the machine, the top portions ground with flour of emery and made ready for polishing again in about an hour. The two $6\frac{1}{2}$-inch specula which are at present used were treated in that way.

On Stained Glass: its Origin, Development, and Methods of Production. By HERBERT W. BACON.*

Stained Glass is a subject upon which much may be said, but little that is new. Its history is lost in the midst of antiquity, of coloured glass there are in existence Egyptian beads and odd pieces more than three thousand years old; also glass bottles containing red wine are depicted on tombs of the fourth dynasty, which was about four thousand years ago. The Phœnicians certainly made glass beads, and used them as articles of commerce some centuries before the Christian Era.

The earliest date ascribed to any existing stained

* Read and illustrated before the Society on 13th February 1905.

glass is to the tenth and eleventh century windows at Augsberg, but even that is doubtful. There is, however, a rudely designed figure of Timothy in a church at Neuwiller in Alsace, date about 1050. Though primitive in type, the rich border and ornament show conclusively that the painter was a master of his craft. In the twelfth century the Abbot Suger erected some windows at St Denis, near Paris, which still exist.

It is certain, however, that coloured glass had been used for window purposes some time before, for Theophilus, a priest and monk of Italy, wrote a treatise in the eighth century detailing exactly the system and methods of glass painting—and in the year 709 St Wilfrid of York invited coloured window workers from France to come to England.

It is also quite certain that the great Church of St Sophia at Constantinople and the basilicas of St John Lateran and St Peter at Rome were adorned with coloured glass windows even in the sixth century. By coloured glass windows we do not mean painted or pictorial work, but a mosaic of small pieces of coloured glass.

Probably the mural mosaics of the Byzantine era suggested the use of transparent mosaic for windows—lead being substituted for cement.

However interesting it would be to trace this descent, we find it impossible for lack of material.

The oldest examples we have in England date from about the thirteenth century, but as in the development of stained glass we were always about a century behind our French neighbours, we may conclude that its use became somewhat general about the twelfth century. There is a good deal of it about that date remaining in various French churches. The first stained glass windows were (paradoxical as it seems) of white glass, that is to say, of various tints of white, glazed together into geometrical forms, technically called grisaille. Later, small pieces of coloured glass were introduced as centres of circles and other panels; still later, borders of colour were used to frame the lights—and gradually coloured glass ousted the white until it could no longer be called grisaille. All this time no paint had been used. The effects gained were solely by the tint or colour inherent in the glass itself.

At this point the interesting discovery was made that opaque glass, or the component parts of glass in a raw state, might be finely powdered, mixed with water or other media, painted with a brush on a sheet of glass, and fused by heat to its surface. Until now the art had been that of the glazier; here the painter appears on the scene, and, simply at first, and more elaborately later, natural forms begin to take their place in the window; now a scroll, here a flower, and finally the human figure—small, barbaric, hideous, if you will, but still the figure. The stained and painted window was born. The period of gestation had been long, many centuries long—but its later development and decay were rapid indeed. The painter took greater and greater prominence, the glazier less and less, through the Early, Decorated, and Late Gothic, through the Renaissance down to the seventeenth century, when the painter smothered the glazier, and the art was dead and buried. The efforts of some later painters, notably Sir Joshua Reynolds, only prove how very dead it was, how little they understood of its *raison d'être.*

In the earlier efforts the subjects depicted are always on a small scale, and are contained in panels of circular shape, and form but a subsidiary portion of the whole window. The colours are always primaries—red, blue, and yellow—this probably not from choice, but from lack of greater variety. The drawing was rude and uncouth in the extreme, but this was of no consequence in a time when the art of figure drawing was little understood—and to some degree this shapelessness may be attributed to the lack of proper cutting tools, for the use of the diamond was not discovered until centuries later — their only cutting instrument being a hot iron, with which primitive tool only approximate accuracy is obtainable.

Perspective, too, is entirely absent, not because the absence of it is a principle appropriate to glass, but because no designer down to the middle of the fourteenth century knew anything about it.

Gradually the figure panels grew larger and took a more important part in the decorative scheme until that artistic period associated with Giotto when we find him and his contemporaries designing windows in Florence. About this time the treatment became a vogue, and afterwards descended as a traditional canon of filling a window with a series of single figures of saints set in architectural niches. In Italy these were, and still are, painted on coloured glass—they look very odd to British eyes.

From this time onwards the names of great artists were continually associated with painted glass—Ghiherti, Filipo Lippi, Albert Durer and Michael Angelo, are all said to have designed for glass.

With these great men as the artists and advisers, a very distinct advance was made in the technique of the craft—the glass became finer, the colours more varied, the use of silver nitrate for staining was discovered—but with these improvements began the decay. The great artists, forgetting the necessity for mosaic, or desiring effects not legitimately to be obtained, began to use enamels—that is to say, they painted in colour on white glass—pictorial effects were aimed at, and at last the whole window space was covered in this way; a notable example being the window at New College, Oxford, designed by Sir Joshua Reynolds and executed by Jervais in the early years of the eighteenth century. Nothing of importance seems to have been done until the Oxford or tractarian movement in the Church of England created the desire to imitate the bygone arts; and with this movement came the man—the elder Pugin—to interpret it. Thanks to him, the dry bones were stirred, and though some of us are now inclined to smile at the early and archaic efforts of this master, yet we are compelled to admit that he, first among moderns, understood something of the principles underlying stained glass. The Author believes that he is right in saying that almost all existing stained glass artists of repute trace their artistic genealogy to one or other of Pugin's *protéges*—Mr Wailes of Newcastle, or Mr Hardman of Birmingham. All round progress has taken place since then, we have survived the dogmatism of a Pugin and the obstinacy of a Butterfield, until, perhaps, we are in danger of falling under a still worse *regimé*—that of the crank. Having thus lightly touched on the history and development of our subject, we will consider what a stained glass window should be, the methods of its making, also a few remarks on present day artists and clients.

The Author's definition of a stained glass window is as follows: A mosaic of pieces of vari-coloured glass, so designed as to fittingly decorate and emphasise its architectural framework—and at the same time to fulfil its other purpose—*i.e.*, the illumination of the building in which it is inserted. A mosaic of vari-coloured glass, puts out of court all systems whereby colour is gained by means of enamel, paint, etc. It must be fittingly decorative—that is, the subject must bear some relation to the purpose of the building, not at all like a certain window which exists in Newcastle Cathedral. It depicts the exterior of a chemist's shop, with coloured bottles, and a brass nameplate, the chemist stands at the door vested in shirt-sleeves and apron, and is in the act of giving away boxes of pills. This window, by some stretch of the imagination, is supposed to symbolise Charity—but to the Author it seems to speak of the sweet uses of advertisement.

To proceed, the window must decorate the building—that is, its scheme must be a design, and to some extent flat in treatment; no mere picture accidentally or fortuitously chosen will answer. It must emphasise its stone framing—therefore each panel must be complete in itself—no picture running through a number of lights, ignoring all boundaries and mullions, is admissible; light glass must always be placed in juxtaposition to the stonework, and, above all, it must admit light enough to be a window. In addition, it should be readable, not a puzzle—not necessarily that the onlooker should be able to pluck the heart out of its mystery in a casual glance—quite the contrary; but that at least an interested observer should be able to gather the main lines of its story at once, still leaving the articulation of the details to closer search.

Consider, for instance, a light of the Pope Memorial window. It is a Gothic light, somewhat wide for its height, so the figure is set up rather high; the wings are wide to fill out the breadth—where the drawing touches the stone, there the glass is light. It is in no sense a picture, but a piece of figure decoration designed expressly to be executed in glass and lead only. It is fitting for a church dedicated to St Michael and All Angels, for the figure is St Michael; and there is plenty of white glass for illuminative purposes. Its main story is told at once—it is palpably St Michael, as it is a winged figure holding a cross-headed spear and a shield, and his name is embroidered in pearls on the curtain border, but there is plenty left for the close observer. The uplifted head and gaze and half-open mouth show St Michael's dependence on and inspiration by his Creator, the spear to symbolise attack on sin, the shield of faith, the defence against sin—the cross with which it is emblazoned, the sign and standard of confidence in our religion, emphasised by the labarum of Constantine—*in hoc signo vinces.* Even the decorative crown of pearls worn by the angel is emblematic of the heavenly reward of all who do their duty.

As an instance to the contrary may be cited the case of a well-known and very clever landscape-painter who undertook to fill a window with glass. The window was Gothic of sorts, and consisted of two lights and tracery. His design, which was illustrated and praised as a veritable masterpiece in a notable art journal, was simply a little stream and some flowers at the base, and a tree or two, running behind the mullions and into the tracery, utterly ignoring all stonework, and not even a suggestion by line or otherwise of sympathy with the stone framing. His scheme was faulty therefore, because the subject was unsuited to the purpose of the building: it failed to decorate the space at command, or to emphasise the stonework upon which the architect had spent time and skill.

Once more, and this time breaking the rule that stained glass must be a mosaic, the Author quotes from a client's letter: "Could you not send us a drawing of the Saviour, erect and carrying a lamb, robes falling in straight folds; behind, a perfectly *level* barren wilderness, and the horizon with glimmering light, quite low down. Grey, blue, and threatening clouds. There is a picture of Muller's with exactly our idea. The figure, without rich robing, is full of life and motion; the wind is rushing past and catching the garments, the sky is black, and massive clouds and everything speak of rescue from a terrible storm." This is but a mild sample of the difficulties of a glass picture. Ignoring for a moment the inconsistencies of this letter—once a figure with drapery in straight folds, and later with wind catching up garments—one an erect, statuesque figure, the other full of life and motion — these contradictions only demonstrate that the intending donor did not yet know what he wanted. But the point to be noticed is, how utterly he ignores the fundamental fact that a window is composed of glass and lead. The piece of glimmering sky must be surrounded by a lead—the grey, blue, black, and massive clouds must each and all be enclosed and separated from or joined to its fellows by strips of lead. In order to carry out this gentleman's wishes the mosaic system cannot be used. Atmospheric effect, except in the smallest spaces, is impossible—one piece of atmosphere cannot conceivably be joined to another piece of atmosphere of different tint by strips of lead—the thing is ridiculous. In this case, also, one notices how laymen in these matters assume as a matter of course that what is suitable in a *picture* on *canvas*, is and must be suitable as a *decoration* in *glass*.

In this startling error he is, curiously enough, supported by the great writer on glass, Winston, in his monumental work, who says in effect that nothing is admissible in glass but what is admissible on canvas. It, however, seems nearer the truth to say nothing is admissible in glass *which is* admissible on canvas. Another of the Author's rules is to the effect that the subject of decoration must be complete within the limits of its framework; by this is meant that no pictures should over-run the stop set by stone mullions or overflow into tracery. This is a rule, if rule it be, quite as generally broken as observed. It is well known that many, if not all, modern glass painters have no hesitation in carrying one design through five or more lights, and examples of old work of similar character are numerous.

The Author feels that proper recognition of the architectural stonework is a legitimate, even a necessary, limitation. This view may lack support, for possibly the most exquisite examples of glass painting in existence ignore the rule, notably at Gouda, in Holland, where Gothic windows of many mullions were deliberately built for the reception of Renaissance glass. It must be confessed that in these magnificent works the presence of stone mullions is not even noticed; but ought they not to be noticed? Possibly the truth is that in windows of the size of those at Gouda, the mullions are of no more consideration than stanchion bars—something on which to hang glass and prevent its collapse.

There is an example with which you are all familiar, Kaulbach's great window in the old Parliament House; the picture takes no notice whatever of the stone divisions, and the observer does not even see them, so overpowering is the glass painter. This seems unfair to the designer of the stonework, who intended it to be beautiful in itself, and to take its own part in the *tout ensemble* of this beautiful building. Despite the obviousness of this limitation, ancient and modern glass painters are divided in actual practice, but their opinions are and must be guided by other matters. The greater space at their disposal, if the subject may run through, gives them greater opportunity for effects of colour, drawing, and painting; and it is easier to accept a commission from a client in accordance with his wishes than to fight him and clients in general, and the clergy almost to a man are in favour of the large subject, but *they* are not at all concerned about the *art* of it, only about the story of it; its religious effect as a teaching power, as a sermon.

Only one "don't" now remains, and this is so obvious as to appear absurd to mention—that is to say, don't obstruct the light, either by colour or paint. Before all things, a window exists to give light; if it fail in this particular, it fails in all. But even here a warning is necessary, for one often sees windows the apparent object of which is to darken rather than light the building.

Mr Lewis F. Day, in the interesting and clever book he published a year or two ago, draws attention to and specially commends a window in the Duomo, at Florence. The window, he says, is *all* colour, the only scraps of white in it being a narrow band round the nimbi. This window deserves all the encomiums he bestows upon it; but here in Britain, where our light, to put it mildly, is not that of Italy, this system of colouring would be wrong.

In all the windows for which the Author is in any way responsible, it has been his endeavour to so arrange that about half the glass is white or light, this whether the scheme consists of light figures on colour or coloured figures on white. Such a proportion seems to hold the balance true between the two great purposes of stained glass—*i.e.*, to provide at the same time a light-admitting window and a decoration in colour. One has frequently seen a painted window used as a simile for many things—the mystery of life and death, for instance, life representing the outside, where very little can be distinguished, here and there a suggestion which looks like something within our knowledge, and the rest meaningless or positively ugly, while after death we see from the inside, and all becomes plain to us. Again, the great

German poet-philosopher, Goethe, likens a window to an organ, whose full, rich tones have such an effect of solemnity. Perhaps this thought might be extended a little. Surely all the windows in a church should be in one key, not a patchwork of all keys, as they now sometimes are. Still further, in looking at the work of some painter, one may feel a sort of likeness to a musician—here sweet as Mendelssohn—this one thin like some modern balladist—now, even and somewhat monotonous as our old Handel appeals to us; and so on. A comparison of what a window should be, to Wagner, seems quite fitting. At first glance mysterious, a little later the main theme becomes distinct, and as one grasps it the whole gets firmer, all sorts of minor themes and issues make themselves felt—and so to the glorious harmony of the whole—until the effect left on the mind is, that the master has expressed himself through all the chromatic scales and finished in a glorious concord.

We will now consider briefly the course of execution of a painted window from inception to completion. As soon as the exact shape and proposed subject are known, a water-colour sketch or design is prepared to scale, and here a preliminary difficulty often presents itself—the question of cost. It is really absurd to merely state a given size and then ask the cost, as some architects have been known to do. Stained glass may cost anything, for the cost depends on many and various considerations, chief among them being the standing of the artist to be employed. This question of cost settled, the design is made, then the working drawings in full size. In England, unhappily, though the resultant glass is now the best in the world, the actual glass painter is usually but a workman, a mechanical copyist; on the Continent painters are really qualified artists, and only need the roughest suggestions from the master mind. In our country, therefore, the drawings must be elaborate, and drawn with minute care; nothing can be left to the copyist's imagination, for the simple reason that generally he has none, though there are exceptions. The figure drawings are made in monochrome, charcoal, crayon, pencil, or bistre in wash, or in water-colour or pastel. Every man has his own predilection. The Author's is a lead-pencil and stump. Generally the lead-glazing lines are shown on the drawing; but for the convenience of the cutter a tracing of these lines is made on linen.

Possibly the most important and delicate function in the making of a window now follows. For upon it depends the success or non-success of the work, as, be the drawing excellent and the scheme admirable, without well-chosen colour, stained glass has no reason for its existence.

Each separate piece of glass must be sought, compared, and deliberately chosen for its situation, to be a complement or a contrast to its neighbours; being found, it is cut to fit the shape on the linen tracing. In the case of purely commercial stained window producers, the cutter, an ordinary British workman, is left very much to his own devices; but where artistic glass is aimed at the artist stands by the cutter, choosing each tint, each sheet, and even indicating the particular part of each sheet most suitable for his purpose. This done, a tracer takes the glass in hand, marking on the piece of glass the main lines of the artist's drawing. The colour used for this tracing and all subsequent painting on the glass is an opaque brown pigment, composed of the same earths as glass itself, with some iron or copper added to give opacity. The next process is to stick on to a sheet of plate glass with hot wax all the pieces placed in their proper order and position, and the whole is then covered with a fairly thick coat of the pigment, and, while still wet, stippled to let the light through. When dry, by means of an odd assortment of tools, needles, quills, bits of stick, and hard hogshair brushes, the lights and half-tones are picked out or brushed away; here and there a shadow needs strengthening with more pigment, and the work is ready for diapering and staining. The diapers or patterns on the drapery are done in two ways, sometimes painted on in thick opaque lines, and sometimes the existing paint is etched out with points to the required design. The staining consists in painting the back of such portions of the glass as seems desirable with nitrate of silver, which, when sufficiently heated, turns a pure, brilliant yellow, and can very easily be so manipulated as to give the very palest lemon shades or the deepest orange, almost red. The pieces of glass are now all dismounted and carefully laid flat on iron trays, no piece touching another, inserted into a kiln, heated to a white heat, and as gradually cooled. The pigment is now just as much a part and parcel of the glass on which it was painted as if it had been originally made in that condition. It is itself no longer paint, but glass, and can only be separated from the surface by the action of hydrofluoric acid. The glazier now sorts out this seemingly hopeless jumble of odds and ends by means of the cutter's tracing linen, and joins them all together by grooved leads and solder. Cement is now rubbed into the leads on both sides, pieces of stout copper wire are fastened to the lead, which will ultimately be twisted round iron bars in the stonework. The artist has now finished his labour, and richly deserves every penny of his reward—for labour it has been, all his wits and all his talents exerted to the full, anxiety long continued as to breakages and the final result—for only when all is done can he see how his conception has worked out, or if he has worked it out at all. A painter in canvas can see his work grow under his brush, but the painter on glass, like the etcher on copper, must wait till all is complete. And how many and great are his errors and miscalculations! In a northern cathedral city there is a church containing two windows by Burne Jones—exquisitely beautiful in drawing and colour, but conceived in too high a key; a beautiful reredos, highly decorated with paintings by a clever artist, and the woodwork of the stalls perhaps ranking amongst the most elaborate and delicate specimens of modern wood-carving, simply cannot be seen. The eye involuntarily looks at nothing but those two little windows;—all else is lost—and the other artists, who were represented by their best in this church before Burne Jones inserted these examples of his art, are swamped—indeed ruined. This pitching on the wrong key is a constant danger, but a skilled workman should be able to avoid it, if he has seen the building and studied its lighting.

It is a constant wonderment that while art in almost every form is becoming more refined and respected, the art of glass painting and staining should be so largely a matter of trade.

In order to keep going as a living Art, we must move and adapt ourselves to our own environment.

When the art was revived it fell into the hands of those whose sympathies were in the long dead past, and all their efforts were concentrated in producing imitations of fourteenth and fifteenth century work. In this success was soon attained—and for this class of work, Great Britain stands not only first, but easily first—other nations are in comparison but feeble folk. But we had forgotten that this is not the fourteenth or fifteenth century—other times, other manners. We had run riot in beautiful colours, improved glass, artistic form and drawing—until we were about to take that step again which led once before to ruin—over-elaboration. Burne Jones stopped that.

We are beginning to try what can be done with glass and lead alone, and even glass without lead. So long as our craftsmen thus experiment, and so long as the public and art lovers appreciate and support, for so long will this Ancient Art, which struggled for its birth through many centuries, which emblazoned our cathedrals in glorious colour, which died a noble death, and as wonderfully was born again—for so long will it lift our thoughts from the affairs of the moment and take us to realms of history, poetry, and romance, and teach us that man is not wholly sordid, but has a soul for beauty and colour.

In conclusion, the following quotation from a recent book on Mediæval Art by W. R. Lethaby will be interesting. He says, speaking of the beauties of a Gothic cathedral:

"By picturing the spaces by means of transparent jewels of glass, the interior was lighted by angels and saints innumerable—such a window becomes part of the glory of light—the pitch of colour stimulates the sensibilities like an exultant anthem.

"I am forced to say that the window of dyed glass is the most perfect art-form known."

On a Gas Meter and Governor in Combination. By Daniel Macfie.* (With an Illustration.)

In the early years of gas lighting, the commodity was paid for not by measurement but by time burning, and this system prevailed for some time after the invention of the Gas Meter. When meters came into general use it was not so obviously in the interest of Gas Companies to send out gas at the lowest possible initial pressure, as under the original time-burning system. But it was then as now in the interest of the gas consumer that the commodity should be delivered to him as nearly as possible at an unvarying pressure, and never at such a pressure as would be extravagantly wasteful with the type of gas-burning apparatus in general use. It should be remembered that gas was for at least a generation after its introduction used for lighting only, and further, that the original types of burners (more especially the argand burner, the best early type) gave the highest duty at a pressure not exceeding $\frac{5}{10}$ths of an inch. The iron burners then in general use were the single, double, and treble cockspur jets, followed by the batswing, and finally by the union jet (first made by Milne of Edinburgh), which burners developed their best results at the same low degree

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* Read and illustrated before the Society on 27th February 1905.

of pressure. The ideal condition of pressure in these days was therefore delivery to the consumer at something like $\frac{7}{10}$ths of an inch. That was, of course, impossible of accomplishment throughout the lighting district. One need hardly be reminded that water cannot rise above its own level, and that the greater the head of water the greater the pressure at the draw-off point. The pressure of gas, on the contrary, increases in ratio as it rises from its source by a fixed gradation of $\frac{1}{10}$th of an inch for each 10 feet in its ascent. Suppose, therefore, that gas was in 1830 sent out at New Street Gas Works at a pressure of $\frac{5}{10}$ths, it would under ordinary conditions be delivered at the Castle, 250 feet higher, at $\frac{30}{10}$ths, an exceedingly wasteful pressure for gas-lighting appliances in use at that period, and wasteful at any time. Of course then as now consumers would have it in their power to check the flow of gas by the meter stopcock, but that operation would not effectually prevent waste except with an unvarying pressure in the mains, which is, and has always been, impossible of attainment.

Variation in pressure is not wholly a question of levels, for it is necessary to alter the initial pressure at the Gasworks according to the varying draught which may be made at different hours and seasons as well as to compensate for the inequalities in the size of street mains. It will thus be seen that there could not be uniformity of pressure throughout a given district of supply even if the gas were to leave the Works at a uniform pressure. That would be possible only in a flat country, where the mains were so amply sufficient and the demand so uniformly steady as to permit of unvarying pressure; but these ideal conditions nowhere exist.

The net result of these conflicting elements (leaving out of account for the present such efforts as are now made to redress the inequality by the use of district governors), is that there cannot be uniformity of pressure in any considerable district. But the fallacy is so largely entertained on the part of the public that increase of pressure is in the interest of the consumer, that it becomes necessary to emphasise the fact that the problem is not how to increase the pressure at the point of delivery, but rather how to regulate or control it so that at the point of issue gas will be delivered in *sufficient volume* and at such *unvarying pressure* as is best suited for the local requirements. One of the earliest attempts to realise this was made by James Milne of Edinburgh, whose hydrostatic gas regulator was introduced some seventy years ago. A letter referring to the conditions then prevailing states that "in Glasgow the regulator is not of such advantage as in Edinburgh, on account of the small pressure there." It is claimed that "if the pressure at Grangemouth is an inch or thereby, it will be an advantage. We fitted up a regulator some time since in the Exchange in Glasgow, which we think is the only one there. We have fitted up a great many here and in other towns where the average saving is about 20 per cent." A specimen of the regulator here referred to is exhibited, from which it is evident that gas was not expected to reach the meter at a pressure much exceeding $\frac{15}{20}$ths, and that the saving was effected by adjusting the pressure at the meter to something like $\frac{6}{10}$ths.

Such indications of the then prevailing conditions of gas pressure and consumption imply that even in those early days of gas lighting the necessity for the regulation of pressure was recognised and provided for. As time passed, the range of pressure had doubtless to be increased, because of the growing demand on the mains; and when the employment of gas for heating and cooking by the bunsen flame came into vogue, an increase of pressure was absolutely necessary, and the old non-stuffed iron burner as well as the delicate argand burner for lighting gave place to a variety of contrivances to check the wasteful flow of gas at the burner, because of the inevitable increase in pressure.

The ultimate universal adoption of gas meters and the greatly lowered price of gas per 1000 cubic feet helped, no doubt, to obscure the advantages of meter governors or regulators, and their use has never become general.

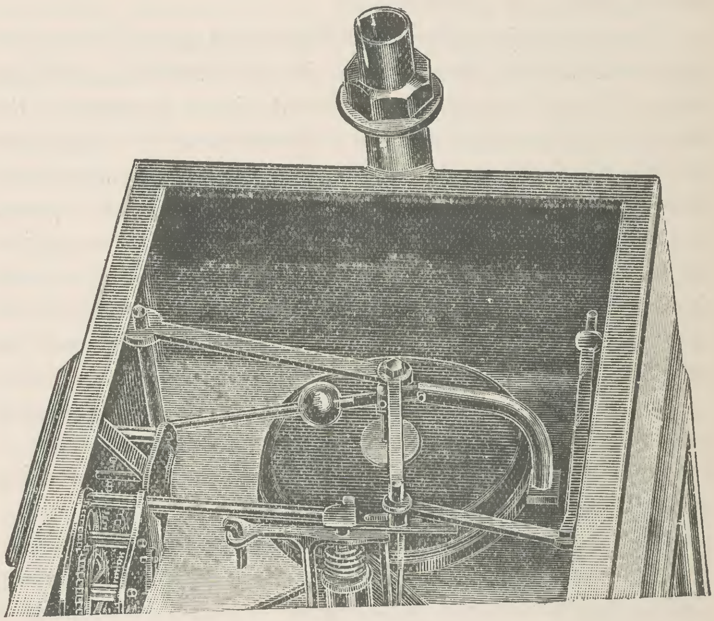
Several causes may be assigned for this state of things, as, for example, the general ignorance on the part of gas consumers as to the questions of volume and pressure, and the widespread belief that all gas economisers should be placed in the same category as that impious fraud the expert, but now almost extinct, burner hawker, who by his wily patter could bedazzle the vision of the most wary consumer. The chief barrier to the general adoption of gas governors has been their first cost and the labour of fixing them in position.

There is this further difficulty, that meter governors have not seldom been fitted in unfavourable positions, where the gas supply was deficient either because of the meter being too small to give a free delivery of the volume of gas required at the adjusted pressure, or because of the gas piping being insufficient for the same reason. It must not be supposed that nothing is done by suppliers of gas to meet so far as possible the needs of the consumers in the matter of volume and pressure. Gas engineers are fully alive to the requirements in both respects, but the problem is by no means an easy one. The modern methods of using gas for cooking, heating, and power purposes, and the popularising of incandescent burners for lighting, bring in their train increased and increasing pressure at distributing centres.

The problem of regulating the pressure in the mains—difficult everywhere—is specially so in Edinburgh, owing to its greatly varying levels, and nowhere have district governors been more widely distributed nor to better purpose. But no system of district governors, useful and necessary as these are, can be entirely or equally effective at each consumer's meter, owing to the inequality of service pipes in relation to the demand; that is to say, that to give sufficient supply to the weakest point involves delivery throughout some districts at a pressure much in excess of what is requisite or reasonable.

The enormous waste in the use of gas which goes on largely unheeded is a serious matter from the point of view of the proper utilisation of a valuable product, and it is generally recognised that sellers of gas should realise their responsibility in this direction, if only on the ground of popularising the use of gas, and enabling consumers to get value for their money.

Within recent years the necessity for some easy and universally applicable method of securing a sufficient but unvarying rate of pressure has become pressing, and the key to the situation may be found in the fixing of gas



governors on all gas meters, properly regulated to give adequate yet economical supply at the measuring point. But the fixing of such governors as have been hitherto procurable is at once a clumsy and expensive method and could not be faced by the suppliers of gas, nor, on the other hand, can consumers be expected to realise the advantages of such expenditure on their own behalf.

The combined meter and governor, which is here exhibited, has been devised with the view of providing a simple, compact, and economical governor forming an integral part of the meter, so that gas may at all times be delivered to the consumer at such uniform and unvarying pressure as his needs demand. This governor meter has met with not a little approval on the part of gas engineers, and is already in successful operation in various parts of the country.

The meter shown is an ordinary 3-light dry gas meter, and there is no alteration whatever in its measuring mechanism. The novel feature is that of a self-contained governor which forms an integral part of the meter. The governor is of the usual diaphragm type, with a cone valve so adjusted as to rise or fall according to the changes of pressure in the mains, when the governor is set to deliver the gas at a given pressure. Any increase of the initial pressure raises and partially closes the governor valve, which in fact adjusts itself automatically and delivers the gas on demand with no variation in the pressure as adjusted, whether the draw-off be great or small, its special claim to novelty (apart from the combination) being the means devised for the regulation of the pressure. This is accomplished by the adjustment of a ball-weighted lever, the weight being actuated by a tubular key which screws the weight inwards or outwards on the lever and gives a range of 1 inch for adjustment of pressure.

The regulation of pressure by the use of the key is intended to be performed by an inspector with official knowledge of the necessities of each meter supply; but this may be done by the intelligent consumer. For present-day requirements, it is suggested that an outlet pressure of $\frac{10}{10}$ths is the minimum at which gas may be anywhere delivered to the consumer, and that under no ordinary circumstances is a greater pressure than $\frac{20}{10}$ths necessary, although a wasteful pressure of $\frac{40}{10}$ths to $\frac{50}{10}$ths is not unusual. The governor meter is arranged to reduce such excessive pressure and deliver gas at any pressure between $\frac{10}{10}$ths and $\frac{20}{10}$ths, the graduations on the key indicating the outlet pressure. In all cases where the pipes are large enough to convey sufficient volume to the various points of issue, a pressure of $\frac{15}{10}$ths may be considered sufficient for all purposes, while pressure in excess of $\frac{20}{10}$ths may (except for specially constructed fittings or apparatus) be deemed wasteful and extravagant, but, where required, the use of a heavier weight may be employed to deliver at any higher pressure.

The additional cost of meters fitted with this self-contained governor is only a few shillings on the ordinary sizes, and it may be suggested that a merely nominal charge such as this removes the only valid objection to the general adoption of meter governors on account of their first cost and the expense of fixing in position.

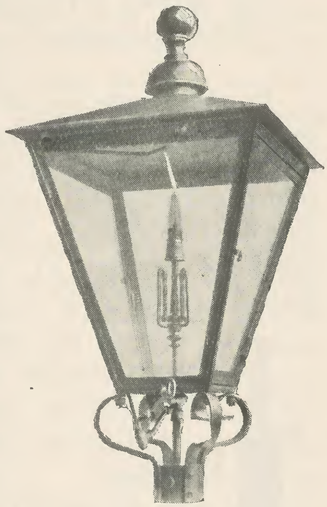
The arrangement whereby a governor can be fitted within the compass of an ordinary meter case makes it possible to have this type of governor applied to meters already in use. The ease and certainty of its regulation, and the use of a single unattachable weight, operated only by a special key graduated to show the outlet pressure at sight without the use of a pressure gauge may be noted as features of the combination.

On a Flashlight for Incandescent Street Lanterns. By HENRY O'CONNOR, Assoc.M.Inst.C.E., F.R.S.E.* (With Illustration.)

To prevent the damage to the mantle or chimney of the incandescent burner by the insertion of the ordinary lighting torch into the lantern, a movable flashlighter is provided which is hinged at one of the upright astragals and may rest against one side of the lantern, or made to pass over the top of the chimney and then to pass out through a tube in the side top horizontal astragal, where it can be lighted outside by the ordinary torch, then passed over the burner (thus igniting it), and afterwards

* Read and illustrated before the Society on 27th February 1905.

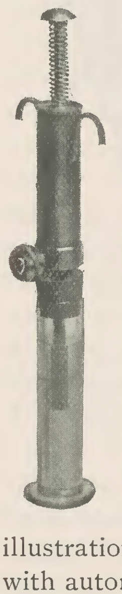
carried further over against the side of the lantern. The accompanying illustration shows the application of the "flashlight" to an ordinary street lantern. By fixing the vertical tube, forming the hinge, into the plug of a cock at the base of the lantern, it can be made to shut off the gas to the flashlight when it is against the side, but permits of a free passage of the gas in other positions. A lever is provided for turning this plug and flashlight tube, and a cam to gear with a similar cam on the plug of another cock placed alongside the other, and regulating the supply of gas to the incandescent burner. When the flashlight is turned on by the torch so that it can be ignited outside the lantern, the gas is



also turned on to the incandescent burner. On the flashlight being turned over the burner the gas issuing therefrom is ignited, and a continuation of the turning process carries the flashlight arm against the side of the lantern and extinguishes the flashlight. But this turning carries the cams out of engagement, and the gas to the incandescent burner is left turned on. When it is desired to turn out the incandescent burner the lever of the plug of its cock is given a quarter turn, and the cams are again brought into engagement ready for a repetition of the cycle of movements. The gas passes to both plugs through suitable passages, and the tube conveying the gas from the plug to the flashlight arm being carried up inside the upright astragal causes no extra shadow.

On an Improved Apparatus for Determining the Percentage of Carbonic Acid Gas in Producer or Flue Gases. By HENRY O'CONNOR, Assoc.M.Inst.C.E., F.R.S.E.* (With Illustration.)

In the regulation of the supply of atmospheric air to furnaces, much difficulty is found in ascertaining rapidly the composition of the various gases in the producer or primary combustion chamber, and also in the flue or chimney. Of these, perhaps the gas which is easiest detachable is the CO_2, and this may be absorbed by lime (CaO) forming $CaCO_3$. The proportion of CO_2 present will indicate whether sufficient air has been admitted both for primary and secondary combustion, and thus affords a method of ascertaining the satisfactory working of the furnace.



To quickly determine the proportion of CO_2 the Author proposes the use of a pump with a fixed travel and known capacity, which shall suck through one inlet and force out, on a reversal of the plunger, through an outlet an exact quantity of the gases, and these being made to pass through an absorbent of known strength, can be made to alter the nature of or combine with the absorbent and so indicate the quantity of CO_2 present.

The apparatus is shown in the accompanying illustration, and consists of an ordinary pump provided with automatic inlet and outlet valves at the bottom end; the inlet pipe is at one side and the downward projecting outlet pipe is perforated with several small holes at the bottom. The plunger is fitted with double cup leathers, one in each direction, and a spring is provided to ensure the return of the plunger to the same position

* Read and illustrated before the Society on 27th February 1905.

after each stroke, so that an impulse in one direction only is required. In this way the travel at each suction-stroke is the same, and thus the quantity of gas drawn in can be easily calculated. The outlet pipe is carried through a rubber cork with a second hole in it, and the cork and outlet pipe are inserted in a test tube or bottle. The latter may contain either lime water or a weak solution of a known alkaline strength coloured with an indicator such as phenol-phthalin.

The action is as follows:—The inlet pump is connected to a pipe leading to the furnace or flue, and the pump worked a number of times until all the air in the pipe and pump has been expelled and the whole filled with the gases to be tested. This should be done before the pump is put into the test tube. The liquid is filled up to a predetermined mark on the test tube (fixed according to the capacity of the pump and the strength of the absorbent liquid), the pump inserted and worked, when the gases will be expelled below the surface of the liquid and the bubbles have to pass up through it until the lime in solution has been converted into $CaCO_3$. The operation is continued until the water becomes so milky and obscure that the outlet tube cannot be distinguished through the liquid. With the pump as shown, the number of pumpings divided into 200 indicates the percentage of CO_2. With the weak alkaline solution, the point of neutrality is noted by the change of colour of the indicator and the number of pumpings also divided into 200 indicates the percentage of CO_2.

On the Effect of Electric Bell Wires in Extending Fire Risks, with a Description of an Apparatus for Reducing Same. By BASIL A. PILKINGTON.*

The introduction of new apparatus and methods of using electricity for any purpose almost invariably brings with it some detractions.

For the most part, the tendency is towards real improvement, but it is questionable sometimes if the old methods were not after all as good—though certainly they would be very much cheaper now—than the methods usually employed to-day.

The introduction of metal conduits or sheathings for the mechanical protection of insulated wires, whilst having certain advantages over, say, open wiring or wood casing, carries with it a possibility of extending fire risks. Until recently it was not by any means a universal practice to bond all conduits mechanically and electrically together; therefore when a fault occurred through abrasion or perishing of insulation, a section of conduit became "live," and liable to cause fire at any point where this conduit made an imperfect earth. Bonding and direct earthing, of course, has the effect of reducing the risks very materially, but does not eliminate them altogether.

Taking an ordinary building in Edinburgh, having, say, 200 lights, and all the pipes properly bonded together, there would be in such a place some four miles of electric light cables, and possibly nearly two miles of metal conduits.

In the same building there would be two or three miles also of electric bell and telephone wires entering the same rooms, and often put side by side with the electric light plugs and switches, and there would probably be a few hundred feet of gaspipe.

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* Read and illustrated before the Society on 10th April 1905.

Now, any good electrician knows that it is both desirable and necessary to keep electric light conduits away from gaspipes, and unless he is unusually careless, he will see that contacts do not occur; but he cannot as reasonably be expected to see that his conduits do not come into contact with structural ironwork, or bell wires insulated or otherwise, or anything else metallic which might at some other invisible point come into contact with another conductor capable of being earthed and of carrying current.

The insulation of either bell or light wires is only temporary; it decays, and in time falls off like dust, and one contact, say between a single bell wire and an iron beam, may connect up to "two miles of conduit" a "mile of bell wires of low insulation resistance"; then comes a time when the insulation on a portion of the lighting circuit breaks down, the cable is earthed on to the conduit, and before the fuse protecting that particular circuit has time to melt—even if the pipes are properly earthed—a heavy flow of current also passes through the whole of the bell circuits, and may cause fire at any point, or at many points on these circuits.

In a recent case under the Author's own experience four bells were simultaneously burnt out, and would under favourable conditions have started as many fires—no doubt bell wires spreading leakages of electricity are responsible in many cases for mysterious outbreaks which puzzle firemen in their work, different portions of the same building being set on fire at once.

It was with a view to minimising these risks that the Author devised the method here described for utilising the general supply to ring the bells, and so controlling it that any defect would at once automatically reveal itself, and also defects occurring by the lighting circuit earthing on to their conduits, would, by breaking down the bell installation, reveal themselves through the bells.

The apparatus consists of a double series of two lamps of the same voltage as the general supply, and the current after passing through them is used for operating the bells.

The size of the lamps required depends, of course, on the bell windings—in this case there are in all four lamps of 32 c.p. in series at 230 volts, the current passing—after allowing for the resistance of the bell—is less than .125 of an ampère and the arc is very small indeed, far too small, in fact, to fuse tin or other soft metal.

In any ordinary installation the worst fault that could occur would be for a current of 230 volts to become connected with the wires. This would have the effect of either making the bell ring continuously—noticeably loud — or of making two of the lamps burn at half incandescence, but the fault would be at once apparent.

The Author showed by diagrams the various positions in which the faults could occur and their effect as indicated by his apparatus.

He also showed that where there was a special installation of current at 460 volts pressure, the maximum current that could pass through the bell installation would be half an ampère—a volume of current that would not injure ordinary bell wires or cause fire, whilst the fault would be quite apparent to any one.

The bell used in the experiments was specially arranged by the Author, so that the contact breaker only broke the current passing through the bell coils, and at the moment of making contact short circuited them—the full pressure of 230 volts being continuous during the period of contact at the ringing push.

Wireless Light Telephony. By CHARLES N. KEMP.*
(With Illustration.)

Students of our *Transactions* wiil have read with interest the "Notes on the Telephone," by a former President, Dr R. M. Ferguson (1878.) We there find a description of the fundamental electro-magnetic phenomena on which the action of the telephone depends, and also an account of its discovery by Professor Reis in Germany and by Graham Bell in America. The Bell Telephone is familiar to us still, though it has been recently much improved and now forms an almost indispensable adjunct to everyday life. It is rather amusing to read an account of Reis's original instrument which consisted of the bung of a beer barrel hollowed out, the cone thus formed being closed by the skin of a German sausage which did duty as membrane. Telephones have been brought to such perfection that there is scarcely any limit to the distance through which sound vibrations can be transmitted. This is of course accomplished by the use either of two conducting wires, or of one such wire and an earth return. Successful telephonic experiments have indeed been performed by E. Ducretet (Comptes Rendus 1902) *using the earth only*, as conductor. These results lead one to ask — Can articulate speech be transmitted from one station to another without the use of any metallic or earth conductor whatever? At first sight such a problem would appear utterly impossible were it not that the ever-growing list of the elements includes one, viz., Selenium, possessing the remarkable and unique property of having its electrical conductivity increased by exposure to light.

The chemical properties of selenium (discovered by Berzelius in 1817), and of the numerous interesting compounds which it forms, have been so well described

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* Read and illustrated before the Society on 10th April 1905.

by various writers that it is unnecessary to refer to them more particularly than by a reference to Roscoe and Schorlemmer's Treatise on Chemistry, vol. i.

Like sulphur, selenium exists in various allotropic modifications distinguished by their solubility in carbon disulphide. The insoluble variety, sometimes known as "metallic" selenium (selenium is usually classed with the metalloids), is a black crystalline solid, of metallic appearance and granular fracture. It is obtained by quickly cooling melted selenium to 210 degrees C, and maintaining that temperature for some time, when the mass solidifies exothermally, the temperature rising to 217 degrees C. Metallic selenium melts at 217 degrees C, and has Sp. Gr. 4.5.

It is this modification only which possesses the electro-optical properties referred to above.

The vitreous translucent variety is a dielectric, and, like many other substances such as glass and ebonite, may be electrified by friction. This substance, however, when suitably heated, changes its molecular condition, and becomes opaque, simultaneously acquiring the power of conducting electricity, thus obeying the law of the Electro-magnetic Theory of Light, that all conducting metals are opaque to light.

The actual resistance of a piece of selenium is very high when in the latter form, and may be several thousand megohms, an actual determination giving 3.8×10^{10} ohms.

Hittorf in 1851 discovered that selenium conducted electricity, but it was J. E. Mayhew, an assistant to Willoughby Smith, who in 1873 accidentally found that some selenium which he was using as a mere resistance, changed its resistance on exposure to light. In his astonishment, Smith says: "By means of a microphone the walking of a fly can be so loudly heard as to resemble the tramping of a horse on a wooden bridge; but it is far more wonderful, in my opinion, that by means of a telephone I can hear the falling of a beam of light upon a metallic plate."

In 1875 Werner Siemens constructed selenium cells, consisting of two close parallel platinum wires wound in a flat spiral, and having the space between them filled by selenium. He thus obtained a sensitiveness of 1 in 15. Similar cells were constructed in 1879 by Graham Bell and Sumner Tainter, the former using them in the construction of an instrument called the Photophone, a description of which may be found in any Text Book of Physics.

A large number of other investigators might be mentioned, but the latest and most extensive experiments have been carried out by Professor Ernst Ruhmer of Berlin, and are to be found described in a booklet by him, entitled "Das Selen und seine Bedeutung für die Elektrotechnik."

In his type of instrument the cell is enclosed in an evacuated glass bulb. This ensures immunity from external effects such as moisture or temperature variations. Another form of cell is that described by Fitzhugh Townsend, in an article on "Photometric Experiments with Selenium," in the New York *Electrical Review*. (Reprinted in the *Electrician*, 7th October 1904.)

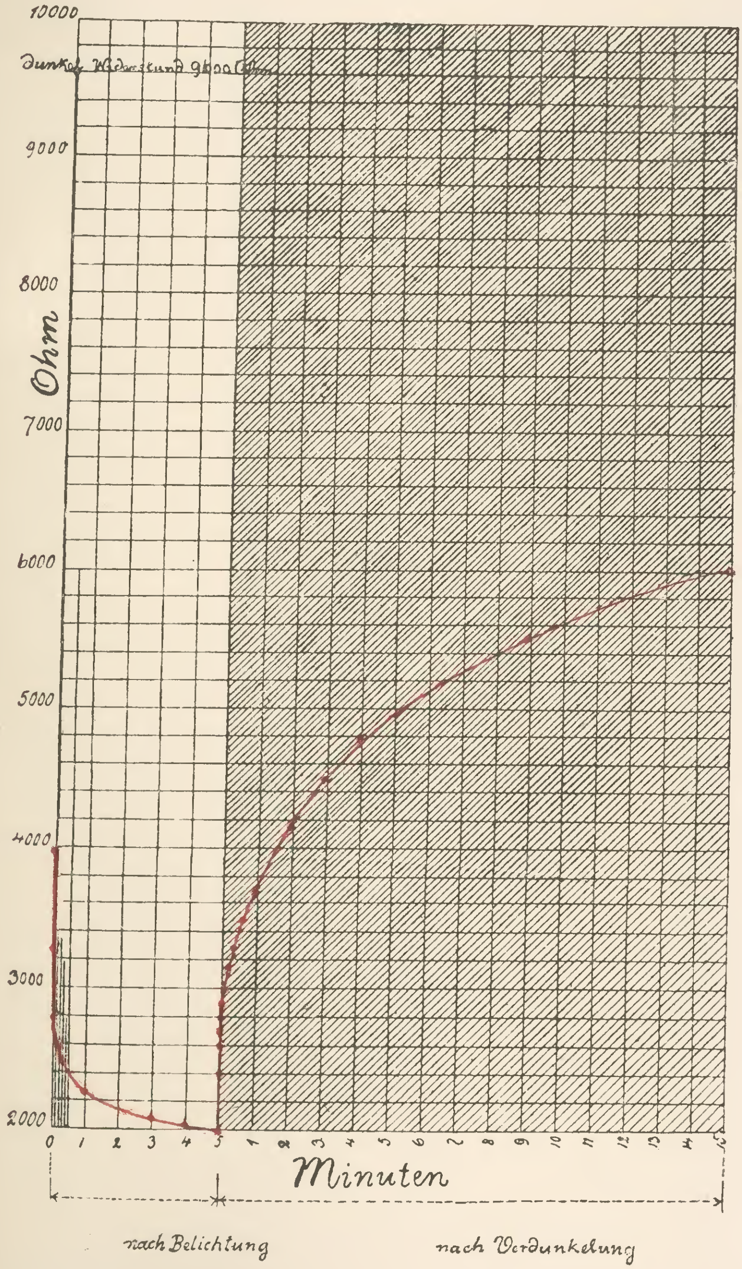
These experiments were conducted with a view to obtaining an efficient photometer, and led Townsend to the conclusion that for general work at least the selenium photometer is not so good as those of the ordinary type. The great advantage of a selenium instrument is, that a determination depends on a definite reading of some electrical instrument, and not on the opinion of an observer.

A difficulty which is met with in using the selenium cell for photometric purposes is that its behaviour varies in different parts of the spectrum, the maximum variation being, as one would naturally expect, in the visible spectrum. Adams has shown that the greenish-yellow rays are the most active, and also that the change in resistance varies directly as the square root of the illumination. He observed that the resistance is less with a high electro-motive force than with a low one, a fact that is contrary to the very definition of resistance as we ordinarily regard it. It is thus evident that though admirably adapted for the comparison of exactly similar but differently intense sources of light, such an instrument is unsuitable when lights of different quality are to be compared.

The mode of construction of a very efficient form of cell which is manufactured by a London firm of electricians is as follows:—Two thin wires are formed into flat spirals, and carefully placed on a small disc of mica. A thin sheet of crystalline selenium is placed on top, and the whole is put under slight pressure. This arrangement is heated to about 220 degrees C, when the melting selenium slowly fills the narrow spaces between the two wires. After cooling, the cell is placed in a paraffin bath and slowly heated to 180-200 degrees C when the selenium again assumes its crystalline condition.

The resistance changes of selenium cells are rendered very clear when considered graphically. The quantities plotted are the resistance of the cell and the time, both during exposure to light, and after the light has been turned off. The annexed diagram (after Ruhmer) was derived from a cell whose maximum resistance was 9600 ohms, and whose minimum resistance was 2000 ohms. When the light is turned on at zero time the resistance falls practically instantaneously from its maximum value to a lower one, the difference between the two values depending on the sensitiveness of the cell employed. The resistance then continues to fall more slowly to its minimum value. When the light is turned off, the resistance increases very rapidly at first, and subsequently much more slowly, the final return to the original value being almost asymptotic, and occupying about twenty hours. The whole time occupied by the observations was twenty minutes, five minutes exposure to light, then fifteen minutes in the dark.

Various authorities agree that the sensibility of the Selenium Cell is due to the presence of certain selenides from which selenium is practically never free.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The facts in support of this theory are :—

(*a*) The conduction is electrolytic in character.

(*b*) Se is a very bad conductor; selenides are relatively good ones.

(*c*) Sunlight actually brings about a combination of metal and Se forming a stable selenide, capable of conducting a current.

In connection with this theory Shelford Bidwell says: "If, as is commonly believed, electrolytic conduction involves a series of decompositions and recompositions throughout the electrolyte, any cause which will assist either separation or recomposition (or both) of the components of the electrolyte might be expected to increase its conductivity; and it seems reasonable to suppose that the same influence which would assist the union of two substances when they have a tendency to unite, would also be favourable to their separation when they have a tendency to separate. It is not impossible, therefore, that radiation, acting on the surface of a thin layer of selenide of silver through which an electric current is passing, might, by facilitating the molecular rearrangement of the atoms of selenium and silver, exert a material influence on the conductivity."

Bidwell also showed that the maximum sensitiveness in a selenium cell is only obtained when about 3 per cent. of a definite selenide is present.

The account of a most interesting "Study of the Selenium Cell," by A. H. Pfund, is to be found in the *Phil. Mag.* for January 1904, in which this point is investigated. The cells used were prepared from the purest Se, to which a definite amount of a pure selenide (of copper, mercury, lead, or silver) had been added.

The electrodes used were of Atchison graphite, separated by mica, this being the method employed to eliminate the formation of a selenide in unknown amount at metallic electrodes.

Pfund's theory of the action of a cell is as follows:—

"Granting that in a selenium cell most, if not all, of the conduction is electrolytic in character, due to the presence of a selenide, it follows that there is an actual motion of the components of the selenide towards the electrodes of the cell. Any cause which will increase the velocity of these components will decrease the resistance of the cell. Selenium is known to exist in at least four allotropic modifications, the metallic or crystalline form being represented in the selenium cell. As it is an established fact that light affects the character of certain crystalline compounds, it is not unreasonable to suppose that light, in falling upon selenium, might also change its crystalline character, and that this new modification might offer less resistance to the components of the selenide as they wander towards the electrodes, thereby producing indirectly an increase in their velocities, which is equivalent to a decrease in the resistance of the cell.

This view gains in plausibility if, with Bidwell, we think of the particles of selenide as being packed in between the particles of selenium. Assuming that this new modification of selenium is stable only in light, it would revert to its original condition when light is cut off, the change taking place more rapidly at first, and more slowly afterwards (comparable, perhaps, to the molecular changes in soft iron when the magnetising force has been withdrawn). This would decrease the velocity of the components of the selenide, which would mean eventually bringing the resistance of the cell back to its original value."

He sums up as follows:—

1. The sensibility of selenium cells containing highly purified selenium mixed with various metallic selenides, was examined in various parts of the spectrum, and it was found that the position of the maximum remained fixed. It was concluded that the position of the maximum was not governed by the metal in the selenide, but probably by the free Se itself.

2. It has been shown that a selenium cell, taken from darkness into light, and again returned to darkness, undergoes changes in resistance whether an electric current flows or does not flow through the cell.

3. A suggestion as to a possible action of a selenium cell has been made. It is supposed that light affects the selenium directly rather than the selenide. This explanation, expressed of necessity in rather indefinite terms, gives promise of accounting for certain phenomena, the explanation of which fails at the hands of the existing theory.

Until comparatively recently the only possible practical application of selenium cells appeared to be to the science of Photometry.

Ruhmer, however, has succeeded in applying them to the transmission of sound by means of light: in other words, he has solved the problem of Wireless Light Telephony. For this purpose a "speaking arc" is required in addition to the sensitive cell. Such an arc differs but little from those in ordinary use for street lighting. The distance between the carbons is, however, made as great as possible. In the same circuit as the arc is a transformer, to the secondary coils of which a microphone and battery is connected. Any sound in the vicinity of the microphone immediately causes a slight change in the strength of the current passing through the arc, and a corresponding change in the intensity of the light proceeding from it. The arc being placed in the focus of a parabolic reflector, ensures that the light rays will emerge as a parallel bundle, which is directed on a suitable selenium-cell-circuit some distance away. Every variation in light-intensity at the sending station causes a corresponding and proportional change in the resistance of the cell, and by including a sensitive telephone receiver in this latter circuit, an intelligible reproduction of speaking, singing, or whistling may be obtained.

In this way Ruhmer has succeeded in speaking over a distance of nearly ten miles.

Perhaps one of the most ingenious of Ruhmer's many applications of the selenium cell is to what he terms the Automatic Lamplighter, which, on the approach of darkness, of itself turns on a gas or electric light.

From what has already been said, it is obvious, without going into somewhat complicated mechanical details, that this is quite easily accomplished. Such an apparatus can be fitted to lighthouses, buoys, etc., which are inaccessible in stormy weather, the very time they are most urgently needed. It is quite evident what a saving such a device would effect.

Using a somewhat modified (but none the less efficient) searchlight as transmitter, and a selenium cell as receiver, warships could carry on conversations with each other, or with shore stations as long as they remained in sight.

Jan Szczepanik has invented an apparatus involving the use of selenium cells whereby pictures can be transmitted by wire.

It seems impossible to assign the future of this remarkable instrument. We can only hope that those who have hitherto worked for its perfection will soon be rewarded by seeing it in everyday use, in the service of man.

A. H. Pfund on "A Study of the Selenium Cell," *Phil. Mag.*, 6th series, No. 37, January 1904; Adams and Day, *Proc. Roy. Soc.*, 1876, p. 113; Shelford Bidwell, *Phil. Mag.* 1895, vol. xl. p. 233; Shelford Bidwell, *Phil. Mag.* 1885, vol. xx. p. 191; Victor Lehner, *Jour. Am. Chem. Soc.*, vol. xx. No. 8; A. P. Saunders, *Jour. of Phys. Chem.*, vol. iv. p. 423; C. F. Adolph, *Technics*, No. 13, January 1905; Ernst Ruhmer, *Das Selen und seine Bedeutung für die Elektrotechnik;* Ernst Ruhmer, *Neuere Elektrophysicalische Erscheinungen.*

Address by Vice-President, Francis G. Baily, M.A., F.R.S.E., *delivered at the Annual General Meeting of the Society, held on 13th November* 1905.

Gentlemen,—My presence in the chair to-night reminds us all of the severe illness with which our retiring President, Dr Dawson Turner, has been afflicted, and I may appropriately preface my address with an expression of sympathy for him, and an earnest wish that he will be with us again before long with completely restored health and strength. In saying this I feel sure that I am expressing the feelings of all Fellows of the Society, and I may add that all who heard his fascinating address last year upon Radium cannot but regret that we have been deprived of a second paper from him.

The session of 1904-5 has not been uneventful. The ten meetings of the Society brought forward a full complement of interesting papers on many and varied subjects. It is gratifying to record that the attendance has been well maintained, and that a considerable number of visitors have shown interest in our meetings. We trust that this interest will lead some of them to become members in the forthcoming session.

For some years past the President has each year recorded a decreasing membership during his period of office. I am glad to say that in the session which is ended our numbers have decreased by only one member, five new Fellows having been elected, while three have resigned membership, and three we have lost through death. It may be hoped that our next president will be able to announce an increase in our numbers when he opens a new session in a year's time.

The three Fellows whose deaths we have to deplore were Mr A. M. Bell, Sir William John Menzies, and Mr John Kolbe Milne. Mr Bell joined the Society in 1850, but as he resided in America he was not an active member. We may recall his paper in 1901 on Visible Speech.

Sir William John Menzies joined our Society in 1865. His manifold activities in this city are fresh in the minds of all.

Mr John Kolbe Milne was elected Fellow in 1848, and served on the Council during the years 1872-3-4. That his interest in the Society was retained to the end of his life is shown by the mention of it in his Will. I have great pleasure in announcing that Mr Milne has left a legacy of £50 to the Society, which will come into our hands in the course of a few months.

During the past session the Society, and more particularly its Council, have given much thought to our present position. The increasing number of technical societies and institutes, and the development of the technical journal, have not conduced to the welfare of the Society, and the question has seriously been asked whether, in the increasing tendency to specialisation, a Society of Arts can maintain its old position. We are the trustees of a substantial property, and it is our duty not only to hand down that property unimpaired, but also to devote it to a good use during the time of our possession. We find ourselves accumulating funds which were bequeathed for the furtherance of invention and progress in the arts, simply because we are unable to find a proper use for the whole of the income if the strict letter of the trust deed is followed. For example, the Keith Fund, originally some £400, at present produces an income of £65 a year, while the other prize funds now produce the whole of the money which the Prize Committee usually considers desirable to award. Under these circumstances it was felt advisable to find some other object to which to devote this excess of income, and after much discussion it was agreed that the wishes of the testator could be carried out in the spirit, if not in the letter, by initiating or assisting researches in technical processes. We propose, in fact, to give grants to promote research, in place of waiting always for the completion of the work, as has been the custom up till now. Endowments for scientific researches are plentiful, and the intrinsic fascinations of the subject attract many enthusiastic workers; but technical research, notwithstanding its immense industrial importance, is poorly supported, and is perhaps less attractive in itself. We may hope, therefore, that our Society will be the initiator or instigator of many useful investigations, and it is not unreasonable to expect that the trades and crafts interested in the work will supplement our little fund as soon as the objects of the investigation have been proved to be of practical importance.

Another worthy use of the money seemed to be presented by the inauguration of special lectures on some technical subject of present or local interest, somewhat on the lines of the Cantor Lectures of the Society of Arts in London. It was felt that a set of lectures, some three or four, devoted to a single subject, would afford scope for a thoroughly sound and instructive treatment, and that on the one hand we should avoid the purely popular peripatetic lecturer, whose art sometimes consists in saying as little as possible in the most interesting manner, and on the other hand, we should leave to its proper place the deeply technical specialist paper in which an audience of experts is assumed.

Permission to devote the income of the Keith bequest with its accumulations to these two purposes was obtained by an application to the Courts, and I am glad to have the opportunity of giving our fellow-member, Mr Ritchie, cordial thanks, in which I feel sure the Society concurs, for the care and skill with which he piloted our case to a successful issue. Our Treasurer likewise, with his accustomed enthusiasm for the welfare of the Society, devoted much time and attention to the furtherance of the proposals.

The exact wording of our new powers is as follows, referring to the Keith bequest and the accumulations, now forming a new consolidated fund :

"This sum is on no account to be encroached upon ; but the interest arising from it is to be applied in sums of money or medals in rewarding Inventions, Improvements, or Discoveries in the Useful Arts, preference being shown to those which shall be primarily submitted to the Society ; or in making money grants in aid of Experiments and of Work of Research in or connected with the Useful Arts in Scotland; and, in so far as the interest may not be required for the foregoing purposes, in providing lectures on subjects connected with, or which may be of service to, the advancement of the Useful Arts, to be delivered by those who have made Inventions, Improvements, or Discoveries, or have engaged in Scientific Research in such subjects."

It may be noted that the giving of lectures is not considered to be quite so closely in agreement with the testator's wishes as the endowment of research, and I hope personally that that will be kept in mind by the Society. For our first session, however, it was thought better to start with a course of lectures and to give prominence to work already done, letting the question of research mature more gradually. A small sub-committee has been appointed to consider the question, and we hope to be able to arrange a course for this session which will serve as a worthy precedent for coming years. In case of misapprehension I should say that we are reserving for the customary prizes a sum considerably in excess of that which will probably be required; and as our accumulations have now been funded into a new capital, we propose to build up a small reserve fund for prizes, that any especially meritorious invention or paper may be adequately rewarded, notwithstanding any commitments into which the Society may have entered.

When I was informed that the duties of this evening would devolve upon me, my gratification at the unexpected honour was considerably damped by the thought that there was little time for the preparation of an address of proper standard, and, more fatal than lack of time, there was no particular subject which I could discuss in a manner which would interest the Society. But when the municipal elections came on, the subject of the tramways came so vigorously to the front, and it gave rise to statements so contradictory and confused, that it occurred to me to deal with the matter in the calm of this hall, when the heat and shoutings of the battle were past.

The publication of Sir Alexander Kennedy's report, followed by a substantial abstract of that of the Town Clerk, have rather taken the wind out of my sails, but since the two documents aforesaid are cautious in their discussion of the future, perhaps some consideration of our position and some unofficial proposals may be of interest.

The question whether the present cable is or is not the best thing for Edinburgh has been discussed so much that nothing new can be said about it. Moreover, I do not wish to spend time in discussing unpractical schemes, and no one will advocate the abolition of the existing cable *in toto* at the present time. It is worth while to remember that the working expenses come out at 5.8d. per car mile, while those of the Glasgow tramways are 5.2d. The receipts per mile of track in Edinburgh are much the same as those in Glasgow before the long-distance extensions were opened, amounting to about £11,000 per mile of double track, so in spite of alleged shortcomings our cars appear to be popular. It is beside the point to discuss the question of initial expense. By removing the cable system we should obviously not remove the expenditure incurred, and therefore, unless a definite gain in running expenses can be proved, so great as to pay for the alteration to a new system, a change would not be economical, whatever other advantages it might have. With running costs at the figure given above, no such economy is likely to be effected, and especially must estimated costs of upkeep of untried systems be scrutinised with suspicious care.

Other possible advantages are increase of speed, reduction of stoppages by breakdown, and freedom from accidents to people and other vehicles. Confining our attention strictly to urban traffic, and bearing in mind the severe gradients on many of the routes, it may be questioned whether any material increase in average speed can be obtained above the speeds now proposed, although some advantage might be gained at certain points, and more varied routes could be arranged. [These increased speeds have now been sanctioned by the Board of Trade.] Statistics of stoppages are hard to come by, but I do not think, so far as I can gather, that we have any reason to complain in this respect. Last, but by no means least, in regard to collisions and street accidents the Edinburgh tramways compare favourably with those of other large towns. In the descent of heavy gradients there is no doubt that the strict limit of speed enforced by the use of the cable is an important safeguard, whereas several instances of cars getting beyond control of the driver are unfortunately recorded in the annals of electric traction.

But while retaining the cable system substantially as it is at present, we are in a quandary about extensions. There is no finality about extensions. They start out to suburbs, then extend to incipient suburbs, then to holiday resorts and neighbouring villages and towns. Therefore, a part of the system will certainly be of a cheap form, suitable for high speeds and country roads, and I think it is doubtful whether any of the surface contact systems are likely to defeat the overhead trolley in this application. Moreover, it is possible that long-distance tramways will in the future use high pressure and alternate current single phase motors, which will scarcely be permitted on a surface contact system. Therefore, I believe that the trolley will be in the future no less in evidence than it is now, and its only rival will be the motor omnibus, though from an æsthetic standpoint neither of them are unexceptionable.

I consider, therefore, that any comprehensive and extensive tramway system will involve the use of the trolley outside the town, along some routes at least; and if we refuse admission to the overhead wires, either we must invent a composite car to run over both inside and outside systems, or we must change cars. The first method is objectionable in that our composite car must be fitted, not only with pole and gripper, but with complete motor equipment and controllers. Its weight and cost will therefore be considerably greater than are the weight and cost of a cable car. But the gripper will add little to the weight, so it will be quite a good trolley car, and so long as the greater part of its journey is over trolley lines there will be little technical objection to allowing it to run a short distance over the urban lines if necessary. Hauling up or letting down the gripper will probably take a minute or so, but over a run of several miles this is hardly a serious objection.

This combination car can scarcely be arranged for the magnetic contact system, for the space underneath the car is much taken up, and the addition of a gripper would be difficult. Also the weight of the car is still further increased by the skates and magnets, with corresponding wear and tear on the lines and cable in the city. Further, it might be in many places desirable to allow the systems to overlap for some distance, and the combination of surface contacts and slot all on the same track would be both objectionable and difficult to arrange. With the trolley no such difficulty would arise.

[Since writing this paragraph I have had an opportunity of inspecting the new designs of the Kingsland system, which have been specially arranged for use in combination with a centre slot. While the modifications proposed have not as yet been subjected to actual working conditions, they appear to be successful in overcoming the difficulties above mentioned. If the system were found desirable for extensions, some over-lapping of routes could be permitted, although I should not care to advocate any extensive running through. A double system track obviously increases the chances of blocking.]

An easy solution of all these difficulties is afforded if the plan is boldly adopted of breaking system at the outskirts of the city, and I hope to show that this is not so impracticable a proposal as may appear at first sight. We have had Pilrig before us for so long that the idea may be repellant; but I propose something better than Pilrig. Let it be supposed that the two systems run right up to one another, so that the two single lines, in which each finishes, overlap a car length. The two cars are then drawn up alongside each other at the changing station, and as the speed at this point will necessarily be reduced to a slow crawl, probably no objection will be raised to a reduction of the space between the pairs of lines, so that the cars will almost touch as they lie side by side. It has been pointed out to me that a reduction of the distance between the cars is contrary to the regulations of the Board of Trade; but in these special circumstances, when the speed is almost nothing, this regulation might be relaxed. In any case, however, there would be no difficulty in erecting a narrow platform between the cars, and a second one overhead for the outside passengers, which would entirely obviate the difficulty, and such platforms would cause no more permanent obstruction to the traffic than is produced by the present islands for the convenience of foot passengers, which are frequent in the most crowded thoroughfares. By a small alteration of the staircase, egress and ingress may be obtained on both sides of the platform, and the process of changing cars merely involves a step from one platform to the other. All outward bound passengers would walk out of one end of the car into the other car, while at the same time the city going passengers would enter by the other end. It would, moreover, be easy to have sliding doors in the railings on the roof, so that outside passengers would exchange in the same way, and the doors could be worked by the conductor from below, with locking arrangements to prevent accidents during the journey. This does not differ from the method of boarding passenger steamers through a gap in the bulwarks or rails, and it is clear that the crossing from a stationary car would be much safer than from a heaving boat.

The time required for such a change would be no more than that required to change from gripper to trolley, and probably rather less. The changing stations would be robbed of many inconveniences if a light glass roof were thrown over them, if they were lit up at night, and if seats were placed along the sides of the footway. A structure of this kind would be very cheap, as it would only be a little longer than a car, and with such a station, a wait of a few minutes for an infrequent long-distance car would be no hardship.

It will be noted that the change from the country car to the town car will take place on the outskirts of the town, where traffic is small. I think it no small advantage to move the changing stations as far out as possible, consistent with the greater cost of the town system, in order to avoid the accumulation of cars at termini in the city. Moreover, passengers will be able to take the frequent city service from the streets, avoiding waiting about in crowded thoroughfares, and any wait that takes place for the less frequent long-distance cars will occur at the outside terminus, where there is room to erect the before-mentioned covering. As the change of system need not take place exactly at the municipal boundary line, considerable latitude is permissible in the choice of position for these changing places; hence any requisite widening of the street at these points will not involve any great expense, and they may therefore be easily raised to the dignity of a station.

In considering the advantages of this arrangement we may examine the traffic conditions in Glasgow. There the tramcar service is a very complete through system, all cars, or almost all, even from great distances, running into the heart of the city and out to the other side. I have vivid recollections of waiting at a crowded corner in Argyle Street, obstructing the traffic and being myself jostled by hurrying wayfarers, while car after car of the wrong colour passed by. And after all, when the right car comes up, it may happen to be full of people who are travelling only a short distance, but who crowd out the long-distance passengers. An expert in cars will doubtless be able to take another car for a portion of his journey and change into his proper car when this has dropped many of its passengers. What I discuss here is exactly the process which the expert would adopt, with the additional advantage that there would be a recognised and comfortable changing place.

Looking at the whole question of urban and country traffic, I am inclined to think that the last described arrangement is the best. It is certainly the most flexible as regards cars. It avoids the objections to through routes that they entail giving running powers to outside companies over the city streets. The city would indeed have no contact with outside companies beyond the few yards of overlap, and no interest in them beyond seeing that a satisfactory time-table was kept.

Our cable cars already run nearly to the boundary in many directions. I should advocate stopping there, or even perhaps short of this point on some routes, and continuing by electric car. Whether it is better to obtain powers to run the country cars ourselves, or to leave it to the country authorities to settle matters with private companies, is a question outside of my province in this discussion, but either way can be adopted without injury to the car service. In either case we keep the cream of the business in our own hands by terminating our urban system at the city boundary. Any extension can only bring more traffic to the urban service, whatever its individual success over its own portion of the route, and increase of traffic is unalloyed gain to a cable system.

I am aware that the adoption of changing stations on a tramcar system as a comprehensive and intentional policy is novel, but I believe that it merits consideration. Tramcar systems have grown from small beginnings and have extended tentatively. They have followed the idea of the horse-tram, which with its flexibility and freedom is a dangerous example. Now that there is more choice of methods of traction, and the area to be served has much increased, it is desirable to consider whether in striving after unity of system we do not sacrifice more than we gain, and whether urban and country traffic should not be considered separately and dealt with by the systems most suitable for each.

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APPENDIX (A).

PROCEEDINGS OF THE ROYAL SCOTTISH SOCIETY OF ARTS, SESSION 1902–1903 (BEING THE 82ND SESSION).

First Meeting.—THE ANNUAL GENERAL MEETING was held in the Hall, 117 George Street, on Monday evening, the 10th of November 1902, at 8 o'clock. Mr F. Grant Ogilvie, President of the Society, occupied the Chair, and was supported by Lord Kingsburgh and Mr A. Beatson Bell.

In opening the session the President referred to the losses which the Society had sustained in the past two sessions by the death of many Fellows who had taken active part in the life of the Society. He then reviewed the papers which had been submitted during the past session. The altered conditions under which the Society now existed were drawn attention to, and the means of meeting successfully these conditions pointed out. The system of education in Scotland was fully discussed, and Technical Education in particular referred to.

Lord Kingsburgh moved a vote of thanks to the President for his able address. This was seconded by Mr Beatson Bell, and carried unanimously.

The Secretary then read the Report of the Prize Committee, and the President presented the Prizes to the several recipients.

Private Business.

The Minute of the meeting on 23rd June was read and approved.

The Society unanimously elected the following list of

Office-Bearers for Session 1902–1903, the same having been recommended by the Council :—

President, . .	F. GRANT OGILVIE, M.A., B.Sc., F.R.S.E.
Vice-Presidents, .	DAWSON TURNER, M.D. COL. A. B. M'HARDY, C.B.
Secretary, . .	WM. ALLAN CARTER, M.Inst.C.E., F.R.S.E.
Assistant Secretary, .	ANDREW WILSON, Assoc.M.Inst.C.E.
Treasurer, . .	C. J. SHIELLS, C.A.
Editor of Transactions,	RICHARD STANFIELD, M.Inst.C.E.
Librarian, . .	E. M. HORSBURGH, M.A., B.Sc.
Medallists, . .	ALEXANDER KIRKWOOD & SONS.
Officer, . . .	FRANCIS DUFFY.

Councillors.

Dr R. M. FERGUSON.
JAMES MASSIE.
STEPHEN SMITH, B.Sc.
ARCH. WILSON, A.M.I.C.E.
ALEX. CLARK, Assoc.M.Inst.C.E.
ROBERT CRANSTON.
A. D. MACKENZIE.
W. CARMICHAEL PEEBLES.
F. G. BAILY, M.A.
T. HUDSON BEARE, M.Inst.C.E., M.Inst.M.E.
H. M. CADELL, B.Sc., F.R.S.E.
GILBERT THOMSON.

The Secretary then submitted a statement of the membership of the Society, and a discussion took place on the continued decrease.

The following candidates were proposed, balloted for, and duly elected Ordinary Fellows of the Society :—

Jas. B. Bennett and Henry O'Connor.

The Society then adjourned.

Second Meeting—*24th November* 1902.—The President occupied the Chair.

Mr Proctor read his communication on the Position and Material of Soil and Waste Pipes in Houses. The author reviewed the question generally, and advanced the opinion that the proper material for such pipes was lead and that the proper position was inside the house. In the discussion which followed Messrs Hume, Watson, Paterson, Knox, and Cunningham, and the Secretary, took part. In general these gentlemen did not agree with Mr Proctor's opinion.

Mr Proctor then described his Ball-Valve Flushing Cistern. He claimed for it that it was simple and noiseless and that it gave a good flush. His claims were fully substantiated in the demonstration which followed. Messrs Ritchie, Firth, Paterson and Frazer spoke on the subject. Both communications were remitted to a Committee consisting of Messrs Thomas Hume, J. B. Bennett and H. J. Blanc, the last to be Convener.

Private Business.

The Minute of the Annual General Meeting was read and approved.

Alexander Kirkwood was proposed, balloted for, and duly elected an Ordinary Fellow of the Society.

The Society then adjourned.

Third Meeting—8th December 1902.—Colonel M'Hardy, Vice-President of the Society, occupied the Chair, and was supported by Dr Ferguson.

Mr Herdman described his Direct Reducing Levelling Staff. In this staff a shoe is fitted to the top, having an arrangement similar to a vernier for extending it. After the height of the level is determined as usual, the shoe is extended a distance equal to the decimal points of the height. The staff is then reversed, and the readings on it give the correct decimal points of the reduced level.

Mr Herdman then described a form of hinged joint suitable for levelling staves. The hinge was clamped by a turnbuckle at the back.

After the discussion the papers were remitted to a Committee consisting of Messrs Blaikie, Clark and Westland, the last to be Convener.

Mr M'Kinnon then described and exhibited his Patent Window. Three windows were shown, two being suitable for ordinary requirements, while the third was specially adapted for use in lunatic asylums.

After some discussion the invention was remitted to a Committee consisting of Messrs Massie, Hislop, Blanc and Watherston, the last to be Convener.

Private Business.

The Minute of the previous meeting was read and approved.

The following were proposed, balloted for, and duly elected Ordinary Fellows of the Society:—

Montague T. Pickstone.
Arthur Pillans Laurie.
Alphonse Louis Reis.

The Society then adjourned.

Fourth Meeting—12th January 1903.—Mr F. Grant Ogilvie, President of the Society, occupied the Chair, and was supported by Mr A. Beatson Bell, Past-President.

Mr J. G. Goodchild read his communication on the Evolution of the Japanese Clock. The different times, civil, astronomical, sidereal, were first explained and their sub-divisions pointed out. The sub-divisions of time in Oriental and Occidental countries were then explained and the method of their measurement alluded to. Mr Goodchild described the sand-glass and various forms of water clock, and then proceeded to a most interesting description of the modern Japanese clock. Three models were exhibited in going order, and many interesting and beautiful lantern slides were shown to the meeting.

Mr Blaikie, Dr Watson and Professor Baily took part in the subsequent discussion. At the conclusion Mr Goodchild was heartily thanked for his communication.

Mr Goodchild then described his Improved Form of Cyclograph. Pressure was applied at two points of an elastic and flexible lath by means of a screw attachment to two fulcra. A curve of any desired radius could thus be obtained, and this was specially useful for stereographic projection.

Messrs Baily, Blaikie, and O'Connor took part in the discussion which followed, and the communication was remitted to these gentlemen to report on, Mr O'Connor being appointed Convener by the meeting.

Private Business.

The Minute of the previous meeting was read and approved.

Mr R. W. Vawdrey was proposed, balloted for, and duly elected an Ordinary Fellow of the Society.

The Society then adjourned.

Fifth Meeting—26th January 1903.—Mr F. Grant Ogilvie, President of the Society, occupied the Chair.

Mr D. G. Ednie described and exhibited his Patent Window. The window sashes were attached to their supporting cords in such a manner that, when the batten rods were removed, they could be rotated and easily cleaned. If desired, the sashes could be taken out altogether in a very simple manner, while the pocket holes were easily accessible.

Messrs Hume, Wilson and Ogilvie took part in the discussion, after which the communication was remitted to a Committee, consisting of Messrs Massie, Hislop, Blanc and Watherston, the last to be Convener.

Mr Montague Pickstone then read his paper on British Manufacture and Foreign Competition. The paper dealt chiefly with methods of workshop management. The author referred to the methods of Germany and the United States. The applicability of these methods to British practice was taken up, and in conclusion a detailed description of the admirable and complete system carried out at the works of Messrs Bruce, Peebles & Co. was given.

Judge Mackenzie and Messrs Macdonald and Peebles having spoken, and Mr Pickstone having replied, the hearty thanks of the Society were awarded him.

Private Business.

The Minute of the previous meeting was read and approved.

The Society then adjourned.

Sixth Meeting—9th February 1903.—Dr Dawson Turner, Vice-President of the Society, occupied the Chair.

Professor F. G. Baily read his paper on Wireless Telegraphy to a large attendance of the Fellows and their friends in the Heriot-Watt College. Treating firstly the development of his subject, the author passed on to speak of the general principles underlying this application of electrical science. The facts which he enunciated were illustrated by numerous experiments. The author described various forms of the apparatus in use for the transmission and reception of messages. This part of the subject was illustrated by diagrams and lantern slides. In conclusion the question of one set of instruments being able to pick up messages not intended for it was answered by the author, who showed that messages could be read with no great difficulty in such a case. Finally the theory was propounded that the undoubted success of this method of communication at sea was due, not to the level surface, but to the transmitting power of the water.

At the conclusion of his interesting lecture the author was awarded the Society's heartiest thanks.

The Society then adjourned.

Seventh Meeting—23rd *February* 1903.—Mr F. Grant Ogilvie, President of the Society, occupied the Chair, and was supported by Colonel M'Hardy and Dr Ferguson.

Colonel M'Hardy opened the proceedings by congratulating the President on his appointment as head of the Technological Department of the Board of Education. Mr Grant Ogilvie suitably replied.

The Report by Committee on Mr Proctor's Flushing Cistern (No. 4835) was read and approved.

Mr A. J. Whyte then read, on behalf of Mr Scott Snell, his communication on High-Pressure Gas Lighting and recent Developments in the Scott Snell High-Pressure Lamp. The question of high-pressure lighting was taken up generally ; then the Scott Snell Lamp was fully described. In this lamp the heat generated by the burner actuates a most ingenious compressor, and thus each lamp is entirely self-contained and independent of its neighbours. Two lamps were shown in operation, and the mechanism was explained by means of them and also by a series of excellent diagrams and working models. An anti-vibrator for use with incandescent mantles was exhibited. The support for the mantle floated in a tray of mercury, and it was stated that, where formerly the life of a mantle had sometimes been only a day, by the use of this device the life had been extended to several months.

An interesting discussion followed, in which Professor Baily, Dr Ferguson, and Messrs Peebles, Grieve, Wilson and Cadell took part. Mr Whyte having replied, the communication was remitted to a Committee, consisting of Messrs Baily, O'Connor and Peebles, the last to be Convener.

Dr Black then exhibited a parcel of gold ores from the Robinson Deep Gold Mining Company, Johannesburg.

Private Business.

The Minutes of the two previous meetings were read and approved.

The Treasurer laid his accounts for Session 1901–1902 on the table.

The Society then adjourned.

Eighth Meeting—9th March 1903.—Mr F. Grant Ogilvie, President of the Society, occupied the Chair, and was supported by Dr Ferguson and Professor Baily.

Mr Henry O'Connor submitted his communication on the Measurement of Light and a new Photometer. The different photometers commonly used were described, and it was pointed out that generally the gas to be tested was supplied at a fixed rate, while the light obtained was compared to a standard. The composition and specification of the standard candle were described, as also the more refined standard obtained by passing a gas over a volatile hydro-carbon penthane. This latter standard was used in the latest type of photometer used in London for testing coal gas. In this table photometer the gas was adjusted by means of a micrometer cock to give a light equal to the standard, and the quantity of gas used gave a measure of the quality of the gas under test. In addition to this instrument the author had several others on exhibition, including the jet photometer for rapid tests. A pressure gauge designed by the author and used by the Board of Trade as a standard for testing other gauges was shown in connection with one of the photometers.

Dr Black, Professor Baily, Dr Hunter, Mr Cadell, and the Chairman joined in the ensuing discussion. After Mr O'Connor had replied, the communication was remitted to a Committee of Dr Ferguson, Alex. Frazer, and Professor Baily, the last to be Convener.

Private Business.

The Minute of the previous meeting was read and approved.

The Society then adjourned.

Ninth Meeting—23rd March 1903.—Colonel M'Hardy, Vice-President of the Society, occupied the Chair.

The Reports by Committee on Mr Herdman's Direct-Reducing Levelling Staff and Hinged Joint for Levelling Staves were read and adopted by the Society.

Mr Alexander Ogilvie then read his communication on the Application of Electricity to Coal Mining. Many most interesting lantern slides were shown to illustrate the machines described by the author. These included appliances for lighting, pumping, hauling, cutting, ventilating, drilling, signalling, and firing. The saving brought about by the use of an electrical cutter was shown.

Messrs Cadell and Whitelaw having spoken on the subject, Mr Ogilvie replied, and was awarded the Society's heartiest thanks.

Private Business.

The Minute of the previous meeting was read and approved.

Professor Baily moved, and Mr Carmichael Peebles seconded, that the Treasurer be granted discharge for his intromissions for Session 1901–1902. This motion was carried unanimously.

The Society then adjourned.

Tenth Meeting—13th April 1903.—Dr R. M. Ferguson, Past-President of the Society, occupied the Chair, and was supported by Mr A. Beatson Bell.

The Report by Committee on the Scott Snell Lamp was read and approved.

Mr H. M. Cadell read his communication on the Watering of Egypt. Beginning with a general description of the country, the author described the crops and their values. Touching on the history of the first Barrage, the steps taken to remedy its defects were pointed out. The success of these measures and the benefits accruing to the country therefrom led the way for the works on the Upper Nile, which were then described. The Assiut Barrage and the Assuan Dam were described in considerable detail, and the author concluded a most interesting paper by a look into the past and one into the future. The communication was illustrated throughout by a series of admirable lantern slides.

Dr Black and Messrs Ogilvie and Bennett having spoken, and Mr Cadell having replied, he was awarded tbe Society's heartiest thanks.

Private Business.

The Minute of the previous meeting was read and approved.

The Society then adjourned.

Eleventh Meeting—27th April 1903.—Colonel M'Hardy, Vice-President of the Society, occupied the Chair.

Mr Stephen Smith submitted his communication on a Safety Hook. The hook was shown in attachment to chains of various sizes, from a gold bracelet to chains for cranes. The impossibility of the hook being shaken loose was clearly demonstrated. After discussion the communication was remitted to a Committee, consisting of Messrs Hislop, John Smith, and Proctor, the last to be Convener.

Mr Smith then exhibited his New Map of the British Empire. The distances of Britain from her various colonies were all shown to the same scale. After some discussion the communication was remitted to the following Committee:—Messrs Thomson, Horsburgh, and Dr Ferguson, Convener.

Mr Archibald Wilson next described his Feed-Gear for a Coal-Cutting Machine. By means of wheel gearing this apparatus automatically regulated the feed of that type of coal-cutter which is fed forward by rope. After discussion the paper was remitted to a Committee consisting of Messrs G. H. Geddes, John Ritchie, and H. M. Cadell, the last to be Convener.

Private Business.

The Minute of the previous meeting was read and approved.

The Society then adjourned.

Twelfth Meeting—13*th July* 1903.—Dr Dawson Turner, Vice-President of the Society, occupied the Chair.

Reports by Committees on the following communications were read and adopted by the Society:—

On Dr Dawson Turner's three communications held over from Session, 1901–1902.
On Mr Goodchild's Paper No. 4840.
On Mr O'Connor's do. No. 4845.
On Mr Smith's do. No. 4848.
On Mr Smith's do. No. 4849.
On Mr Wilson's do. No. 4850.

It was unanimously agreed to remit direct to the Prize Committee those reports which were not to hand at this meeting.

Private Business.

The Minute of the previous meeting was read and approved.

The Society unanimously elected as its Prize Committee for the current Session the following:—

Col. M'Hardy, Vice-President.
Professor Stanfield.
Professor Beare.
Messrs Blaikie.
Blanc.
Dr Ferguson.
Messrs R. G. Hislop.
Thos. Hume.
D. W. Kemp.
W. Carmichael Peebles.
Jas. Watherston.
D. M. Westland.

The Society then adjourned until the beginning of the next Session.

APPENDIX (B).

DONATIONS TO THE LIBRARY RECEIVED DURING THE SESSION 1902–1903.

Proceedings of the Royal Society, Year Book, and Reports and Proceedings of Malaria Committee.
" " Royal Society, Edinburgh.
" " Royal Physical Society.
" " Royal Dublin Society.
" " Royal Irish Academy.
" " Glasgow Philosophical Society.
" " Institution of Civil Engineers.
" " Institution of Mechanical Engineers.
" " Institution of Electrical Engineers.
" " Staffordshire Iron and Steel Institute.
" " Liverpool Literary and Philosophical Society.
" " Boston Society of Natural History.
" " American Philosophical Society.
" " American Academy of Arts and Sciences.
" " Royal Society of Victoria.
" " Royal Institution of Great Britain.
" " Canadian Institute.
" " Iron and Steel Institute.
" " Nova Scotian Institute of Science.
Transactions of the Royal Society, Edinburgh.
" " Institution of Engineers and Shipbuilders in Scotland.
" " North of England Institute of Mining and Mechanical Engineers.
" " Edinburgh Architectural Association.
" " Canadian Society of Civil Engineers.
" " St Louis Academy of Science.
" " Institution of Junior Engineers.
" " Ottawa Literary and Scientific Society.
Memoirs and Proceedings of the Manchester Literary and Philosophical Society.

Journal of the Society of Arts.
,, ,, Western Society of Engineers.
,, ,, Franklin Institute.
,, ,, Association of Engineering Societies.
British Association Report, 1901.
Smithsonian Institution Annual Report.
Memoirs of the Geological Survey of India.
Atti e Memorie della R. Accademia di Scienze Lettere ed Arti in Padova.
Atti della R. Accademia delle Scienze di Torino.
Annales de l'Association des Ingénieurs sortis des Écoles Spéciales de Gand.
Engineering.
The Engineer.
The Electrical Engineer.
The English Mechanic.
The Queen's Quarterly.
The Periodical.
Cassier's Magazine.
The Book Lover.
Machinery Market.
American Machinist.
Boston Public Library Monthly Lists of Books.
Edinburgh University Calendar.
John Crerar Library. Annual Reports.
Syllabus of Diplomas of French Universities.
Gas World.
International Engineering Congress, Glasgow, 1901. Report.
Manchester Steam Users' Association. Memo. by Chief Engineer.
Tetrahedral Principle in Kite Structure.
Report of American Association to Promote the Teaching of the Deaf.

(482 Publications in all.)

ELLICE M. HORSBURGH,
Librarian.

APPENDIX (C).

LIST OF PRIZES OFFERED BY THE ROYAL SCOTTISH SOCIETY OF ARTS FOR PAPERS WHICH MAY BE SUBMITTED DURING THE SESSION 1903–1904.

(1) A KEITH PRIZE, value Thirty Sovereigns.

For some important "Invention, Improvement, or Discovery in the Useful Arts which shall be primarily submitted to the Society" during the Session.

(2) A HEPBURN PRIZE, value Twelve Sovereigns.

For such Invention or Communication submitted to the Society as shall be approved of by the Society, or by their Prize Committee.

(3) A MAKDOUGALL-BRISBANE PRIZE, value Ten Sovereigns.

To the Authors of Communications of Merit, or for Inventions which shall be approved of by the Society, or its Committee, and judged by them deserving of such distinction.

(4) REID and AULD PRIZES. Value about Seven Sovereigns.

For the First, Second, and Third best Models of anything new in the Art of Clock or Watch Making—by Journeymen or Master Watch and Clock Makers—if these should be considered worthy of prizes. The sum mentioned above to be divided in such proportions as the Prize Committee shall fix. The Society, if it sees fit, may add to the amount available for these Prizes out of its general funds.

The Society may offer a Special Keith Prize to be competed for during the Session, details of which will be submitted to the Society at a later date.

The Society proposes to award the above Prizes for approved Communications submitted to the Society by Fellows or others, relative to Inventions, Discoveries, and Improvements in the Industrial Arts, or to means by which the Natural Productions of the Country may be made more available, whether the subjects treated have been patented or not. The Society suggests the following as a few of the many subjects suitable for such Communications:—

1. *Mechanical Arts.*

Inventions of, or Improvements relating to, Wind and Water Prime Motors; Steam and other Heat Engines; Pumping, Blowing, Rolling, Sawing, Agricultural and other Engines and Machines; Machinery used in the manufacture of Cotton or other Textile Fabrics; Shipbuilding, including Machinery, Appliances, and Materials used in same; Marine Propellers; Lighthouses and Lighthouse Appliances; Railways, including Structural Work, Plant, and Signals; Electrical Machinery and Apparatus; Mechanical Photographic Processes; Fireproof Buildings; Water Works; Sewage Works; Methods and Appliances for improving the Sanitary Conditions of Towns; Appliances for the Prevention of Smoke and Extinction of Fires; Gas Works and Gas Lighting; Canals, Inland Navigation, and Machinery employed for Canal Traffic, including Locks, Inclines, and Lifts; Hydraulic Machinery as applied to Lifts, Cranes, Printing Presses, Organ Blowers, and other purposes; Tools, Implements, and Appliances used in the various Trades; Bricks, Tiles, Cements, and Mortars; Printing Machines and Appliances connected therewith; Stereotyping and other similar Processes; Processes for the Preservation of Timber and Metals; Optical and other Scientific Apparatus; etc., etc., etc

2. *Chemical Arts.*

Inventions or Improvements relating to Processes for the Treatment of Natural Productions; the Manufacture of Chemical Substances used in Commerce, Science, or Art; the Application of Chemistry to particular Manufactures and Trades; etc., etc., etc.

3. *Fine Arts.*

INVENTIONS or IMPROVEMENTS relating to all kinds of Photographic Processes as applied to the Production of Illustrations; Engraving Processes; Lithography; Die-Sinking; Methods of applying Colours for Decorative Purposes; the Use and Treatment of various Materials for Wall Decoration; etc., etc., etc.

GENERAL OBSERVATIONS.

Communications are also invited describing Processes and Important Works, although no claim may be made by the Author on the score of Invention or the introduction of Improvements.

The Society reserves the right to withhold any of the Prizes offered for competition if the Papers submitted do not possess sufficient merit, or to award Prizes of smaller amounts, or to split up the amounts into a larger number of Prizes, as the Prize Committee may see fit.

In preparing Papers, the descriptions of Inventions, etc., should be full and distinct, written legibly on one side only of Foolscap paper, and when necessary, the Communications should be accompanied by Specimens, Drawings, or Models. The Drawings should be in bold lines about one-quarter of an inch broad, and strongly coloured, so as to be easily seen at about the distance of 30 feet when hung up in the Hall. Letters or Figures of Reference should be at least 1½ inch long. When necessary, smaller and more minutely detailed Drawings should accompany the larger ones, for the use of the Committee, having the same letters of reference.

The Society shall be at liberty to publish in their *Transactions* Copies or Abstracts of all Papers submitted to them.

All Models, Drawings, etc., accompanying Papers for which Prizes are given shall be held to be the property of the Society; but the value of Models, if retained, will be allowed for.

Communications, Models, etc., are to be addressed to the Secretary, 117 George Street, Edinburgh, Postage or Carriage Paid. Communications lodged after the 1st of March may not be read or reported on till the following Session.

By Order of the Society,

WM. ALLAN CARTER,

Secretary.

APPENDIX (D).

REPORT OF THE COMMITTEE APPOINTED TO AWARD PRIZES FOR COMMUNICATIONS READ OR REPORTED ON DURING THE SESSION 1902–1903.

Your COMMITTEE having met and carefully considered the Communications laid before and definitely disposed of by the Society, during the Session 1902–1903, begs to report that it has awarded the following Prizes and Medals:—

To Dr DAWSON TURNER,—for his papers on "Improvements in Röntgen Apparatus" (No. 4819), "An Apparatus for measuring the Electrical resistance of the Blood, with some Deductions therefrom" (No. 4820), and "An Experiment with Ultra-Violet Light" (No. 4824),—read on the 9th of December 1901 and 27th January 1902,

A Keith Prize, value Twenty Sovereigns.

To FRANCIS G. BAILY, M.A.,—for his paper on "Wireless Telegraphy" (No. 4843),—read on the 9th of February 1903,

A Makdougall-Brisbane Prize, value Ten Sovereigns.

To ARCHIBALD WILSON, A.M.I.E.E.,—for his paper on "A new Feed-Gear for a Coal-cutting Machine" (No. 4850),—read on the 27th of April 1903,

A Hepburn Prize, value Ten Sovereigns.

To HENRY O'CONNOR, Assoc.M.Inst.C.E.,—for his paper on "The Measurement of Light and a New Photometer' (No. 4845), —read on the 9th of March 1903,

A Reid and Auld Prize, value Seven Sovereigns.

To THOMAS RODGER PROCTOR,—for his paper on "A Ball Valve Flushing Cistern for W.C.'s without Syphon, and Silent" (No. 4835),—read on the 24th of November 1902,

A Keith Prize, value Five Sovereigns.

To MONTAGUE T. PICKSTONE,—for his paper on "British Manufacture and Foreign Competition" (No. 4842),—read on the 26th of January 1903,

A Hepburn Prize, Value Five Sovereigns.

To C. SCOTT SNELL,—for his paper on "High-Pressure Gas Lighting and the Scott Snell Lamp" (No. 4844),—read on the 23rd of February 1903,

A Keith Prize, value Five Sovereigns.

To ALEXANDER OGILVIE, B.Sc.,—for his paper on "The Application of Electricity to Coal Mining" (No. 4846),—read on the 23rd of March 1903,

A Makdougall-Brisbane Prize, value Three Sovereigns.

To HENRY M. CADELL, B.Sc., F.R.S.E.,—for his paper on "The Watering of Egypt" (No. 4847),—read on the 13th of April 1903,

The Society's Complimentary Silver Medal.

That the hearty thanks of the Society are due to the President, Mr F. GRANT OGILVIE, for his Opening Address, delivered on the 10th of November 1902, and to Messrs G. W. HERDMAN, ARCHIBALD M'KINNON, J. G. GOODCHILD, D. G. EDNIE, and STEPHEN SMITH for their communications.

The Committee also recommend that the Society should make a grant towards the cost of the models of windows submitted by ARCHIBALD M'KINNON and D. G. EDNIE, *of Three Sovereigns in each case.*

All of which is reported in name and by order of the Committee by

WM. ALLAN CARTER, *Secretary*,
Convener ex officio.

SOCIETY'S HALL, 117 GEORGE STREET,
EDINBURGH, 14*th October* 1903.

APPENDIX (E).

Royal Scottish Society of Arts.

ABSTRACT OF THE ACCOUNTS OF THE SOCIETY FOR 1901–1902.

I. GENERAL FUND.

CHARGE.

Income—	
Arrears of Subscriptions at 15th November 1901	£9 9 0
Subscriptions for Session 1901–1902	104 9 6
	£113 18 6
Less—Unpaid at 15th November 1902	11 11 0
	£102 7 6
Balance at Credit of Building Fund	59 14 5
Interest received	1 3 0
Miscellaneous Receipts	1 2 6
Total Income	£164 7 5
Sum on Deposit with Commercial Bank at 15th November 1901	7 5 1
Subscriptions Unpaid at 15th November 1902	11 11 0
	183 3 6
Balance due to the Treasurer at 15th November 1902	20 18 1
Sum of the Charge..	£204 1 7

DISCHARGE.

Ordinary Expenditure—				
Printing and Advertising		£21 2 3		
Salaries and Expenses of Collection,	£100 16 0			
Less—Charged to Prize Funds	5 4 9			
		95 11 3		
Expenses connected with the Society's Printed Transactions		32 15 11		
Interest paid to Keith Fund on Loan		1 19 5		
Miscellaneous Payments (Lantern and fittings, £21, 18s.)		34 0 6		
Total Ordinary Expenditure....			£185 9 4	
Prizes Awarded			6 0 3	
Arrears of Subscriptions written off			1 1 0	
Subscriptions Outstanding at 15th November 1902			11 11 0	
Sum of the Discharge ...				204 1 7

II. KEITH BEQUEST.

CHARGE.

Sum on Deposit with the Commercial Bank at 15th November 1901		£50 6 4
Income—		
Dividends from Stocks, viz. :—		
Edinburgh and Leith Gas Annuity	£28 3 6	
Great North of Scotland Railway Company Debenture Stock	18 15 8	
Forth and Clyde Junction Railway Preference Stock	4 13 11	
North British Railway Company Consolidated Lien Stock...	11 5 11	
	£62 19 0	
Interest on Loan to General Fund	1 19 5	
Bank Interest received	1 0 5	
		65 18 10
Sum of the Charge...		£116 5 2

II. KEITH FUND.

Charge Amount......Forward,		£116 5 2

DISCHARGE.

Expenditure—		
Prizes awarded	£31 0 0	
Commission on Revenue, credited General Fund	3 3 3	
	£34 3 3	
Sum on Deposit with the Commercial Bank at 15th November 1902	80 2 6	
Balance due by the Treasurer at do.	1 19 5	
Sum of the Discharge		116 5 2

III. REID AND AULD BEQUEST.

CHARGE.

Sum on Deposit with the Commercial Bank at 15th November 1901		£121 10 2
Income—		
Interest on Great North of Scotland Railway Company Debenture Stock	£16 18 1	
On Forth and Clyde Junction Railway Preference Stock	2 7 2	
On North British Railway Consolidated Lien Stock	3 15 0	
On Bank Deposit Receipts	2 4 9	
		25 5 0
Sum of the Charge...		£146 15 2

DISCHARGE.

Expenditure—		
Donations to poor Clockmakers in terms of the Bequest	£6 0 0	
Commission on Revenue, credited General Fund	1 5 3	
	£7 5 3	
Sum on Deposit with the Commercial Bank at 15th November 1902	139 9 11	
Sum of the Discharge		146 15 2

IV. BRISBANE BIENNIAL PRIZE FUND.

CHARGE.

Sum on Deposit with the Commercial Bank at 15th November 1901		£47 18 9
Income—		
Interest on Forth and Clyde Junction Railway Preference Stock	£7 1 0	
Bank Interest	0 17 1	
		7 18 1
Sum of the Charge...		£55 16 10

DISCHARGE.

Expenditure—		
Prize awarded	£5 0 0	
Commission on Revenue, credited General Fund	0 8 0	
Sum on Deposit with the Commercial Bank at 15th November 1902	50 8 10	
Sum of the Discharge		55 16 10

V. HEPBURN PRIZE FUND.

Charge.

Sum on Deposit with the Commercial Bank at 15th November 1901		£61 9 8
Income—		
Dividends on Caledonian Railway Company Stocks...............	£6 19 11	
Bank Interest..	1 2 2	
		8 2 1
Sum of the Charge...		£69 11 9

Discharge.

Expenditure—		
Prizes awarded..	£8 0 0	
Commission on Revenue, credited General Fund..................	0 8 3	
Sum on Deposit with the Commercial Bank at 15th November 1902	61 3 6	
Sum of the Discharge...		69 11 9

VI. BUILDING FUND.

Charge.

Rents drawn from Letting the Hall..		£225 2 6

Discharge.

Payments on Account of the Hall, viz., Taxes, Feu-duty, Insurance, Coals, Gas, Cleaning, &c., and Hallkeeper's Salary..	£150 0 3	
Repairs and alterations to the Hall..................................	15 7 10	
		165 8 1
Balance transferred to the General Fund, page 17....		£59 14 5

FUNDS OF THE SOCIETY,

As at 15th November 1902, per Report of the Auditor.

I. GENERAL FUND.

Price of Hall in George Street and Furnishings, and of the additional Premises purchased at Whitsunday 1863..	£2712 0 3
Arrears of Annual Contributions..........	11 11 0
	£2723 11 3
Deduct Loan from Keith Fund, £70, and balance due to Treasurer, £20, 18s. 1d.	90 18 1
Amount of General Fund...	£2632 13 2

II. KEITH BEQUEST.

£30 Annuity of the Edinburgh and Leith Gas Commission.....	£870 0 0	
£500 Great North of Scotland Railway Company Debenture Stock..	612 10 0	
£100 Preference Stock No. 1 of the Forth and Clyde Junction Railway Company..	137 0 0	
£300 4 per cent. Consolidated Lien Stock of the North British Railway Company..	406 15 0	
Sum on Deposit with the Commercial Bank........................	80 2 6	
Loan to General Fund..	70 0 0	
Balance in Treasurer's hands..	1 19 5	
		2178 6 11
Carry forward,		£4811 0 1

II. FUNDS OF THE SOCIETY—continued.

Brought forward,		£4811 0 1
III. REID AND AULD BEQUEST.		
£450 Great North of Scotland Railway Company Debenture Stock	£551 5 0	
£50 Preference Stock No. 1 of the Forth and Clyde Junction Railway Company	68 10 0	
£100 4 per cent. Consolidated Lien Stock of the North British Railway Company	135 11 10	
Sum on Deposit with the Commercial Bank	139 9 11	
		894 16 9
IV. BRISBANE PRIZE FUND.		
£150 Preference Stock No. 1 of the Forth and Clyde Junction Railway Company	£205 10 0	
Sum on Deposit with the Commercial Bank	50 8 10	
		255 18 10
V. HEPBURN PRIZE FUND.		
£175 Caledonian Railway Company Consolidated 4 per cent. Stock, No. 2	£209 2 6	
£11 do., No. 1	13 6 0	
Sum on Deposit with the Commercial Bank	61 3 6	
		283 12 0
Total Property and Funds under Charge of the Society as at 15th November 1902		£6245 7 8

C. J. SHIELLS, *Treasurer.*

EDINBURGH, 29*th January* 1903.—I have examined and audited the Accounts of the Treasurer to the Royal Scottish Society of Arts for the Session 1901–1902, of which the foregoing is an Abstract, and beg to report that I have found the same to be correctly stated and sufficiently vouched. I have also examined the securities for the Invested Funds of the Society, and have found them in order.

GEORGE H. CARPHIN, C.A., *Auditor.*

APPENDIX (F).

LIST

OF THE

OFFICE-BEARERS AND FELLOWS

OF THE

ROYAL SCOTTISH SOCIETY OF ARTS.

THE KING, PATRON.

OFFICE-BEARERS FOR SESSION 1903–1904.

As elected on 9th November 1903.

President . . . Dawson Turner, M.D., 37 George Square.

Vice-Presidents . . { Lieut.-Col. A. B. M'Hardy, C.B., 3 Ravelston Park. Henry M. Cadell, B.Sc., F.R.S.E., of Grange, Bo'ness.

Secretary . . . { William Allan Carter, M. Inst. C.E., F.R.S.E., 117 George Street.

Assistant Secretary . { Andrew Wilson, Assoc. M. Inst. C.E., 5 St Andrew Square.

Treasurer . . . C. J. Shiells, C.A., 141 George Street.

Editor of Transactions { Richard Stanfield, F.R.S.E., M. Inst. C.E., Heriot-Watt College.

Librarian . . . { E. M. Horsburgh, M.A., B.Sc., 11 Granville Terrace.

Medallists . . . Alexander Kirkwood & Son, 9 St James Sq.

Officer . . . . Francis Duffy, 117 George Street.

Councillors.

Alexander Clark, Assoc. M. Inst. C.E., 11 Blacket Place.

The Rt. Hon. Sir Robert Cranston, Lord Provost, 33 Princes Street.

A. Donald Mackenzie, 14 Greenhill Park.

W. Carmichael Peebles, Hope Lodge, Trinity.

Francis G. Baily, M.A., Heriot-Watt College.

T. Hudson Beare, M. Inst. C.E., Edinburgh University.

Gilbert Thomson, C.E., 164 Bath Street, Glasgow.

John Ayling, 22 Inverleith Place.

Alexander W. Cockburn, C.E., 39 York Place.

G. H. Gemmell, F.I.C., F.C.S., 14 Thirlstane Road.

Alexander Ogilvie, B.Sc., Leith Electric Works.

James Pirie, C.E., 135 George Street.

LIST OF THE ORDINARY FELLOWS AND ASSOCIATES

AS AT 16TH NOVEMBER 1903.

*Those marked * are Life Fellows.*

NOTE.—Fellows may become "Life Fellows" at any time on paying £10, 10s., from which they are allowed a deduction of half the amount they may have paid previously in Annual Contributions.

1865 *Aitken, Henry, manager, Darroch Coal and Iron Works, Falkirk
1871 *Aitken, John, F.R.S.E., Ardenlea, Falkirk
1851 *Alexander, William, M.E.
1896 *Archer, Robert S., Craigleith, 5 Lowwood Road, Birkenhead
1868 *Archibald, John, M.D. (No address)
1891 Ayling, John, 22 Inverleith Place, *Councillor*

1896 Baily, Francis G., M.A., F.R.S.E., M.I.E.E., Professor of Applied Physics, Heriot-Watt College, *Councillor*
1895 Barron, James, M. Inst. C.E., 1 Bon Accord Street, Aberdeen
1878 *Barton, John Fraser, plumber, 11 Forrest Road
1901 Beare, T. Hudson, B.Sc., M. Inst. C.E., M. Inst. M.E., F.R.S.E., Professor of Engineering, Edinburgh University, *Councillor*
1871 *Beatson, William, burgh surveyor, Town Hall, Leith
1850 *Bell, Alexander Melville, 1525 35th Street, West Washington
1859 *Bell, Andrew Beatson, advocate, F.R.S.E., 17 Lansdowne Crescent
1889 Bell, Duncan, Queen's Hotel, Musselburgh
1902 Bennett, James B., Assoc. M. Inst. C.E., F.R.S.E., 12 Hill Street
1879 *Black, William Galt, F.R.M.S., 2 George Square
1883 Blaikie, Walter Biggar, F.R.S.E., printer, 11 Thistle Street
1879 *Blanc, Hippolyte Jean, architect, 25 Rutland Square
1877 *Blyth, James, F.R.S.E., Professor of Mathematics and Natural Philosophy, Andersonian University, Glasgow
1888 Boa, Peter, pharmaceutical chemist, 119 George Street
1892 Bonar, Horatius, W.S., 3 St Margaret's Road
1853 *Bow, Robert Henry, C.E., F.R.S.E., 7 South Gray Street
1868 *Boyd, James L., S.S.C., Glendouglie, Glenfarg
1890 Brebner, R. C., 28 Hermitage Gardens
1864 *Brown, Geo. Bruce, architect. (No address)
1880 *Bruce, A. Fairlie, C.E. (No address)
1868 *Bruce, C., banker, 3 Melville Crescent
1850 *Bruce, George Cadell, C.E.
1893 Buchan, Mathew, electrician, 67 George Street
1893 Buchanan, James, Oswald Road
1879 *Buchanan, John, C.E., 12 Hill Street

1891 Cadell, Henry Moubray, B.Sc., F.R.S.E., of Grange, Bo'ness, *Vice-President*
1879 *Carfrae, George Somervel, C.E., 1 Erskine Place
1880 *Carmichael, Neil, M.D., 23 Nithsdale Road, Pollokshields, Glasgow
1892 *Carphin, G. H., C.A., 3 Abinger Gardens, Murrayfield
1840 *Carstairs, Drysdale, merchant, Hailes House, Fairfield, Liverpool
1875 *Carter, William Allan, M. Inst. C.E., F.R.S.E., 5 St Andrew Square, *Secretary*
1872 *Cattanach, Peter Lorimer, advocate, 14 London Street
1867 *Cay, William Dyce, M. Inst. C.E., F.R.S.E., 1 Albyn Place
1860 *Charnock, Richard Stephen, Yorick Club, 30 Bedford Street, Strand, London, W.C.
1879 *Clark, Alexander, Assoc. M. Inst. C.E., 8 Bright's Crescent, *Councillor*

1878 *Clement, Adam Ferguson, telegraph engineer, Egmont, 59 Braid Road
1901 Cockburn, Alexander W., civil engineer, 39 York Place, *Councillor*
1889 Colam, William N., M. Inst. C.E., 57 Henderson Row
1862 *Copland, Harry Y. D., 21 Manor Place
1876 *Cormack, D. Adair, marine engineer, 17 Abercorn Terrace, Portobello
1872 *Couper, Charles Tennant, advocate, 3 Charlotte Square
1888 Cowan, John, 6 Salisbury Road
1883 Crabbie, George, merchant, 8 Rothesay Terrace
1885 Cran, John, mechanical engineer, Albert Engine Works, Leith
1876 *Cranston, The Rt. Hon. Sir Robert, Lord Provost, 33 Princes Street, *Councillor*
1879 *Cunningham, James H., Assoc. M. Inst. C.E., 2 Ravelston Place

1892 Davidson, John, Langley Park, Wick
1882 *Dickson, Lamont, C.E., 135 George Street
1887 Drysdale, Alexander, builder, 70 Pilrig Street
1894 Dunbar, James, Elgin House, Easter Road
1893 *Duncan, D. J. Russell, 28 Victoria Street, London, S.W.

1896 Eaton, Edmond, 99 Cannon Street, London, E.C.
1892 Elgin and Kincardine, The Right Hon. The Earl of, K.G., Broomhall, Dunfermline

1878 *Farquharson, Thomas Ker, accountant, 100 Thirlstane Road
1857 *Ferguson, R. M., LL.D., Ph.D., F.R.S.E., 5 Douglas Gardens
1895 *Ferranti, S. Z. de, engineer, Ingleside, Lyndhurst Road, Hampstead, London, N.W.
1860 *Firth, William, secy., N. B. Rubber Co., Wideford, Granton Road
1894 Foulis, David, jun., 42 Shandwick Place
1850 *Fraser, Alexander, printer, 17 Eildon Street
1879 *Frazer, Alexander, M.A., optician, 22 Teviot Place

1856 *Geddes, A. C., C.E., 14 Ettrick Road
1896 *Geddes, C. D., mining engineer, 21 Young Street
1856 *Geddes, G. H., M.E., 21 Young Street
1899 Gemmell, George H., F.I.C., F.C.S., 14 Thirlstane Road, *Councillor*
1889 Gibson, J. D., ordained surveyor, 60 Frederick Street
1887 Gilmour, George, builder, 19 Rosslyn Crescent
1871 *Glover, Thomas Craigie, C.E., 29 Hope Terrace, Grange
1857 *Gordon, Alexander. (No address)
1851 *Gordon, James Newall, London
1860 *Gray, Rev. W. H., M.A., D.D., 3 Carlton Terrace
1893 *Grieve, George K., 12 Cambridge Avenue

1860 *Hardie, Walter, 5 Bellevue Street
1888 *Harris, William A., F.S.S., F.I. Inst., secretary, Phœnix Fire Office, Exchange, Liverpool
1870 *Hartnell, Wilson, engineer, Park Row, Leeds
1879 *Heath, Thomas, assistant observer, Royal Observatory
1891 *Herdman, G. W., M.A., B.Sc., Assoc. M. Inst. C.E., Irrigation Department, Pretoria
1898 Herring, W. R., C.E., Granton House, Granton
1871 *Hislop, George Robertson, F.C.S., gas engineer, Blackstone Road, Paisley
1898 *Hislop, Laurence, gas engineer, Uddingston
1894 Hislop, R. G., 11 Pitt Street
1863 *Hogue, D. W., M.D., dentist, 8 Glencairn Crescent
1900 *Horne, Wm. James, A.M.I.E.E., South African College, Cape Town
1900 Horsburgh, E. M., M.A., B.Sc., 11 Granville Terrace, *Librarian*
1868 *Horsburgh, John, Aberdour House, Aberdour
1893 Horsburgh, J. Alfred, photographer, 4 West Maitland Street
1892 Howkins, John, C.E., Granton
1897 Hume, John, 46 Torphichen Street
1888 Hume, Thomas, plumber, 2A Stafford Street
1876 *Hutchison, James T., 12 Douglas Crescent

1882 *Inglis, John William, F.R.S.E., M. Inst. C.E., Paeroa, Auckland, New Zealand

1884 Jenkinson, Alexander Dixson, glass manufacturer, 10 Princes Street

1872 *Kemp, D. William, Ivy Lodge, Trinity
1872 *Key, William, Drumcarro, Newlands, near Glasgow
1902 Kirkwood, Alexander, 9 St James Square, *Medallist*
1898 Knoblauch, Louis, merchant, 22 Baltic Street, Leith
1887 Knox, Patrick, plumber, 31 Crichton Place
1899 Kyles, David, plumber, 14 Torphichen Place

1884 Laidlaw, Robert, engineer, 147 East Milton Street, Glasgow
1894 Laing, J. H. A., M.B., C.M., 11 Melville Street
1902 Laurie, A.P., D.Sc., Principal, Heriot-Watt College
1856 *Lees, William, A.M., 12 Morningside Place
1892 Leighton, John T., 20 Picardy Place
1873 *Lewis, David, Roselea Villa, Grange
1877 *Lockie, John, engineer, 2 Commercial Street, Leith

1882 *Macdonald, James, plumber, 3 Dundas Street
1889 *Macdonald, The Right Hon. Sir J. H. A., K.C.B., LL.D., F.R.SS. (L. & E.), M.I.E.E., Lord Justice-Clerk of Scotland, 15 Abercromby Place
1898 M'Greggor, Walter, accountant, 32 York Place
1898 M'Hardy, Lieut.-Col. A. B., C.B., 3 Ravelston Park, *Vice-President*
1888 Mackenzie, A. Donald, 14 Greenhill Park, *Councillor*
1867 *Maclagan, R. Craig, M.D., 5 Coates Crescent
1872 *M'Neill, John, plumber, Balhousie House, Perth
1899 Maloney, Bernard J., 2 West Crosscauseway
1886 *Martin, William James, C.E., Rosario de Santa Fé, S. America
1884 Massie, James, burgh engineer, 1 Parliament Square
1876 *Mather, Edward, Marchfield, Davidson's Mains
1881 *Maxwell-Müller, R. W., C.E.
1894 Meek, John, watchmaker, 13 Bristo Place
1863 *Menzies, Duncan, C.E., 39 York Place
1865 *Menzies, Sir Wm. John, W.S., Canaan Cottage, Grange Loan
1858 *Mercer, James Tod, advocate
1894 Miller, James Newlands, Broomlea, Joppa
1890 Miller, Robert, 38 Lauder Road
1879 *Milne, James, Herdmanston, Pencaitland
1848 *Milne, John Kolbe, dressing-case maker, Kevock Tower, Lasswade
1888 Mitchell, James D., 30 Fettes Row
1889 *Moncrieff, D. Scott, W.S., 28 Rutland Square
1872 *Morrison, James, City of Glasgow Improvement Trust, 98 Sauchiehall Street, Glasgow
1857 *Muir, John, brewer, 28 N. Back of Canongate
1866 *Muir, W. J. Cockburn, C.E.
1861 *Muirhead, Andrew, painter, 14 Castle Street
1902 Murdoch, James, late Secretary to the Board of Northern Lighthouses, St Kilda, York Road, Trinity
1884 Murray, Robert M., M.A., M.B., M.R.C.P., 11 Chester Street

1874 *Noble, William, millwright, 27 Rosebank Cottages

1902 O'Connor, Henry, Assoc. M.Inst.C.E., P. Pres. Soc. Eng., 1 Drummond Place
1898 Ogilvie, Alexander, electrical engineer, Leith Electric Works, *Councillor*
1889 Ogilvie, F. Grant, M.A., B.Sc., F.R.S.E., 15 Evelyn Gardens, London, S.W.

1885 Paterson, Oscar, glass stainer, 118 West Regent Street, Glasgow
1894 Peebles, W. Carmichael, Hope Lodge, Trinity, *Councillor*
1902 Pickstone, Montague T., electrical engineer, Tay Works
1882 *Pirie, James, C.E., 135 George Street, *Councillor*
1878 *Proctor, Thomas Rodger, 21 West Maitland Street
1864 *Proudfoot, David C., City Road Trust, 10 City Chambers
1896 Purvis, George Carrington, M.D., Bacteriological Institute, Grahamstown, Cape Colony

1894 Readman, James B., D.Sc., F.R.S.E., 4 Lindsay Place
1902 Reis, Alphonse Louis, ophthalmic optician, The Laurels, Bright's Crescent
1890 *Ritchie, Charles, S.S.C., 20 Hill Street
1865 *Ritchie, Frederick James, clockmaker, 25 Leith Street
1866 *Ritchie, Jas., M.R.C.S., M.B., C.M., 22 Charlotte Square
1896 Ritchie, James, clockmaker, 25 Leith Street
1879 *Ritchie, John, C.E., The Knowe, Lygon Road
1857 *Rollo, Right Hon. Lord, Duncrub House, Bridge of Earn
1853 *Rose, J. T., shipbuilder. (No address)
1875 *Russell, Sir J. A., M.A., M.B., F.R.S.E., Woodville, Canaan Lane

1896 Sanderson, Frederick R., 5 Carlton Terrace
1867 *Sanderson, William, rectifier, Talbot House, Ferry Road
1878 *Scott, David A., S.S.C., 20 St Andrew Square
1900 Scott, J. Gray, A.I.E.E., Electric Light Station, Croydon
1862 *Shedden, Thomas, M.A., 47 West Cromwell Road, London
1893 Shiells, C. J., C.A., 141 George Street, *Treasurer*
1883 *Shiells, Henry Kenward, C.A., 141 George Street
1856 *Slight, G. H., Kendall, Meadfoot Road, Torquay
1902 Smith, John, engineer, Penicuik
1895 *Smith, J. Ciceri, 61 Hatton Gardens, London, E.C.
1877 *Smith, J. Turnbull, C.A., LL.D., 5 Belgrave Place
1894 Smith, Stephen, B.Sc., 47 George Street
1889 Stanfield, Richard, F.R.S.E., M. Inst. C.E., Professor of Engineering, Heriot - Watt College, *Editor of Transactions*
1850 *Stark, James, M.D., F.R.C.P., F.R.S.E. (No address)
1879 *Steuart, Robert Bromfield, C.E. (No address)
1896 Stevenson, Alexander, North British Distillery
1881 *Stevenson, Charles Alexander, B.Sc. Edin., 28 Douglas Crescent
1879 *Stevenson, David Alan, C.E., B.Sc. Edin., F.R.S.E., 84 George Street
1884 *Stevenson, Peter, instrument maker, 14 Seton Place
1850 *Stewart, James W., C.E. (No address)
1857 *Sturrock, John, Peffermill House, Liberton
1899 Sutherland, Charles S., 20 Lauriston Gardens

1876 *Taylor, William, M.D., 12 Melville Street
1851 *Tennant, Sir Charles, Bart., St Rollox, Glasgow
1860 *Thomson, Alex., teacher, 40B George Square
1883 Thomson, Gilbert, C.E., 164 Bath Street, Glasgow, *Councillor*
1878 *Thorburn, William, builder, 86 Buccleuch Street
1894 *Turnbull, William James, 16 Grange Terrace
1892 Turner, Dawson, M.D., 37 George Square, *President*

1903 Vawdrey, R. W., B.A. (Cantab.), Assoc. M. Inst. C.E , 42 Frederick Street

1882 Waldie, David, coal merchant, 25 Douglas Crescent
1892 Walmsley, R. M., Professor, 23 Hilldrop Road, Camden Road, London, N.
1856 *Waterston, George, stationer, 35 George Street
1890 Waterston, James H., 37 Lutton Place
1866 *Watherston, James, builder, Pentland Villa, West Coates
1892 *Watson, James, M. Inst. C.E., Town Hall, Bradford
1892 Wemyss and March, The Right Hon. The Earl of, Gosford House, Aberlady
1879 *Westland, David Monro, M.Inst.C.E., 135A George Street
1861 *Whimster, T., gas engineer, 17 York Place, Perth
1879 *White, John, C.E., 17 E. Claremont Street
1884 Whyte, Peter, M. Inst. C.E., superintendent, Leith Docks, 4 Magdala Crescent
1877 *Wilkins, Samuel B., 17 Wellington Street, Portobello

1898 Wilson, Andrew, Assoc. M. Inst. C.E., 5 St Andrew Square, *Assistant Secretary*

1898 Wilson, Archibald, A.M.I.E.E., electrical engineer, Leith Electric Works

1859 *Wyllie, James S., 21 Barnton Terrace

1890 *Yooll, W. Graham, oil refiner, 45 Stirling Road, Trinity

1893 *Young, Robert, 3 Abbotsford Park

TOTAL ORDINARY FELLOWS 206.

Associate.

1902. Hunter, James, engineer, 23 Craigmillar Park.

APPENDIX (G).

PROCEEDINGS OF THE ROYAL SCOTTISH SOCIETY OF ARTS, SESSION 1903–1904 (BEING THE 83RD SESSION).

First Meeting.—THE ANNUAL GENERAL MEETING of the Royal Scottish Society of Arts was held in the Hall, 117 George Street, on Monday evening, the 9th of November 1903, at 8 o'clock. Colonel M'Hardy, Vice-President of the Society, occupied the Chair, and was supported by Dr Ferguson.

In the unavoidable absence of the President, Dr Dawson Turner delivered the Opening Address for Session 1903–1904. Dealing with the continued decrease in the membership, Dr Turner pointed out that the meetings might be made more convenient for some of the Fellows by being held in the afternoon instead of in the evening. The communications brought before the Society the previous Session were next reviewed. Dr Turner then described what he characterised as the discovery of the year—radium. Its properties and possible applications were discussed, and in conclusion those present had an opportunity of seeing specimens of radium in the Society's library.

Dr Turner was, on the motion of Dr Ferguson, heartily thanked for his able and interesting address.

The Secretary then read the Report of the Prize Committee, and the Chairman presented the Prizes to the various recipients.

Private Business.

The Minute of the meeting of 13th July was read and approved.

The Society elected its Officers for Session 1903–1904, as follows :—

President, . .	Dawson Turner, M.D.
Vice-Presidents, .	Col. A. B. M'Hardy, C.B. Henry M. Cadell, B.Sc., F.R.S.E.
Secretary, . .	Wm. Allan Carter, M.Inst.C.E., F.R.S.E.
Assistant Secretary, .	Andrew Wilson, Assoc.M.Inst.C.E.
Treasurer, . .	C. J. Shiells, C.A.
Editor of Transactions,	Richard Stanfield, M.Inst.C.E., F.R.S.
Librarian, . .	Ellice M. Horsburgh, M.A., B.Sc.
Medallists, . .	Alex. Kirkwood & Son.
Officer, . . .	Francis Duffy.

Councillors.

Alex. Clark, Assoc.M.Inst.C.E.
The Rt. Hon. Sir Robert Cranston, Lord Provost of the City.
A. Donald Mackenzie.
W. Carmichael Peebles.
Francis G. Baily, M.A., F.R.S.E.
T. Hudson Beare, B.Sc., M.Inst.C.E.
Gilbert Thomson, C.E.
John Ayling.
Alex. W. Cockburn, C.E.
G. H. Gemmell, F.I.C., F.C.S.
Alexander Ogilvie, B.Sc.
James Pirie, C.E.

The Society then adjourned.

Second Meeting—In the Chemistry Class Room, New University, 23*rd November* 1903.—Dr Dawson Turner, President of the Society, occupied the Chair.

Dr Hugh Marshall submitted his paper on the Use of Carburetted Air. The principle adopted by Dr Marshall in the apparatus exhibited was to use an absorbent block saturated with petrol, and allow air to pass by gravitation through perforations in the block and thus become carburetted. In the earlier types of lamp the carburetter was at a higher level than the lamp ; but the author had devised a lamp in which the carburetter was below, and the effect of gravity overcome by means of the induced draught. Many interesting experiments illustrated the paper, at the conclusion of which Messrs Cadell, Proctor, Macdonald, and the Secretary spoke. The communication was remitted to a Committee consisting of Messrs Gemmell and O'Connor and Professor Baily, Convener.

The Society then adjourned.

Third Meeting—14*th December* 1903.—Dr Dawson Turner, President of the Society, occupied the Chair, and was supported by Colonel M'Hardy and Mr H. M. Cadell, Vice-Presidents.

Mr Arthur A. W. Wynne read his paper on Steam Turbine Machinery. The development of the turbine from the simple appliance of Hero of Alexandria to the mighty engines of the present was described. In particular, the Parsons type of turbine was described in some detail. Its applicability to marine, electrical, and general purposes was shown. The paper was illustrated throughout by lantern slides of much interest. In the discussion which followed Messrs Mackenzie, Cadell, Stanfield, Houston, Baily, and the Secretary took part. Mr Wynne having replied, was awarded the heartiest thanks of the Society.

Private Business.

The Minutes of the two previous meetings were read and approved.

Johnstone Christie Wright, F.R.S.E., was unanimously admitted an Ordinary Fellow of the Society.

The Society then adjourned.

Fourth Meeting—11*th January* 1904.—Dr Dawson Turner, President of the Society, occupied the Chair, and was supported by Professors Baily and Stanfield.

Mr Basil Pilkington described his Apparatus for Automatically Regulating Temperatures by Electrical Means. A compound strip of brass and iron changed its curvature under the influence of varying temperatures, and made or broke an electrical circuit connected with an electrical heater. Professor Baily and Messrs Wilson and Ritchie joined in the discussion which followed. The communication was remitted to a Committee consisting of Messrs Wilson, Ogilvie, and Buchan, the last to be Convener.

Mr Muir then described and exhibited his Combined Level, Plumb-rule, and Batter Gauge. An enclosed pendulum actuated an index-finger moving along a graduated scale, and the degree of divergence from the vertical or horizontal positions was thus shown. Messrs Hislop, Stanfield, Baily, Kemp, Hume, and the Secretary took part in the ensuing discussion, after which the communication was remitted to Messrs Hume, Hislop, and Cockburn, Convener.

Private Business.

The Minute of the previous meeting was read and approved.

James Leslie was proposed, balloted for, and duly elected an Ordinary Fellow of the Society.

The Society then adjourned.

Fifth Meeting—25th January 1904.—Dr Dawson Turner, President of the Society, occupied the Chair, and was supported by Mr H. M. Cadell, Vice-President.

Mr A. J. Pressland, of the Edinburgh Academy, read his paper on the School Training of Future Engineers. The author took as his standards of comparison the Scotch system of schools and the system of Canton Zurich. The latter was described in some detail. Proposed curricula were submitted, and in conclusion various objections were answered.

In the interesting discussion which followed the paper, the following gentlemen took part:—Dr Laurie, Professors Beare and Stanfield, Messrs Cadell, Kemp, and White, and the Secretary. Mr Pressland having replied, the communication was remitted to a Committee as follows:—Drs Laurie and Ferguson, Professors Beare and Stanfield, and Mr Kemp, Professor Beare to be Convener.

Private Business.

The Minute of the previous meeting was read and approved.

The Society then adjourned.

Sixth Meeting—8th February 1904.—Dr Dawson Turner, President of the Society, occupied the Chair, and was supported by Mr Cadell, Vice-President, and Professor Stanfield.

Mr D. W. Kemp read his communication on the Royal Institution and its Future: as a Home for the Scientific Societies of Edinburgh; or a National Library for Scotland, or other essentially National Purpose. Mr Kemp gave a short history of the Society, which was followed by a history of the Royal Institution. The former conferences between the Scientific Societies of Edinburgh in 1880 and in 1884 were then described, as was the recent meeting of their delegates with the Secretary for Scotland. The author gave his opinion that the buildings under discussion would be better used as a National Library than as a home for Scientific Societies. The immunity of the buildings from the risk of fire, their central situation, and their capability of extension underground were pointed out by Mr Kemp.

Dr Black and Messrs Cadell, Shiells, Ogilvie, and Wilson, and the Secretary having spoken, and Mr Kemp having replied, he was awarded the Society's heartiest thanks for his most interesting communication.

Private Business.

The Minute of the previous meeting was read and approved.

The Treasurer laid his accounts for Session 1902–1903 on the table.

James Andrew Somerville and Charles Norman Kemp were admitted Ordinary Fellows of the Society.

The Society then adjourned.

Seventh Meeting—22nd February 1904.—Dr Dawson Turner, President of the Society, occupied the chair.

Mr William Finlay read his paper on the Pearson Fire Alarm. A detailed description of this ingenious invention was given, and was illustrated by diagrams, etc. The alarm was given by the expansion of a curved piece of metal. The platinum point against which this curved piece pressed in its expansion, and so completed an electrical circuit, was capable of regulation, so that the alarm could be set to go at any desired temperature. At the conclusion of his paper, Mr Finlay ignited a quantity of inflammable material, so that the apparatus, which he had fixed up in the Hall, could be seen actually giving the alarm of fire. The bell rang forty-six seconds after the match was applied.

After Messrs Hislop, Wilson, Kemp, Ogilvie, and Pilkington had spoken, the communication was remitted to a Committee consisting of Messrs Hislop, Mackenzie, and Ogilvie, the last to be Convener.

Private Business.

The Minute of the previous meeting was read and approved.

William Finlay, Stevenson Macadam, and Alexander F. Ross were unanimously elected Ordinary Fellows of the Society.

Dr Black then reported that he had attended, on behalf of the Society, the funeral of the late Dr Milne Murray. The President referred in feeling terms to the loss not only the Society, but also the City, the medical profession, and a wide circle of friends had sustained in Dr Milne Murray's death. It was agreed that the President should send a suitable message of condolence to Mrs Milne Murray.

The Society then adjourned.

Eighth Meeting—14th March 1904.—Dr Dawson Turner, President of the Society, occupied the Chair, and was supported by Col. M'Hardy.

Mr Archibald Wilson read his communication on the Chamounix Railway. A very full description of the railway and the power stations, etc., was given. The interest of the paper was much enhanced by the beautiful lantern slides by which it was illustrated.

In the discussion which followed, Professor Baily, Dr Black, Mr Macdonald, and the Secretary took part. Mr Wilson having replied, the heartiest thanks of the Society were accorded him for his communication.

Private Business.

The Minute of the previous meeting was read and approved.

The Treasurer was unanimously granted discharge of his intromissions for Session 1902–3.

The Society then adjourned.

Ninth Meeting—28th March 1904.—Mr H. M. Cadell, Vice-President of the Society, occupied the Chair, and was supported by Professor Stanfield.

Dr Laurie read his paper on the Technical Education of the Engineer. After the methods used in Germany and the United States had been alluded to, the author said that the problem was twofold—the training of men who were to be owners and managers, and the training of the ambitious workman. The "sandwich" system was described as it was carried out at the Heriot-Watt College, and its suitability for training young engineers who were to occupy positions of trust pointed out. Dr Laurie thought that there was something wrong with the system of classification or examination in the Board Schools of Edinburgh, as his experience had been that lads from these schools were not thoroughly grounded in the three R's, but had smatterings of various subjects which were of little use to them.

In the discussion which followed, Bailie Mackenzie, Professors Baily and Stanfield, Messrs Tait, Ritchie, and Pressland, and Delegates from the Edinburgh, Leith and District United Trades and Labour Council, who had been specially invited, took part. Dr Laurie replied, and was awarded the Society's heartiest thanks for his communication.

Private Business.

The Minute of the previous meeting was read and approved.

The Society then adjourned.

Tenth Meeting—11*th April* 1904.—Mr H. M. Cadell, Vice-President of the Society, occupied the Chair.

Mr E. M. Horsburgh read his communications on a Method of Plotting certain Intrinsic Equations and on an Improved Polar Paper. After some discussion both papers were remitted to a Committee consisting of Professors Blyth, Stanfield, and Beare, the last to be Convener.

Mr C. N. Kemp then read his communication on Interrupters for Induction Coils, with special reference to the recent developments in connection with Electrolytic Interrupters. The paper was illustrated in a most interesting manner by experiments and lantern slides. After Professor Baily and the Secretary had spoken, the communication was remitted to a Committee consisting of Messrs Ogilvie and Wilson and Professor Baily, the last to be Convener.

Private Business.

The Minute of the previous meeting was read and approved.

The Society then adjourned.

Eleventh Meeting—11*th July* 1904.—Dr Dawson Turner, President of the Society, occupied the Chair, and was supported by Professor Stanfield.

Reports by Committees on the following communications were read and adopted by the Society :—

On Dr Marshall's	Paper,	No. 4852.
On Mr Pilkington's	do.	No. 4854.
On Mr Muir's	do.	No. 4855.
On Mr Finlay's	do.	No. 4858.
On Mr Kemp's	do.	No. 4863.

It was unanimously agreed to remit direct to the Prize Committee those reports which were not to hand at this meeting.

Private Business.

The Minute of the previous meeting was read and approved.

The Society unanimously elected its Prize Committee as follows :—

Dr Dawson Turner, President; Col. M'Hardy, Vice-President; H. M. Cadell, Vice-President; Professors Baily, Beare, and Stanfield; Messrs Buchan, Cockburn, Hislop, Mackenzie, O'Connor, and Alexander Ogilvie.

The Society then adjourned until the beginning of next Session.

APPENDIX (H).

DONATIONS TO THE LIBRARY RECEIVED DURING THE SESSION 1903–1904.

Proceedings of the Royal Society, Year Book, and Reports and Proceedings of the Sleeping Sickness Commission.
" " Royal Dublin Society.
" " Royal Irish Academy.
" " Institution of Civil Engineers.
" " Institution of Mechanical Engineers.
" " Institution of Electrical Engineers.
" " Staffordshire Iron and Steel Institute.
" " Boston Society of Natural History.
" " American Philosophical Society.
" " American Academy of Arts and Sciences.
" " Royal Society of Victoria.
" " Royal Institution of Great Britain.
" " Nova Scotian Institute of Science.
Transactions of the Institution of Engineers and Shipbuilders in Scotland.
" " North of England Institute of Mining and Mechanical Engineers.
" " Institution of Civil Engineers in Ireland.
" " Canadian Society of Civil Engineers.
" " Institution of Junior Engineers.
Memoirs and Proceedings of the Manchester Literary and Philosophical Society.
Journal of the Society of Arts.
" " Scottish Meteorological Society.
" " Western Society of Engineers.
" " Franklin Institute.
" " Association of Engineering Societies.
Smithsonian Institution Annual Report.
Memoirs of the Geological Survey of India.
Atti e Memorie della R. Accademia di Scienze Lettere ed Arti in Padova.

Atti della R. Accademia delle Scienze di Torino.

Annales de l'Association des Ingénieurs sortis des Écoles Spéciales de Gand.

Engineering.

The Engineer.

The English Mechanic.

The Periodical.

Cassier's Magazine.

The Book Lover.

Machinery.

Boston Public Library Monthly Lists of Books.

Edinburgh University Calendar.

John Crerar Library. Annual Report.

Gas World.

Manchester Steam Users' Association. Memo. by Chief Engineer.

The Refrigerating Engineer.

The Incorporated Accountants' Year Book, 1903–1904.

The Industrial Development of the Forth Valley. By H. M. Cadell, Esq. of Grange.

(405 Publications in all.)

ELLICE M. HORSBURGH,
Librarian.

APPENDIX (I).

LIST of PRIZES OFFERED by the ROYAL SCOTTISH SOCIETY of ARTS for PAPERS WHICH MAY BE SUBMITTED DURING THE SESSION 1904–1905.

(1) A KEITH PRIZE, value Thirty Sovereigns.

For some important "Invention, Improvement, or Discovery in the Useful Arts which shall be primarily submitted to the Society" during the Session.

(2) A HEPBURN PRIZE, value Twelve Sovereigns.

For such Invention or Communication submitted to the Society as shall be approved of by the Society, or by their Prize Committee.

(3) A MAKDOUGALL-BRISBANE PRIZE, value Ten Sovereigns.

To the Authors of Communications of Merit, or for Inventions which shall be approved of by the Society, or its Committee, and judged by them deserving of such distinction.

(4) REID and AULD PRIZES. Value about Seven Sovereigns.

For the First, Second, and Third best Models of anything new in the Art of Clock or Watch Making—by Journeymen or Master Watch and Clock Makers—if these should be considered worthy of prizes. The sum mentioned above to be divided in such proportions as the Prize Committee shall fix. The Society, if it sees fit, may add to the amount available for these Prizes out of its general funds.

The Society may offer a Special Keith Prize to be competed for during the Session, details of which will be submitted to the Society at a later date.

The Society proposes to award the above Prizes for approved Communications submitted to the Society by Fellows or others, relative to Inventions, Discoveries, and Improvements in the Industrial Arts, or to means by which the Natural Productions of the Country may be made more available, whether the subjects treated have been patented or not. The Society suggests the following as a few of the many subjects suitable for such Communications :—

1. *Mechanical Arts.*

Inventions of, or Improvements relating to, Wind and Water Prime Motors; Steam and other Heat Engines; Pumping, Blowing, Rolling, Sawing, Agricultural and other Engines and Machines; Machinery used in the manufacture of Cotton or other Textile Fabrics; Shipbuilding, including Machinery, Appliances, and Materials used in same; Marine Propellers; Lighthouses and Lighthouse Appliances; Railways, including Structural Work, Plant, and Signals; Electrical Machinery and Apparatus; Mechanical Photographic Processes; Fireproof Buildings; Water Works; Sewage Works; Methods and Appliances for improving the Sanitary Conditions of Towns; Appliances for the Prevention of Smoke and Extinction of Fires; Gas Works and Gas Lighting; Canals, Inland Navigation, and Machinery employed for Canal Traffic, including Locks, Inclines, and Lifts; Hydraulic Machinery as applied to Lifts, Cranes, Printing Presses, Organ Blowers, and other purposes; Tools, Implements, and Appliances used in the various Trades; Bricks, Tiles, Cements, and Mortars; Printing Machines and Appliances connected therewith; Stereotyping and other similar Processes; Processes for the Preservation of Timber and Metals; Optical and other Scientific Apparatus; etc., etc., etc.

2. *Chemical Arts.*

Inventions or Improvements relating to Processes for the Treatment of Natural Productions; the Manufacture of Chemical Substances used in Commerce, Science, or Art; the Application of Chemistry to particular Manufactures and Trades; etc., etc., etc.

3. *Fine Arts.*

INVENTIONS OR IMPROVEMENTS relating to all kinds of Photographic Processes as applied to the Production of Illustrations; Engraving Processes; Lithography; Die-Sinking; Methods of applying Colours for Decorative Purposes; the Use and Treatment of various Materials for Wall Decoration; etc., etc., etc.

GENERAL OBSERVATIONS.

Communications are also invited describing Processes and Important Works, although no claim may be made by the Author on the score of Invention or the introduction of Improvements.

The Society reserves the right to withhold any of the Prizes offered for competition if the Papers submitted do not possess sufficient merit, or to award Prizes of smaller amounts, or to split up the amounts into a larger number of Prizes, as the Prize Committee may see fit.

In preparing Papers, the descriptions of Inventions, etc., should be full and distinct, written legibly on one side only of Foolscap paper, and when necessary, the Communications should be accompanied by Specimens, Drawings, or Models. The Drawings should be in bold lines about one-quarter of an inch broad, and strongly coloured, so as to be easily seen at about the distance of 30 feet when hung up in the Hall. Letters or Figures of Reference should be at least $1\frac{1}{2}$ inch long. When necessary, smaller and more minutely detailed Drawings should accompany the larger ones, for the use of the Committee, having the same letters of reference.

The Society shall be at liberty to publish in their *Transactions* Copies or Abstracts of all Papers submitted to them.

All Models, Drawings, etc., accompanying Papers for which Prizes are given shall be held to be the property of the Society; but the value of Models, if retained, will be allowed for.

Communications, Models, etc., are to be addressed to the Secretary, 117 George Street, Edinburgh, Postage or Carriage Paid. Communications lodged after the 1st of March may not be read or reported on till the following Session.

By Order of the Society,

WM. ALLAN CARTER,

Secretary.

APPENDIX (J).

REPORT OF THE COMMITTEE APPOINTED TO AWARD PRIZES FOR COMMUNICATIONS READ OR REPORTED ON DURING THE SESSION 1903–1904.

Your COMMITTEE having met and carefully considered the Communications laid before and definitely disposed of by the Society, during the Session 1903–1904, begs to report that it has awarded the following Prizes and Medals:—

To ELLICE M. HORSBURGH, M.A., B.Sc.,—for his papers on "A Method of Plotting certain Intrinsic Equations" and on "An Improved Polar Paper and its Use as compared with Squared Paper" (Nos. 4861 and 4862),—read on the 11th of April 1904,

A Keith Prize, value Ten Sovereigns.

To HUGH MARSHALL, D.Sc., F.R.S.,—for his paper on "Improvements relating to the Use of Carburetted Air for Lighting and other Purposes" (No. 4852),—read on the 23rd of November 1903,

A Keith Prize, value Five Sovereigns.

To BASIL A. PILKINGTON,—for his paper on "An Apparatus for Maintaining Exact Temperatures Automatically by Electric Means" (No. 4854),—read on the 11th of January 1904,

A Keith Prize, value Five Sovereigns.

To A. J. PRESSLAND, M.A., F.R.S.E.,—for his paper on "The School Training of the Future Engineer" (No. 4856),—read on the 25th of January 1904,

A Hepburn Prize, value Three Sovereigns.

To CHARLES NORMAN KEMP,—for his paper on "Interrupters for Induction Coils, with Special Reference to the recent Developments in Connection with Electrolytic Interrupters" (No. 4863),—read on the 11th of April 1904,

A Hepburn Prize, value Three Sovereigns.

To Arthur A. W. Wynne, Assoc.M.Inst.C.E.,—for his paper on "Steam Turbine Machinery" (No. 4853),—read on the 14th of December 1903,

A Makdougall-Brisbane Complimentary Medal.

To William Finlay,—for his paper on "A Practical Description and Demonstration of the Pearson Fire Alarm" (No. 4858),—read on the 22nd of February 1904,

A Makdougall-Brisbane Complimentary Medal.

That the hearty thanks of the Society are due to the President, Dr Dawson Turner, for his Opening Address, delivered on the 9th of November 1903, and to Messrs Muir, D. W. Kemp, Archibald Wilson, and Dr A. P. Laurie for their communications.

All of which is reported in name and by order of the Committee by

Wm. ALLAN CARTER, *Secretary*,
Convener ex officio.

Society's Hall, 117 George Street,
Edinburgh, 18*th July* 1904.

APPENDIX (K).

Royal Scottish Society of Arts.

ABSTRACT OF THE ACCOUNTS OF THE SOCIETY FOR 1902–1903.

I. GENERAL FUND.

CHARGE.

Income—			
Arrears of Subscriptions at 15th November 1902			£11 11 0
Subscriptions for Session 1902–1903			99 4 6
			£110 15 6
Less—Unpaid at 15th November 1903			5 5 0
			£105 10 6
Balance at Credit of Building Fund			75 7 4
Interest received			1 0 1
Total Income			£181 17 11
Sum borrowed from Keith Fund during year			50 0 0
Subscriptions Unpaid at 15th November 1903			5 5 0
Sum of the Charge...			£237 2 11

DISCHARGE.

Balance due to the Treasurer at 15th November 1902			£20 18 1	
Ordinary Expenditure—				
Printing and Advertising		£19 17 3		
Salaries and Expenses of Collection,	£97 13 0			
Less—Charged to Prize Funds	5 8 3			
		92 4 9		
Expenses connected with the Society's Printed Transactions		52 4 0		
Interest paid to Keith Fund on Loan		2 0 1		
Miscellaneous Payments		13 6 1		
Total Ordinary Expenditure....			179 12 2	
Prizes Awarded			9 7 6	
Arrears of Subscriptions written off			12 12 0	
Subscriptions Outstanding at 15th November 1903			5 5 0	
Sum on Deposit with Commercial Bank at 15th November 1903			9 8 2	
Sum of the Discharge ...				£237 2 11

II. KEITH BEQUEST.

CHARGE.

Sum on Deposit with the Commercial Bank at 15th November 1902		£80 2 6
Balance due by the Treasurer at 15th November 1902		1 19 5
		£82 1 11
Income—		
Dividends from Stocks, viz. :—		
Edinburgh and Leith Gas Annuity	£28 8 7	
Great North of Scotland Railway Company Debenture Stock	18 19 2	
Forth and Clyde Junction Railway Preference Stock	4 14 3	
North British Railway Company Consolidated Lien Stock...	11 6 4	
	£63 8 4	
Interest on Loan to General Fund	2 0 1	
Bank Interest received	1 16 4	
		67 4 9
Sum of the Charge...		£149 6 8

II. KEITH FUND.

Charge Amount..Forward,				£149	6	8

Discharge.

Expenditure—						
Prizes awarded	£30	0	0			
Commission on Revenue, credited General Fund...............	3	5	3			
	£33	5	3			
Loan to General Fund during year	50	0	0			
Sum on Deposit with the Commercial Bank at 15th November 1903..	66	1	5			
Sum of the Discharge....................				149	6	8

III. REID AND AULD BEQUEST.

Charge.

Sum on Deposit with the Commercial Bank at 15th November 1902..............				£139	9	11
Income—						
Interest on Great North of Scotland Railway Company Debenture Stock..	£17	1	1			
On Forth and Clyde Junction Railway Preference Stock.......	2	7	1			
On North British Railway Consolidated Lien Stock............	3	15	5			
Bank Interest	3	1	10			
				26	5	5
Sum of the Charge...				£165	15	4

Discharge.

Expenditure—						
Donations to poor Clockmakers in terms of the Bequest	£15	0	0			
Commission on Revenue, credited General Fund................	1	6	3			
Prize awarded	7	0	0			
	£23	6	3			
Sum on Deposit with the Commercial Bank at 15th November 1903..	142	9	1			
Sum of the Discharge....................				165	15	4

IV. BRISBANE BIENNIAL PRIZE FUND.

Charge.

Sum on Deposit with the Commercial Bank at 15th November 1902..............				£50	8	10
Income—						
Interest on Forth and Clyde Junction Railway Preference Stock	£7	1	5			
Bank Interest..	1	2	2			
				8	3	7
Sum of the Charge...				£58	12	5

Discharge.

Expenditure—						
Prize awarded ....,..................................	£13	0	0			
Commission on Revenue, credited General Fund.........	0	8	3			
	£13	8	3			
Sum on Deposit with the Commercial Bank at 15th November 1903..	45	4	2			
Sum of the Discharge....................				58	12	5

V. HEPBURN PRIZE FUND.

Charge.

Sum on Deposit with the Commercial Bank at 15th November 1902				£61	3	6
Income—						
Dividends on Caledonian Railway Company Stocks	£7	0	4			
Bank Interest	1	7	2			
				8	7	6
Sum of the Charge...				£69	11	0

Discharge.

Expenditure—						
Prizes awarded	£15	0	0			
Commission on Revenue, credited General Fund	0	8	6			
	£15	8	6			
Sum on Deposit with the Commercial Bank at 15th November 1903	54	2	6			
Sum of the Discharge...				69	11	0

VI. BUILDING FUND.

Charge.

Rents drawn from Letting the Hall				£231	12	6

Discharge.

Payments on Account of the Hall and Hallkeeper's House, viz., Taxes, Feu-duty, Insurance, Coals, Gas, Cleaning, &c., and Hallkeeper's Salary	£145	18	5			
Repairs and alterations to the Hall	10	6	9			
				156	5	2
Balance transferred to the General Fund, page 42				£75	7	4

FUNDS OF THE SOCIETY,

As at 15*th November* 1903, *per Report of the Auditor.*

I. GENERAL FUND.

Price of Hall in George Street and Furnishings, and of the additional Premises purchased at Whitsunday 1863	£2712	0	3
Arrears of Annual Contributions	5	5	0
Sum on Deposit with Commercial Bank	9	8	2
	£2726	13	5
Deduct Loan from Keith Fund	120	0	0
Amount of General Fund...	£2606	13	5

II. KEITH BEQUEST.

£30 Annuity of the Edinburgh and Leith Gas Commission	£870	0	0			
£500 Great North of Scotland Railway Company Debenture Stock	612	10	0			
£100 Preference Stock No. 1 of the Forth and Clyde Junction Railway Company	137	0	0			
£300 4 per cent. Consolidated Lien Stock of the North British Railway Company	406	15	0			
Sum on Deposit with the Commercial Bank	66	1	5			
Loan to General Fund	120	0	0			
				2212	6	5
Carry forward,				£4818	19	10

II. FUNDS OF THE SOCIETY—continued.

Brought forward,		£4818 19 10

III. REID AND AULD BEQUEST.

£450 Great North of Scotland Railway Company Debenture Stock	£551 5 0	
£50 Preference Stock No. 1 of the Forth and Clyde Junction Railway Company	68 10 0	
£100 4 per cent. Consolidated Lien Stock of the North British Railway Company	135 11 10	
Sum on Deposit with the Commercial Bank	142 9 1	
		897 15 11

IV. BRISBANE PRIZE FUND.

£150 Preference Stock No. 1 of the Forth and Clyde Junction Railway Company	£205 10 0	
Sum on Deposit with the Commercial Bank	45 4 2	
		250 14 2

V. HEPBURN PRIZE FUND.

£175 Caledonian Railway Company Consolidated 4 per cent. Stock, No. 2	£209 2 6	
£11 do., No. 1	13 6 0	
Sum on Deposit with the Commercial Bank	54 2 6	
		276 11 0
Total Property and Funds under Charge of the Society as at 15th November 1903		£6244 0 11

C. J. SHIELLS, *Treasurer.*

Edinburgh, 14*th January* 1904.—I have examined and audited the Accounts of the Treasurer to the Royal Scottish Society of Arts for the Session 1902–1903, of which the foregoing is an Abstract, and beg to report that I have found the same to be correctly stated and sufficiently vouched. I have also examined the securities for the Invested Funds of the Society, and have found them in order.

George H. Carphin, C.A., *Auditor.*

APPENDIX (L).

LIST

OF THE

OFFICE-BEARERS AND FELLOWS

OF THE

ROYAL SCOTTISH SOCIETY OF ARTS.

THE KING, PATRON.

OFFICE-BEARERS FOR SESSION 1904–1905.

As elected on 14th November 1904.

President . . .	DAWSON TURNER, M.D., 37 George Square.
Vice-Presidents . .	HENRY M. CADELL, B.Sc., F.R.S.E., of Grange Bo'ness. FRANCIS G. BAILY, M.A., F.R.S.E., Heriot-Watt College.
Secretary . . .	WILLIAM ALLAN CARTER, M. Inst. C.E., F.R.S.E., 117 George Street.
Assistant Secretary .	ANDREW WILSON, Assoc. M. Inst. C.E., 14 Queen Street.
Treasurer . . .	C. J. SHIELLS, C.A., 141 George Street.
Editor of Transactions	RICHARD STANFIELD, F.R.S.E., M. Inst. C.E., Heriot-Watt College.
Librarian . . .	E. M. HORSBURGH, M.A., B.Sc., 3 Eglinton Crescent.
Medallists . . .	ALEXANDER KIRKWOOD & SON, 9 St James Sq.
Officer	FRANCIS DUFFY, 117 George Street.

Councillors.

T. HUDSON BEARE, B.Sc., M. Inst. C.E., Edinburgh University.
GILBERT THOMSON, C.E., 164 Bath Street, Glasgow.
JOHN AYLING, 22 Inverleith Place.
ALEXANDER W. COCKBURN, C.E., 39 York Place.
G. H. GEMMELL, F.I.C., F.C.S., 14 Thirlstane Road.
ALEXANDER OGILVIE, B.Sc., Leith Electric Works.
JAMES PIRIE, C.E., 135 George Street.
JAMES B. BENNETT, Assoc. M. Inst. C.E., F.R.S.E., 12 Hill Street.
R. G. HISLOP, 11 Pitt Street.
A. P. LAURIE, D.Sc., F.R.S.E., Heriot-Watt College.
HENRY O'CONNOR, Assoc. M. Inst. C.E., 1 Drummond Place.
JOHN SMITH, Engineer, Penicuik.

LIST OF THE ORDINARY FELLOWS AND ASSOCIATES

AS AT 14TH NOVEMBER 1904.

*Those marked * are Life Fellows.*

NOTE.—Fellows may become "Life Fellows" at any time on paying £10, 10s., from which they are allowed a deduction of half the amount they may have paid previously in Annual Contributions.

1871 *Aitken, John, F.R.S.E., Ardenlea, Falkirk
1851 *Alexander, William, M.E.
1896 *Archer, Robert S., Craigleith, 5 Lowwood Road, Birkenhead
1868 *Archibald, John, M.D., Hazelden, Wimborne Road, Bournemouth
1891 Ayling, John, 22 Inverleith Place, *Councillor*

1896 Baily, Francis G., M.A., F.R.S.E., M.I.E.E., Professor of Applied Physics, Heriot-Watt College, *Vice-President*
1895 Barron, James, M. Inst. C.E., 1 Bon Accord Street, Aberdeen
1878 *Barton, John Fraser, plumber, 11 Forrest Road
1901 Beare, T. Hudson, B.Sc., M. Inst. C.E., M. Inst. M.E., F.R.S.E., Professor of Engineering, Edinburgh University, *Councillor*
1850 *Bell, Alexander Melville, 1525 35th Street, West Washington
1859 *Bell, Andrew Beatson, advocate, F.R.S.E., 17 Lansdowne Crescent
1902 Bennett, James B., Assoc. M. Inst. C.E., F.R.S.E., 12 Hill Street, *Councillor*
1879 *Black, William Galt, F.R.M.S., 2 George Square
1883 *Blaikie, Walter Biggar, F.R.S.E., printer, 11 Thistle Street
1879 *Blanc, Hippolyte Jean, architect, 25 Rutland Square
1877 *Blyth, James, F.R.S.E., Professor of Mathematics and Natural Philosophy, Andersonian University, Glasgow
1888 Boa, Peter, pharmaceutical chemist, 119 George Street
1892 Bonar, Horatius, W.S., 3 St Margaret's Road
1853 *Bow, Robert Henry, C.E., F.R.S.E., 7 South Gray Street
1868 *Boyd, James L., S.S.C., Glendouglie, Glenfarg
1890 Brebner, R. C., 28 Hermitage Gardens
1864 *Brown, Geo. Bruce, architect. (No address)
1880 *Bruce, A. Fairlie, C.E. (No address)
1868 *Bruce, C., banker, 3 Melville Crescent
1850 *Bruce, George Cadell, C.E.
1893 Buchan, Mathew, electrician, 67 George Street
1893 Buchanan, James, Oswald Road
1879 *Buchanan, John, C.E., 12 Hill Street

1891 Cadell, Henry Moubray, B.Sc., F.R.S.E., of Grange, Bo'ness, *Vice-President*
1879 *Carfrae, George Somervel, C.E., 1 Erskine Place
1880 *Carmichael, Neil, M.D., 23 Nithsdale Road, Pollokshields, Glasgow
1892 *Carphin, G. H., C.A., 3 Abinger Gardens, Murrayfield
1840 *Carstairs, Drysdale, merchant, Hailes House, Fairfield, Liverpool
1875 *Carter, William Allan, M. Inst. C.E., F.R.S.E., 14 Queen Street, *Secretary*
1872 *Cattanach, Peter Lorimer, advocate, 14 London Street
1867 *Cay, William Dyce, M. Inst. C.E., F.R.S.E., 1 Albyn Place
1860 *Charnock, Richard Stephen, Yorick Club, 30 Bedford Street, Strand, London, W.C.
1879 *Clark, Alexander, Assoc. M. Inst. C.E., 8 Bright's Crescent
1878 *Clement, Adam Ferguson, telegraph engineer, Egmont, 59 Braid Road

1901 Cockburn, Alexander W., civil engineer, 39 York Place, *Councillor*
1889 Colam, William N., M. Inst. C.E., 57 Henderson Row
1862 *Copland, Harry Y. D., 21 Manor Place
1876 *Cormack, D. Adair, marine engineer, 17 Abercorn Terrace, Portobello
1872 *Couper, Charles Tennant, advocate, 3 Charlotte Square
1888 Cowan, John, 6 Salisbury Road
1883 *Crabbie, George, merchant, 8 Rothesay Terrace
1885 Cran, John, mechanical engineer, Albert Engine Works, Leith
1876 *Cranston, The Rt. Hon. Sir Robert, Lord Provost, 33 Princes Street
1879 *Cunningham, James H., Assoc. M. Inst. C.E., 2 Ravelston Place

1892 Davidson, John, Langley Park, Wick
1882 *Dickson, Lamont, C.E., 135 George Street
1887 Drysdale, Alexander, builder, 70 Pilrig Street
1894 Dunbar, James, Elgin House, Easter Road
1893 *Duncan, D. J. Russell, 28 Victoria Street, London, S.W.

1896 Eaton, Edmond, 99 Cannon Street, London, E.C.
1892 Elgin and Kincardine, The Right Hon. The Earl of, K.G., Broomhall, Dunfermline

1878 *Farquharson, Thomas Ker, accountant, 100 Thirlstane Road
1857 *Ferguson, R. M., LL.D., Ph.D., F.R.S.E., 5 Douglas Gardens
1895 *Ferranti, S. Z. de, engineer, Ingleside, Lyndhurst Road, Hampstead, London, N.W.
1904 Finlay, William, electrical engineer, 16 North St Andrew Street
1860 *Firth, William, secy., N. B. Rubber Co., Wideford, Granton Road
1894 Foulis, David, jun., 42 Shandwick Place
1850 *Fraser, Alexander, printer, 17 Eildon Street
1879 *Frazer, Alexander, M.A., optician, 22 Teviot Place
1856 *Geddes, A. C., C.E., 14 Ettrick Road
1896 *Geddes, C. D., mining engineer, 21 Young Street
1856 *Geddes, G. H., M.E., 21 Young Street
1899 Gemmell, George H., F.I.C., F.C.S., 14 Thirlstane Road, *Councillor*
1889 Gibson, J. D., ordained surveyor, 60 Frederick Street
1887 Gilmour, George, builder, 19 Rosslyn Crescent
1857 *Gordon, Alexander. (No address)
1851 *Gordon, James Newall, London
1860 *Gray, Rev. W. H., M.A., D.D., 3 Carlton Terrace
1893 *Grieve, George K., 12 Cambridge Avenue

1860 *Hardie, Walter, 5 Bellevue Street
1888 *Harris, William A., F.S.S., F.I. Inst., secretary, Phœnix Fire Office, Exchange, Liverpool
1870 *Hartnell, Wilson, engineer, Park Row, Leeds
1879 *Heath, Thomas, assistant observer, Royal Observatory
1891 *Herdman, G. W., M.A., B.Sc., Assoc. M. Inst. C.E., Irrigation Department, Pretoria
1898 Herring, W. R., M. Inst. C. E., Granton House, Granton
1871 *Hislop, George Robertson, F.C.S., gas engineer, Blackstone Road, Paisley
1898 *Hislop, Laurence, gas engineer, Uddingston
1894 Hislop, R. G., 11 Pitt Street, *Councillor*
1863 *Hogue, D. W., M.D., dentist, Roxburgh, Marlborough Road, Bournemouth
1900 *Horne, Wm. James, A.M.I.E.E., South African College, Cape Town
1900 Horsburgh, E. M., M.A., B.Sc., 3 Eglinton Crescent, *Librarian*
1868 *Horsburgh, John, Aberdour House, Aberdour
1893 Horsburgh, J. Alfred, photographer, 4 West Maitland Street
1892 Howkins, John, C.E., Granton
1897 Hume, John, 46 Torphichen Street
1888 Hume, Thomas, plumber, 2A Stafford Street
1876 *Hutchison, James T., 12 Douglas Crescent

1882 *Inglis, John William, F.R.S.E., M. Inst. C.E., Paeroa, Auckland, New Zealand

1884 Jenkinson, Alexander Dixson, glass manufacturer, 10 Princes Street

1904 Kemp, Charles N., Ivy Lodge, Trinity
1872 *Kemp, D. William, Ivy Lodge, Trinity
1872 *Key, William, St Cyr, Ceres, Fife
1902 Kirkwood, Alexander, 9 St James Square, *Medallist*
1898 Knoblauch, Louis, merchant, 22 Baltic Street, Leith
1887 Knox, Patrick, plumber, 31 Crichton Place

1884 Laidlaw, Robert, engineer, 147 East Milton Street, Glasgow
1894 Laing, J. H. A., M.B., C.M., 11 Melville Street
1902 Laurie, A. P., D.Sc., Principal, Heriot-Watt College, *Councillor*
1856 *Lees, William, A.M., 12 Morningside Place
1904 Leslie, James, C.E., 5 Douglas Gardens
1873 *Lewis, David, Roselea Villa, Grange
1877 *Lockie, John, engineer, 2 Commercial Street, Leith

1904 Macadam, Stevenson, F.I.C., F.C.S., 55 York Place
1882 *Macdonald, James, plumber, 3 Dundas Street
1889 *Macdonald, The Right Hon. Sir J. H. A., K.C.B., LL.D., F.R.SS. (L. & E.), M.I.E.E., Lord Justice-Clerk of Scotland, 15 Abercromby Place
1898 M'Gregor, Walter, accountant, 32 York Place
1898 M'Hardy, Lieut.-Col. A. B., C.B., 3 Ravelston Park
1888 Mackenzie, A. Donald, 14 Greenhill Park
1867 *Maclagan, R. Craig, M.D., 5 Coates Crescent
1899 Maloney, Bernard J., 33 Frederick Street
1886 *Martin, William James, C.E., Rosario de Santa Fé, S. America
1884 *Massie, James, burgh engineer, 1 Parliament Square
1876 *Mather, Edward, Marchfield, Davidson's Mains
1881 *Maxwell-Müller, R. W., C.E.
1894 Meek, John, watchmaker, 13 Bristo Place
1863 *Menzies, Duncan, C.E., 39 York Place
1865 *Menzies, Sir Wm. John, W.S., Canaan Cottage, Grange Loan
1858 *Mercer, James Tod, advocate
1894 *Miller, James Newlands, Broomlea, Joppa
1879 *Milne, James, Muirend, Colinton
1848 *Milne, John Kolbe, dressing-case maker, Kevock Tower, Lasswade
1888 Mitchell, James D., 30 Fettes Row
1889 *Moncrieff, D. Scott, W.S., 28 Rutland Square
1872 *Morrison, James, City of Glasgow Improvement Trust, 98 Sauchiehall Street, Glasgow
1857 *Muir, John, brewer, 28 N. Back of Canongate
1866 *Muir, W. J. Cockburn, C.E.
1902 Murdoch, James, late Secretary to the Board of Northern Lighthouses, St Kilda, York Road, Trinity

1874 *Noble, William, millwright, 27 Rosebank Cottages

1902 O'Connor, Henry, Assoc. M. Inst. C.E., P. Pres. Soc. Eng., 1 Drummond Place, *Councillor*
1898 Ogilvie, Alexander, electrical engineer, Leith Electric Works, *Councillor*
1889 Ogilvie, F. Grant, M.A., B.Sc., F.R.S.E., 15 Evelyn Gardens, London, S.W.
1904 Omit, Thomas, 15 Torphichen Place

1885 Paterson, Oscar, glass stainer, 118 West Regent Street, Glasgow
1894 Peebles, W. Carmichael, Hope Lodge, Trinity
1902 Pickstone, Montague T., electrical engineer, Pilton Works, Ferry Road
1882 *Pirie, James, C.E., 135 George Street, *Councillor*
1878 *Proctor, Thomas Rodger, 21 West Maitland Street
1864 *Proudfoot, David C., City Road Trust, 10 City Chambers
1896 Purvis, George Carrington, M.D., Grahamstown, Cape Colony

1894 Readman, James B., D.Sc., F.R.S.E., 4 Lindsay Place
1902 Reis, Alphonse Louis, ophthalmic optician, The Laurels, Bright's Crescent
1890 *Ritchie, Charles, S.S.C., 20 Hill Street
1865 *Ritchie, Frederick James, clockmaker, 25 Leith Street
1866 *Ritchie, Jas., M.R.C.S., M.B., C.M., 22 Charlotte Square
1896 Ritchie, James, clockmaker, 25 Leith Street
1879 *Ritchie, John, C.E., The Knowe, Lygon Road
1857 *Rollo, Right Hon. Lord, Duncrub House, Bridge of Earn
1904 Ross, Alexander F., engineer, 6 East Fettes Avenue
1875 *Russell, Sir J. A., M.A., M.B., F.R.S.E., Woodville, Canaan Lane

1867 *Sanderson, William, rectifier, Talbot House, Ferry Road
1878 *Scott, David A., S.S.C., 20 St Andrew Square
1900 Scott, J. Gray, A.I.E.E., Electric Light Station, Croydon
1862 *Shedden, Thomas, M.A., 47 West Cromwell Road, London
1893 Shiells, C. J., C.A., 141 George Street, *Treasurer*
1883 *Shiells, Henry Kenward, C.A., 141 George Street
1856 *Slight, G. H., Kendall, Meadfoot Road, Torquay
1902 Smith, John, engineer, Penicuik, *Councillor*
1895 *Smith, J. Ciceri, 6 Holborn Viaduct, London, E.C.
1877 *Smith, J. Turnbull, C.A., LL.D., 5 Belgrave Place
1894 Smith, Stephen, B.Sc., 47 George Street
1904 Somerville, James A., engineer and shipbuilder, Glenesk Crescent, Dalkeith
1889 Stanfield, Richard, F.R.S.E., M. Inst. C.E., Professor of Engineering, Heriot - Watt College, *Editor of Transactions*
1850 *Stark, James, M.D., F.R.C.P., F.R.S.E. (No address)
1879 *Steuart, Robert Bromfield, C.E. (No address)
1896 Stevenson, Alexander, North British Distillery
1881 *Stevenson, Charles Alexander, B.Sc. Edin., 28 Douglas Crescent
1879 *Stevenson, David Alan, C.E., B.Sc. Edin., F.R.S.E., 84 George Street
1884 *Stevenson, Peter, instrument maker, 14 Seton Place
1857 *Sturrock, John, Peffermill House, Liberton
1899 Sutherland, Charles S., 20 Lauriston Gardens

1876 *Taylor, William, M.D., 12 Melville Street
1851 *Tennant, Sir Charles, Bart., St Rollox, Glasgow
1860 *Thomson, Alex., teacher, 40B George Square
1883 Thomson, Gilbert, C.E., 164 Bath Street, Glasgow, *Councillor*
1878 *Thorburn, William, builder, 86 Buccleuch Street
1894 *Turnbull, William James, 16 Grange Terrace
1892 Turner, Dawson, M.D., 37 George Square, *President*

1882 *Waldie, David, coal merchant, 25 Douglas Crescent
1892 Walmsley, R. M., D.Sc., 23 Hilldrop Road, Camden Road, London, N.
1856 *Waterston, George, 10 Claremont Crescent
1866 *Watherston, James, builder, Pentland Villa, West Coates
1892 *Watson, James, M. Inst. C.E., Town Hall, Bradford
1892 Wemyss and March, The Right Hon. The Earl of, Gosford House, Aberlady
1879 *Westland, David Monro, M. Inst. C.E., 135A George Street
1861 *Whimster, T., gas engineer, 17 York Place, Perth
1879 *White, John, C.E., 17 E. Claremont Street
1884 *Whyte, Peter, M. Inst. C.E., superintendent, Leith Docks, 4 Magdala Crescent
1877 *Wilkins, Samuel B., 38 Wellington Street, Portobello
1898 Wilson, Andrew, Assoc. M. Inst. C.E., 14 Queen Street, *Assistant Secretary*

1898 Wilson, Archibald, A.M.I.E.E., electrical engineer, Leith Electric Works
1903 Wright, Johnstone C., F.R.S.E., Northfield, Colinton
1859 *Wyllie, James S., 21 Barnton Terrace
1890 *Yooll, W. Graham, oil refiner, 45 Stirling Road, Trinity
1893 *Young, Robert, 3 Abbotsford Park

Total Ordinary Fellows, 199.

Associate.

1902. Hunter, James, engineer, 23 Craigmillar Park.

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APPENDIX (M).

REPORT by Committee on Mr A. Clark's Paper on "The Tram and Road Car of the Future."

The Committee appointed by the Royal Scottish Society of Arts to report upon Mr Clark's Paper upon "The Tram and Road Car of the Future," as read before the Society of 28th November 1904, have dealt with the matter, and beg to submit their Report.

Mr Clark has not exaggerated the importance of the problem of rapid and cheap transit, which so greatly affects the comfort and convenience of the population of our overgrown cities, and not less the industrial development of our rural districts. It is hardly to be doubted that road motor vehicles, petrol or steam, will come into extensive use for the latter purpose. Where the traffic, however, is sufficiently great within a limited area to warrant the laying down of rails, it becomes a question, in the first place, of the relative economy of a large number of independent prime movers, and of the production of power on an extensive scale in a central station, and its transmission to each separate vehicle.

Assuming it proved that the system advocated by the Author of this Paper—taking into account jointly capital expenditure and working cost—would be more economical than the simplest form of electric tramway, there still remain the probable objections to the pungent odour of improperly consumed waste gases from a petrol driven motor, and the noise and vibration of a reciprocating explosion motor in place of a balanced rotary motor. Mr Clark, however, appears to be sanguine that these difficulties will be overcome.

Mr Clark has described several ingenious combinations of motor and gearing, as applied to tram and road cars, which appear to be of some practical value.

Mr Clark has done well to direct attention to the reckless finance which characterises, in so many cases, the management of tramway schemes by local authorities; but when he comes to place before us his own estimates, we are hardly able to admit his claim to have erred only on the safe side.

His figures for the cost of petrol and the allowance for repairs and renewals seem to us insufficient, and in his comparison with the electric system, we think he has exaggerated the cost of labour at the generating station and attendance on the overhead equipment.

It seems to us that the claims put forward by the Author on behalf of the petrol motor tramcar can only be substantiated by an exhaustive and prolonged trial under all the possible conditions. We consider it most desirable that such a trial should be carried out, and we hope that facilities may be given by some enterprising authority or tramway company to enable this to be done.

The best thanks of the Society should be extended to the Author for bringing such an important subject before the notice of the Society, and for dealing with it in such an exhaustive manner.

STEPHEN SMITH.
HENRY O'CONNOR.
MATHEW BUCHAN, *Convener.*

P.S.—Your Committee would point out to Mr Clark that on page 225 he has apparently, by a clerical error, underrated the consumption of petrol by 50 per cent.; and on page 231 the tractive force he has calculated is not that at the circumference of the driving wheel.

Report by Committee on Mr T. Omit's Paper on "Improvements in Kitchen Ranges."

Your Committee have carefully considered this communication, and have examined minutely the apparatus as shown by Mr Omit, and now beg to report that they are of opinion that considerable merit attaches to these improvements.

Defects in connection with kitchen ranges are well known, and many efforts have been made in the past to overcome these, with more or less success, but it must be admitted that the improvements made and patented by Mr Omit's firm are superior to all others known to your Committee.

To fully understand the advantages of these improvements the following points have to be kept in view:—

(1) That while the fire of a kitchen range is in use all day long, the strength of the fire required varies almost in every hour of the day.

(2) The rate at which the fire burns in a kitchen range largely depends on the open surfaces of the fire, and the current of air passing into it by these surfaces.

(3) That if the air that feeds the fire can be heated before reaching it, the more effective is the consumption of the fuel.

If a ready and simple means of reducing the exposed surfaces —shutting off the supply of air—and of heating the air before it reaches the fire can be secured, the regulating of the fire to its fluctuating requirements and a saving of fuel would be effected. And your Committee are of opinion that these advantages are all secured in an easy and effective manner by the ingenious improvements made by Mr Omit.

These improvements are evidently the result of long experience and careful study of the subject, and your Committee have pleasure in recommending this communication to the Prize Committee.

A. Donald Mackenzie.
David Foulis, Jun.
Thomas Hume.

Report by Committee on Mr J. Ritchie's Paper on "Electrical Hoisting Machinery."

The Committee have carefully considered Mr Ritchie's communication on "Electrical Hoisting Machinery," read on the 16th January 1905. This is the second communication from Mr Ritchie to the Society on this subject, the former Paper having been read on the 25th March 1892.

As the writer points out, there has been a great increase in the use and a great development in the construction of Electrical Plant in the intervening thirteen years.

The various classifications of motors and their applications to the circumstances of the work which they are required to perform, were described in the Paper, and many illustrations given of the motors employed under the various circumstances.

A very interesting part of the Paper was the description of the crossing of the Zambesi River, which shows how readily a work of this vast magnitude can be undertaken when the electric motor can be brought into operation.

The whole Paper was most interesting and instructive as to the construction and use of electrical machinery, and the Committee have pleasure in recommending it to the consideration of the Prize Committee.

Alex. F. Ross.
Archibald Wilson.
Alex. Clark, *Convener.*

Report by Committee on Mr H. W. Bacon's Paper on "Stained Glass: its Origin, Development and Method of Production."

The Committee having met and together read over the Paper submitted by Mr Herbert W. Bacon upon the treatment of Stained Glass, and having conferred with one of Mr Bacon's representatives, from whom several further particulars in explanation from the Paper were obtained, recognised in the Paper a very interesting and instructive *résumé* of the art of Stained and Painted Glass from the earliest efforts.

In the Paper Mr Bacon notes what he considers commendable in the treatment of Stained Glass Windows, and also gives instances of what, in his opinion, is undesirable, and notes concisely what it is necessary to fulfil to make an appropriate and successful artistic effect.

With reference further to what Mr Bacon advances as a point, namely, certain experiments in the way of overlapping and fusing clear glass, this was really never before the Society, not having been shown or discussed, but were explained afterwards to the Committee. On referring to the literature of Stained Glass, however, it is found that these experiments do not represent anything novel or useful. In 1898 Mr Lewis F. Day referred to similar treatment; but where such treatment has been tried, it is found that, in the course of time, disintegration sets in, and that the glass is separate. There being no novelty nor invention exhibited, the Committee do not feel warranted in advancing the Paper to a place on the Prize List, but recommend rather that, as a carefully considered and concise treatise on Stained Glass, the best thanks of the Society should be extended to the Author.

Reported by—

Oscar Paterson.
Stephen Smith.
Hippolyte J. Blanc, R.S.A., *Convener.*

Report by Committee on Mr Forgan's Paper on "Machines for Grinding Telescope Specula, and a Simple Addition to an Ordinary Lathe for that Purpose."

Your Committee having carefully considered this communication, beg to report that Mr Forgan is to be highly commended for the concise and perspicuous account given regarding the methods adopted by various makers for the production of Glass Silvered Specula. Your Committee are of opinion that the process followed by Mr Forgan seems likely to simplify the grinding of these "specula," but they are unable to give a final opinion regarding the quality of mirrors produced by this process, until a finished silvered speculum has been tried upon the stars in actual observations. We recommend that Mr Forgan should submit his specula to the usual tests, and in the meantime we recommend this communication to the favourable consideration of the Prize Committee.

THOMAS HEATH.
PETER STEVENSON.
ALEXANDER FRAZER, *Convener.*

REPORT by Committee on Mr Daniel Macfie's Paper on a "Gas Meter and Governor in Combination."

Your Committee has examined the combination gas governor and meter invented by Mr Macfie, and they are of opinion that, although the actual form of the governor presents no novel feature, the combination is very compact and ingenious. They wish to commend the method of adjustment—that the weight which runs on a screw is adjustable by a key from the outside, and that the adjustment of the pressure is read off on the shank of the key. The fact that the combination is enclosed in one case no larger than that of an ungoverned meter, and increases the cost by a few shillings only, makes it a thoroughly practical arrangement. Moreover, it can be fitted to existing meters with little trouble.

They think that this invention will be found a considerable benefit to consumers, and they desire to commend it to the favourable consideration of the Prize Committee.

R. G. HISLOP.
THOS. HUME.
FRANCIS G. BAILY, *Convener.*

REPORT by Committee on Mr Henry O'Connor's Paper on a "Flashlight for Incandescent Street Lanterns."

Your Committee has examined Mr O'Connor's method of lighting mantle burners in street lamps and similar outside lamps, and are of opinion that it is a great improvement over the methods generally adopted. It is very simple, strong, and easily worked, with a minimum of opportunity for mistaken use at the hands of the operator. The method avoids any degree of damage to the mantle or smoking of the glass; we consider that the external lighting of the flash and the single movement igniting the lamp and extinguishing the flash will obviate any blackening, and the fact that the lamp case is not opened is important in preventing damage to the mantle. We desire to recommend it to the favourable consideration of the Prize Committee.

R. G. HISLOP.
THOS. HUME.
FRANCIS G. BAILY, *Convener.*

REPORT by Committee on Mr Henry O'Connor's Paper on an "Improved Apparatus for Determining the Percentage of Carbonic Acid Gas in Producer or Flue Gases."

Your Committee has examined the apparatus for testing carbonic acid gas, and they are of opinion that the instrument is very well adapted to its purpose—that of taking rapid approximate tests of furnace gases with unskilled operators. The process is very simple, consisting merely of counting the strokes of the pump and judging the discoloration of the liquid which can easily be identified with sufficient accuracy. While small inaccuracies will occur due to effects of temperature on the solubility of the CO_2 and the rate of working the pump, these may be safely neglected for the purpose required—that of determining the proper admission of air to the furnace. The apparatus is simple and strong, and suitable for being placed in the hands of an ordinary stoker, while its use will conduce to great economy in the working of all kinds of furnaces. We desire to commend it to the favourable consideration of the Prize Committee.

R. G. Hislop.
Thos. Hume.
Francis G. Baily, *Convener.*

Report by Committee on Mr Basil A. Pilkington's Paper on "The Effect of Electric Bell Wires in Extending Fire Risks, with a Description of an Apparatus for Reducing Same."

Your Committee have carefully considered Mr Pilkington's Paper on the above subject. Mr Pilkington's arrangement consists in substituting for low pressure currents derived from primary batteries at from 2 to 8 volts, high pressure currents as obtainable from public supply mains at 200 volts and over, incandescent lamps being inserted at the junction of the bell circuits and the supply mains for the purpose of preventing excessive currents from passing through the bell system. Your Committee are of the opinion that the Author has somewhat overstated the risks involved by the use of the ordinary electric bell systems, and that it is open to question whether the introduction of high pressures as suggested would not increase rather than diminish fire risks. It is also questionable whether the Fire Insurance offices would sanction the use of such high pressures in connection with the ordinary indicators, bells, and pushes, mounted on combustible wood boxes, such as your Committee understand the Author suggests the use of.

While your Committee thus differ from the Author as to the general advantages of the proposed arrangements, they consider that with suitably designed apparatus they may be found useful under special circumstances.

Wm. Finlay.
W. Carmichael Peebles.
Archibald Wilson.

APPENDIX (N).

Proceedings of the Royal Scottish Society of Arts, Session 1904-1905 (being the 84th Session).

First Meeting.—The Annual General Meeting of the Royal Scottish Society of Arts was held in the Hall, 117 George Street, on Monday evening, the 14th of November 1904, at 8 o'clock. Dr Dawson Turner, President of the Society, occupied the Chair, and was supported by Lord Kingsburgh and Mr Beatson Bell, Past-Presidents.

In opening the Session the President gave statistics of the membership of the Society, which showed that the membership was still decreasing. He then briefly reviewed the work of the past Session, and paid a high tribute to the many good qualities of the late Dr Milne Murray. Dr Turner then proceeded to speak of the agents other than drugs which were being used in the prevention and cure of disease. The influence of waters, massage and exercise, air, light, heat and electricity were discussed, and reference was made to the great work done by the late Dr Finsen.

At the conclusion of the address, Lord Kingsburgh moved a very hearty vote of thanks to Dr Turner for his able and interesting address. This motion was seconded by Mr Beatson Bell, and carried with acclamation.

The Secretary then read the report of the Prize Committee, and the President presented the prizes to the various recipients.

Private Business.

1. The Minute of the meeting on 11th July was read and approved.

2. The Society approved of the Office-bearers nominated by the Council, and elected them as follows:—

President . . .	DAWSON TURNER, M.D.
Vice-Presidents . .	HENRY M. CADELL, B.Sc., F.R.S.E. FRANCIS G. BAILY, M.A., F.R.S.E.
Secretary . . .	WM. ALLAN CARTER, M.Inst.C.E., F.R.S.E.
Assistant Secretary .	ANDREW WILSON, Assoc.M.Inst.C.E., F.R.S.E.
Treasurer . .	C. J. SHIELLS, C.A.
Editor of Transactions	RICHARD STANFIELD, M.Inst.C.E., F.R.S.E.
Librarian . .	ELLICE M. HORSBURGH, M.A., B.Sc.
Medallists . .	A. KIRKWOOD & SON.
Officer . . .	FRANCIS DUFFY.

Councillors.

T. HUDSON BEARE, B.Sc., M.Inst.C.E., F.R.S.E.
GILBERT THOMSON.
JOHN AYLING.
A. W. COCKBURN, C.E.
G. H. GEMMELL, F.I.C., F.C.S.
ALEX. OGILVIE, B.Sc.
JAMES PIRRIE, C.E.
J. B. BENNETT, Assoc.M.Inst.C.E., F.R.S.E.
R. G. HISLOP.
A. P. LAURIE, M.A., D.Sc., F.R.S.E.
HENRY O'CONNOR, Assoc.M.Inst. C.E.
JOHN SMITH.

3. Thomas J. K. Omit was proposed, balloted for, and duly elected an Ordinary Fellow of the Society.

The Society then adjourned.

Second Meeting—28th November 1904.—Dr Dawson Turner, President of the Society, occupied the Chair, and was supported by Professors Baily and Stanfield.

Mr Alexander Clark read his Paper on the "Tram and Road Car of the Future." The Paper described the new motor tramcar worked by a petrol engine and noiseless gearing. The gear was capable of reversing and of giving various speeds. It was pointed out that the car could be worked by steam, and a full description was given of the arrangement of a steam car. Road cars to run without rails and forms of carriage suitable for use by Railway Companies on their branch lines were also described and illustrated. The Paper was illustrated throughout by lantern slides.

Professor Baily, Messrs Cairns and Ritchie, and the President having spoken, Mr Clark replied, and was awarded the hearty thanks of the Society for his Paper.

Private Business.

1. The Minute of the Annual General Meeting was read and approved.

2. Basil A. Pilkington was proposed, balloted for, and elected an Ordinary Fellow of the Society.

The Society then adjourned.

Third Meeting—19th December 1904.—Dr Dawson Turner, President of the Society, occupied the Chair, and was supported by Professor Stanfield.

It was unanimously agreed to remit Mr Clark's communication read at the previous meeting to the following committee, Messrs Westland, Stephen Smith and Buchan, the last being Convener.

Mr Gilbert Thomson then read his communication on Ben Nevis and its Observatories. The Paper was illustrated by many beautiful lantern slides, and besides describing the apparatus and methods used for taking the meteorological observations, a most interesting description of the mountain itself was given. In concluding, the Author referred to the financial reasons which had caused the Directors to close the Observatories.

Messrs Smith, Bacon, Frazer and the Chairman contributed to the ensuing discussion. Mr Thomson having replied, the Chairman moved that the lecturer should be most cordially thanked for his interesting communication, and that the Secretary should be instructed to convey to the Prime Minister an expression of the Society's regret that the Government had not as yet seen its way to give such financial assistance to the Observatories as would ensure a continuance of their admirable and valuable work. This motion was unanimously carried.

Private Business.

The Minute of the previous meeting was read and approved.

The Society then adjourned.

Fourth Meeting—16th January 1905.—The President occupied the Chair, and was supported by Professor Baily.

Mr Thomas J. K. Omit described his improvement in kitchen ranges. The fire was enclosed by a ventilating fire-door, and the bottom of the grate was movable so that the front could be raised, thus diminishing the size of the fire. The increased draught, which would otherwise have played on the reduced fire, was checked by an ingenious arrangement. Full utilisation of heat and economy of fuel were claimed for the invention. After discussion and Mr Omit's reply, the communication was remitted to a committee of Messrs Mackenzie, Foulis and Hume, the first to be Convener.

Mr John Ritchie then read his communication on "Electric Hoisting Machinery." The types of motors suitable for cranes were described, and many examples of electric cranes for a great variety of purposes were illustrated, including the recently erected conveyor across the Zambesi River. In conclusion the cost and economy of the electric crane were treated by the Author.

Unfortunately, owing to the lateness of the hour, no discussion followed the Paper, which was remitted to a committee of Messrs Clark (Convener), Archibald Wilson, and A. F. Ross.

Private Business.

1. The Minute of the previous meeting was read and approved.

2. William Pryde Watson was proposed, balloted for, and duly elected an Ordinary Fellow of the Society.

The Society then adjourned.

Fifth Meeting—30th January 1905.—Dr Dawson Turner, President of the Society, occupied the Chair, and was supported by Mr Cadell, Vice-President, and Mr Beatson Bell, Past-President.

Lord Kingsburgh read his communication on Roads, what they are, and what they should be. An interesting history of roads in early times was given, and this was followed by a consideration of the question of speed. Then the materials of which roads were composed were described, and the essentials of a good road pointed out. The lecturer alluded to the good work which Mr Hooley, the Burgh Surveyor of Nottingham, had done in connection with the road problem, and specimens of the Tar-Mac invented by him were passed round the audience. The Paper was illustrated by diagrams and various samples of road construction materials.

The following took part in the discussion which ensued:—The Chairman, Mr Cadell, Professor Baily, Messrs Hislop, Macdonald, and Dobbie, and the Secretary. Lord Kingsburgh replied, and was awarded the Society's heartiest thanks for his communication.

Private Business.

The Minute of the previous meeting was read and approved.
The Society then adjourned.

Sixth Meeting—13*th February* 1905.—The President occupied the Chair, and was supported by Mr Cadell, Vice-President.

The President read a letter which he had received from the Treasury, acknowledging the letter containing the resolution of the Society with regard to the closing of Ben Nevis Observatory.

Mr Forgan then gave his communication on Machines for Grinding Telescope Specula and a Simple and Effective Addition to an Ordinary Lathe for that purpose. Mr Forgan exhibited a model of his apparatus, and after discussion the Paper was remitted to a committee consisting of Messrs Heath, Stevenson, and Frazer, the last to be Convener.

Mr Herbert W. Bacon then read his communication on Stained Glass. Mr Bacon gave a most interesting history of his subject, and then proceeded to give the objects, rules for, and limitations of stained glass windows. In conclusion, Mr Bacon described various experiments which he had made or was making in connection with his art.

After some discussion, to which Mr Bacon replied, the communication was remitted to the following committee, Messrs Paterson, Stephen Smith, and Blanc, the last to be Convener.

Private Business.

1. The Minute of the previous meeting was read and approved.

2. The Treasurer laid his accounts for Session 1903-1904 on the Table.

The Society then adjourned.

Seventh Meeting— 27*th February* 1905.—Dr Dawson Turner, President of the Society, occupied the Chair, and was supported by Colonel M'Hardy, Past-President.

Mr Macfie read his communication on a Gas Meter and Governor in Combination. Beginning with some interesting facts about the early history of gas-lighting, the Author proceeded to a description of his own invention. His governor was of the diaphragm type, and was wholly contained in the body of the meter. The advantages of this arrangement were pointed out. After some discussion, in which Messrs Hume, Proctor, and Kemp took part, the communication was remitted to a committee consisting of Messrs Hislop and Hume, and Professor Baily, the last to be Convener.

Mr O'Connor then described his Flash-lighter for Incandescent Gas-lighted Lanterns. A full size model was shown, and by means of this the cock, by means of which the gas was directed into the lighting jet or the main light as desired, was easily understood. The communication was remitted to the same committee which had been appointed to report on Mr Macfie's communication.

Mr O'Connor then described his apparatus for the determination of Carbonic Acid and other Gases. A cylinder fitted with a spring plunger withdrew a charge of the gas to be tested, and the cylinder was then discharged into a chemical solution, and the effect of the discharge on the colour of the solution gave a test of the gas. This communication was remitted to the same committee which had been appointed for his previous communication.

Private Business.

1. The Minute of the previous meeting was read and approved.

2. Lachlan P. Mackenzie was proposed, balloted for, and duly elected an Ordinary Fellow of the Society.

The Society then adjourned.

Eighth Meeting— 13*th March* 1905.—Mr H. M. Cadell, Vice-President of the Society, occupied the Chair, and was supported by Professor Baily and Mr Beatson Bell.

Mr W. B. Blaikie read his communication on Sun-dials, more particularly as suited for the interiors of street houses. The Author began by an exposition of elementary astronomy sufficient to enable one to understand the theory underlying the construction of sun-dials. This part of the lecture was illustrated by a wealth of interesting apparatus. Coming to his subject proper, the Author described how dials might be made for all latitudes and in any position, reclined, inclined, horizontal, or vertical. Mr Blaikie showed a most ingenious way of determining the dimensions of the gnonom of a dial and of projecting the hour lines. All sorts of dials were shown to the meeting, including little transparent dials to be fixed to window panes.

After Professor Baily and Dr Ferguson had spoken, the communication was remitted to a committee consisting of Messrs Heath and F. J. Ritchie, and Professor Beare, the last to be Convener.

Private Business.

1. The Minute of the previous meeting was read and approved.

2. John Jordan was proposed, balloted for, and duly elected an Ordinary Fellow of the Society.

3. In terms of Law XX. the Treasurer was granted discharge of his intromissions for Session 1903-1904.

The Society then adjourned.

Ninth Meeting—10th April 1905.—Mr H. M. Cadell, Vice-President of the Society, occupied the Chair.

Mr Basil A. Pilkington read his Paper on the Effect of Electric Bell Wires in Extending Fire Risks and a description of an apparatus for reducing same. Mr Pilkington pointed out the more or less temporary nature of all installations, and showed how, by deriving the power for bell purposes from electrical mains of considerable high pressure, faults on any circuit could very easily be detected, instead of being hidden or unknown, as was often the case with existing bell systems. Messrs Wilson and Hislop having spoken, and Mr Pilkington having replied, the communication was remitted to the following committee, Messrs Archibald Wilson (Convener), William Finlay, and W. Carmichael Peebles.

Mr Charles Kemp then delivered his communication on Wireless Light Telephony. Giving an abstract of the general principles underlying his subject, which included some of the properties of selenium. the Author proceeded to the transmission of electrical waves by means of a beam of light directed to a selenium cell. The Paper was illustrated in a most interesting way by lantern slides, and at the conclusion Mr Kemp was cordially thanked for his communication.

Private Business.

1. The Minute of the previous meeting was read and approved.

2. John Douglas Keiller was proposed, balloted for, and duly elected an Ordinary Fellow of the Society.

The Society then adjourned.

An Extraordinary Meeting of the Royal Scottish Society of Arts was held in the Hall, 117 George Street, on Monday evening, the 5th of June 1905, at 5.30 o'clock.

Dr Dawson Turner, President of the Society, occupied the Chair, and was supported by Professor Baily, Vice-President, The President put the following resolution before the meeting:—

> The Society having found it impossible for many years past to apply the whole of the income of the Keith Fund in terms of the conditions of the Letter of Gift of 8th April 1833, owing to the condition that inventions must be primarily submitted to the Society, and being of opinion that the best mode, and the mode nearest to the Trust purposes, of dealing with the income is by the expenditure of such of it as may not be required for the purposes mentioned in the Letter of Gift, in (1) the payment of the expenses of, or connected with, lectures on the useful arts or scientific subjects; or (2) in making money grants in aid of experiments and of work of research in, or connected with, the useful arts in Scotland, resolve to apply to the Court of Session for power to so use the surplus income of the said fund, or for such other purposes and in such other manner as the Court may authorise.

After the Treasurer, Professor Baily, and Mr Boa had spoken in support of the resolution, Mr Kemp moved as an amendment that consideration of the whole question of the position of the Society should be deferred till the autumn. This amendment was seconded by Mr Grieve.

On the amendment being put to the meeting, only the proposer and seconder of it voted for it, while the resolution as above was supported by thirteen, the rest of the Fellows present.

The President declared the resolution passed, and the Society thereafter adjourned.

Tenth Meeting—26*th June* 1905.—Dr Dawson Turner, President of the Society, occupied the Chair.

Reports by Committees on the following communications were read and adopted by the Society:—

On Mr Omit's	Paper,	No. 4867.
On Mr Ritchie's	do.	No. 4868.
On Mr Macfie's	do.	No. 4872.
On Mr O'Connor's	do.	No. 4873.
On Mr O'Connor's	do.	No. 4874.
On Mr Pilkington's	do.	No. 4876.

Mr Hislop moved and Mr Hume seconded that the report on Mr Clark's Paper, No. 4865, which was read, should be recommitted to the Committee, that Mr O'Connor's name should be added, taking the place of Mr Westland, who declined to act, and that this report and others not definitely disposed of be remitted direct to the Prize Committee for its consideration. This was unanimously agreed to.

Private Business.

1. The Minutes of the Ninth and Extraordinary Meetings were read and approved.

2. In terms of Law XVIII. the Society elected the Prize Committee as follows:—

Dr Dawson Turner, President; Mr H. M. Cadell; Professors Baily and Beare; Messrs Blanc, Buchan, Frazer, Heath, Hislop, Mackenzie, Stephen Smith, and Archibald Wilson.

The Society then adjourned.

APPENDIX (O).

DONATIONS TO THE LIBRARY RECEIVED DURING THE SESSION 1904-1905.

Proceedings of the Royal Society, and Reports to the Evolution Committee.
" " Royal Dublin Society.
" " Royal Irish Academy.
" " Royal Physical Society.
" " Institution of Mechanical Engineers.
" " Institution of Electrical Engineers.
" " Staffordshire Iron and Steel Institute.
" " Royal Philosophical Society of Glasgow.
" " Liverpool Literary and Philosophical Society.
" " Boston Society of Natural History.
" " American Philosophical Society.
" " American Academy of Arts and Sciences.
" " Royal Society of Victoria.
" " Royal Institution of Great Britain.
Transactions of the Institution of Engineers and Shipbuilders in Scotland.
" " North of England Institute of Mining and Mechanical Engineers.
" " Institution of Civil Engineers in Ireland.
" " Canadian Institute.
" " Canadian Society of Civil Engineers.
" " Junior Institution of Engineers.
" " Academy of Science of St Louis.
Memoirs and Proceedings of the Manchester Literary and Philosophical Society.
Transactions and Proceedings of the Botanical Society of Edinburgh.
Journal of the Society of Arts.
" " Scottish Meteorological Society.
" " Western Society of Engineers.
" " Franklin Institute.

Journal of the Association of Engineering Societies.
Smithsonian Institution Annual Report.
Memoirs and Records of the Geological Survey of India.
Atti e Memorie della R. Accademia di Scienze Lettere ed Arti in Padova.
Atti della R. Accademia delle Scienze di Torino.
Annales de l'Association des Ingénieurs sortis des Écoles Spéciales de Gand.
Reports of the British Association for the Advancement of Science, 1903 and 1904.
Engineering.
The Engineer.
The English Mechanic.
Engineering Times.
Public Works.
The Surveyor.
The Periodical.
Cassier's Magazine.
The Book Lover.
The Machinery Market.
Medico-Pharmaceutical Journal.
Boston Public Library Monthly Lists of Books.
Edinburgh University Calendar.
Daily Mail Year Book.
John Crerar Library. Annual Report.
The "London Point" System of Reading for the Blind.
Electricity in the Service of Man. By R. M. Walmsley.
Book of Generation. By Adair Welcker.
Statistical Account of Australia and New Zealand.
Edinburgh Architectural Association Handbook.

(488 Publications in all.)

ELLICE M. HORSBURGH,
Librarian.

APPENDIX (P).

LIST OF PRIZES OFFERED BY THE ROYAL SCOTTISH SOCIETY OF ARTS FOR PAPERS WHICH MAY BE SUBMITTED DURING THE SESSION 1905–1906.

(1) A KEITH PRIZE, value Thirty Sovereigns.

For some important "Invention, Improvement, or Discovery in the Useful Arts which shall be primarily submitted to the Society" during the Session.

(2) A HEPBURN PRIZE, value Twelve Sovereigns.

For such Invention or Communication submitted to the Society as shall be approved of by the Society, or by their Prize Committee.

(3) A MAKDOUGALL-BRISBANE PRIZE, value Ten Sovereigns.

To the Authors of Communications of Merit, or for Inventions which shall be approved of by the Society, or its Committee, and judged by them deserving of such distinction.

(4) REID and AULD PRIZES, value about Seven Sovereigns.

For the First, Second, and Third best Models of anything new in the Art of Clock or Watch Making—by Journeymen or Master Watch and Clock Makers—if these should be considered worthy of prizes. The sum mentioned above to be divided in such proportions as the Prize Committee shall fix. The Society, if it sees fit, may add to the amount available for these Prizes out of its general funds.

The Society may offer a Special Keith Prize to be competed for during the Session, details of which will be submitted to the Society at a later date.

The Society proposes to award the above Prizes for approved Communications submitted to the Society by Fellows or others, relative to Inventions, Discoveries, and Improvements in the Industrial Arts, or to means by which the Natural Productions of the Country may be made more available, whether the subjects treated have been patented or not. The Society suggests the following as a few of the many subjects suitable for such Communications :—

1. *Mechanical Arts.*

INVENTIONS of, or IMPROVEMENTS relating to, Wind and Water Prime Motors; Steam and other Heat Engines; Pumping, Blowing, Rolling, Sawing, Agricultural and other Engines and Machines; Machinery used in the manufacture of Cotton or other Textile Fabrics; Shipbuilding, including Machinery, Appliances, and Materials used in same; Marine Propellers; Lighthouses and Lighthouse Appliances; Railways, including Structural Work, Plant, and Signals; Electrical Machinery and Apparatus; Mechanical Photographic Processes; Fireproof Buildings; Water Works; Sewage Works; Methods and Appliances for improving the Sanitary Conditions of Towns; Appliances for the Prevention of Smoke and Extinction of Fires; Gas Works and Gas Lighting; Canals, Inland Navigation, and Machinery employed for Canal Traffic, including Locks, Inclines, and Lifts; Hydraulic Machinery as applied to Lifts, Cranes, Printing Presses, Organ Blowers, and other purposes; Tools, Implements, and Appliances used in the various Trades; Bricks, Tiles, Cements, and Mortars; Printing Machines and Appliances connected therewith; Stereotyping and other similar Processes; Processes for the Preservation of Timber and Metals; Optical and other Scientific Apparatus; etc., etc., etc.

2. *Chemical Arts.*

INVENTIONS or IMPROVEMENTS relating to Processes for the Treatment of Natural Productions; the Manufacture of Chemical Substances used in Commerce, Science, or Art; the Application of Chemistry to particular Manufactures and Trades; etc., etc., etc.

3. *Fine Arts.*

INVENTIONS or IMPROVEMENTS relating to all kinds of Photographic Processes as applied to the Production of Illustrations; Engraving Processes; Lithography; Die-Sinking; Methods of applying Colours for Decorative Purposes; the Use and Treatment of various Materials for Wall Decoration; etc., etc., etc.

GENERAL OBSERVATIONS.

Communications are also invited describing Processes and Important Works, although no claim may be made by the Author on the score of Invention or the introduction of Improvements.

The Society reserves the right to withhold any of the Prizes offered for competition if the Papers submitted do not possess sufficient merit, or to award Prizes of smaller amounts, or to split up the amounts into a larger number of Prizes, as the Prize Committee may see fit.

In preparing Papers, the descriptions of Inventions, etc., should be full and distinct, written legibly on one side only of Foolscap paper, and, when necessary, the Communications should be accompanied by Specimens, Drawings, or Models. The Drawings should be in bold lines about $\frac{1}{4}$ of an inch broad, and strongly coloured, so as to be easily seen at about the distance of 30 feet when hung up in the Hall. Letters or Figures of Reference should be at least $1\frac{1}{2}$ inches long. When necessary, smaller and more minutely detailed Drawings should accompany the larger ones, for the use of the Committee, having the same letters of reference.

The Society shall be at liberty to publish in their *Transactions* Copies or Abstracts of all Papers submitted to them.

All Models, Drawings, etc., accompanying Papers for which Prizes are given shall be held to be the property of the Society; but the value of Models, if retained, will be allowed for.

Communications, Models, etc., are to be addressed to the Secretary, 117 George Street, Edinburgh, Postage or Carriage Paid. Communications lodged after the 1st of March may not be read or reported on till the following Session.

By Order of the Society,

WM. ALLAN CARTER,

Secretary.

APPENDIX (Q).

REPORT OF THE COMMITTEE APPOINTED BY THE ROYAL SCOTTISH SOCIETY OF ARTS TO AWARD PRIZES FOR COMMUNICATIONS READ OR REPORTED ON DURING THE SESSION 1904-1905.

Your COMMITTEE having met and carefully considered the Communications laid before and definitely disposed of by the Society, during the Session 1904-1905, begs to report that it has awarded the following Prizes:—

To JOHN RITCHIE, — for his Paper on "Electric Hoisting Machinery" (No. 4868), — read on the 16th of January 1905,

A Makdougall-Brisbane Prize, value Ten Sovereigns.

To HENRY O'CONNOR, Assoc.M.Inst.C.E.,—for his Papers on "A Flashlighter for Incandescent Gaslighted Lanterns," and on "A Simple Apparatus for the Detection of CO_2 and other Gases" (Nos. 4873 and 4874),—read on the 27th of February 1905,

A Keith Prize, value Five Sovereigns.

To THOMAS OMIT,—for his Paper on "An Improvement in Kitchen Ranges" (No. 4867),—read on the 16th of January 1905,

A Keith Prize, value Three Sovereigns.

To Daniel Macfie,—for his Paper on "A Gas Meter and Governor in Combination" (No. 4872),—read on the 27th of February 1905,

A Reid and Auld Prize, value Three Sovereigns.

That the hearty thanks of the Society are due to the President, Dr Dawson Turner, for his Opening Address delivered on the 14th of November 1904, and to The Right Hon. Sir John Macdonald, and Messrs Alexander Clark, Gilbert Thomson, W. Forgan, Herbert W. Bacon, W. B. Blaikie, Basil A. Pilkington, and Charles N. Kemp for their communications.

All of which is reported in name and by order of the Prize Committee by

Wm. ALLAN CARTER, *Secretary*,
Convener ex officio.

Society's Hall, 117 George Street,
Edinburgh, 10*th October* 1905.

APPENDIX (R).

Royal Scottish Society of Arts.

ABSTRACT OF THE ACCOUNTS OF THE SOCIETY FOR 1903–1904.

I. GENERAL FUND.

Charge.

Income—		
Arrears of Subscriptions at 15th November 1903		£5 5 0
Subscriptions for Session 1903-1904		89 15 6
		£95 0 6
Less—Unpaid at 15th November 1904		4 4 0
		£90 16 6
Balance at Credit of Building Fund		17 3 9
Interest received		0 13 0
Miscellaneous Receipts		6 12 6
Total Income		£115 5 9
Compositions received		15 4 6
Sum borrowed from Keith Fund during year		60 0 0
Subscriptions unpaid at 15th November 1904		4 4 0
Sum on Deposit with the Commercial Bank at 15th November 1903		9 8 2
	Sum of the Charge...	£204 2 5

Discharge.

Ordinary Expenditure—				
Printing and Advertising		£18 1 6		
Salaries and Expenses of Collection,	£97 13 0			
Less—Charged to Prize Funds	5 1 3			
		92 11 9		
Expenses connected with the Society's Printed Transactions		67 14 7		
Interest paid to Keith Fund on Loan		3 8 5		
Miscellaneous Payments		9 19 4		
Total Ordinary Expenditure...			£191 15 7	
Prizes Awarded				
Arrears of Subscriptions written off			1 1 0	
Subscriptions Outstanding at 15th November 1904			4 4 0	
Sum on Deposit with Commercial Bank at 15th November 1904			6 8 10	
Balance due by Treasurer at 15th November 1904			0 13 0	
Sum of the Discharge...				204 2 5

II. KEITH BEQUEST.

Charge.

Sum on Deposit with the Commercial Bank at 15th November 1903		£66 1 5
Income—		
Dividends from Stocks, viz. :—		
Edinburgh and Leith Gas Annuity	£28 11 0	
Great North of Scotland Railway Company Debenture Stock	19 0 8	
Forth and Clyde Junction Railway Preference Stock	4 15 4	
North British Railway Company Consolidated Lien Stock...	11 9 2	
	£63 16 2	
Interest on Loan to General Fund	3 8 5	
Bank Interest received	1 9 5	
		68 14 0
Sum of the Charge...		£134 15 5

II. KEITH FUND.

Charge Amount .... Forward		£134 15 5

Discharge.

Expenditure—		
Prizes awarded	£20 0 0	
Commission on Revenue, credited General Fund	3 3 9	
	£23 3 9	
Loan to General Fund during year	60 0 0	
Sum on Deposit with the Commercial Bank at 15th November 1904	51 11 8	
Sum of the Discharge		134 15 5

III. REID AND AULD BEQUEST.

Charge.

Sum on Deposit with the Commercial Bank at 15th November 1903		£142 9 1
Income—		
Interest on Great North of Scotland Railway Company Debenture Stock	£17 2 7	
On Forth and Clyde Junction Railway Preference Stock	2 7 8	
On North British Railway Consolidated Lien Stock	3 15 9	
Bank Interest	2 14 8	
		26 0 8
Sum of the Charge...		£168 9 9

Discharge.

Expenditure—		
Donations to poor Clockmakers in terms of the Bequest	£12 0 0	
Commission on Revenue, credited General Fund	1 3 3	
	£13 3 3	
Sum on Deposit with the Commercial Bank at 15th November 1904	155 6 6	
Sum of the Discharge		168 9 9

IV. BRISBANE BIENNIAL PRIZE FUND.

Charge.

Sum on Deposit with the Commercial Bank at 15th November 1903		£45 4 2
Income—		
Interest on Forth and Clyde Junction Railway Preference Stock	£7 2 10	
Bank Interest	0 17 3	
		8 0 1
Sum of the Charge...		£53 4 3

Discharge.

Expenditure—		
Prize awarded	£2 12 0	
Commission on Revenue, credited General Fund	0 7 2	
	£2 19 2	
Sum on Deposit with the Commercial Bank at 15th November 1904	50 5 1	
Sum of the Discharge		53 4 3

V. HEPBURN PRIZE FUND.

Charge.

	£	s.	d.	£	s.	d.
Sum on Deposit with the Commercial Bank at 15th November 1903				£54	2	6
Income—						
Dividends on Caledonian Railway Company Stocks	£7	1	10			
Bank Interest	1	0	8			
				8	2	6
Sum of the Charge...				£62	5	0

Discharge.

	£	s.	d.	£	s.	d.
Expenditure—						
Prizes awarded	£6	0	0			
Commission on Revenue, credited General Fund	0	7	1			
	£6	7	1			
Sum on Deposit with the Commercial Bank at 15th November 1904	55	17	11			
Sum of the Discharge				62	5	0

VI. BUILDING FUND.

Charge.

	£	s.	d.	£	s.	d.
Rents drawn from Letting the Hall				£206	16	6

Discharge.

	£	s.	d.	£	s.	d.
Payments on Account of the Hall and Hallkeeper's House, viz., Taxes, Feu-duty, Insurance, Coals, Gas, Cleaning, etc., and Hallkeeper's Salary	£143	9	3			
Repairs and Furnishings to the Hall	21	18	0			
Extraordinary Repairs	24	5	6			
				189	12	9
Balance transferred to the General Fund, page 77				£17	3	9

FUNDS OF THE SOCIETY.

As at 15th November 1904, per Report of the Auditor.

I. GENERAL FUND.

	£	s.	d.
Price of Hall in George Street and Furnishings, and of the additional Premises purchased at Whitsunday 1863	£2,712	0	3
Arrears of Annual Contributions	4	4	0
Sum on Deposit with Commercial Bank	6	8	10
Balance in hands of the Treasurer	0	13	0
	£2,723	6	1
Deduct Loan from Keith Fund	180	0	0
Amount of General Fund...	£2,543	6	1

II. KEITH BEQUEST.

	£	s.	d.	£	s.	d.
£30 Annuity of the Edinburgh and Leith Gas Commission	£870	0	0			
£500 Great North of Scotland Railway Company Debenture Stock	612	10	0			
£100 Preference Stock No. 1 of the Forth and Clyde Junction Railway Company	137	0	0			
£300 4 per cent. Consolidated Lien Stock of the North British Railway Company	406	15	0			
Sum on Deposit with the Commercial Bank	51	11	8			
Loan to General Fund	180	0	0			
				2,257	16	8
Carry forward,				£4,801	2	9

II. FUNDS OF THE SOCIETY—continued.

Brought forward,		£4,801 2 9

III. REID AND AULD BEQUEST.

£450 Great North of Scotland Railway Company Debenture Stock	£551 5 0	
£50 Preference Stock No. 1 of the Forth and Clyde Junction Railway Company	68 10 0	
£100 4 per cent. Consolidated Lien Stock of the North British Railway Company	135 11 10	
Sum on Deposit with the Commercial Bank	155 6 6	
		910 13 4

IV. BRISBANE PRIZE FUND.

£150 Preference Stock No. 1 of the Forth and Clyde Junction Railway Company	£205 10 0	
Sum on Deposit with the Commercial Bank	50 5 1	
		255 15 1

V. HEPBURN PRIZE FUND.

£175 Caledonian Railway Company Consolidated 4 per cent. Stock, No. 2	£209 2 6	
£11 do. No. 1	13 6 0	
Sum on Deposit with the Commercial Bank	55 17 11	
		278 6 5
Total Property and Funds under Charge of the Society as at 15th November 1904		£6,245 17 7

C. J. SHIELLS, *Treasurer.*

EDINBURGH, 24*th January* 1905.—I have examined and audited the Accounts of the Treasurer to the Royal Scottish Society of Arts for the Session 1903-1904, of which the foregoing is an Abstract, and beg to report that I have found the same to be correctly stated and sufficiently vouched. I have also examined the securities for the Invested Funds of the Society, and have found them in order.

GEORGE H. CARPHIN, C.A., *Auditor.*

APPENDIX (S).

LIST

OF THE

OFFICE-BEARERS AND FELLOWS

OF THE

ROYAL SCOTTISH SOCIETY OF ARTS

THE KING, PATRON

OFFICE-BEARERS FOR SESSION 1905-1906

As elected on 13th November 1905.

President . . .	T. HUDSON BEARE, B.Sc., M. Inst. C.E., Edinburgh University.
Vice-Presidents . .	FRANCIS G. BAILY, M.A., F.R.S.E., Heriot-Watt College. JOHN RITCHIE, C.E., The Knowe, Lygon Road.
Secretary . . .	WILLIAM ALLAN CARTER, M. Inst. C.E., F.R.S.E., 117 George Street.
Assistant Secretary .	ANDREW WILSON, Assoc. M. Inst. C.E., 14 Queen Street.
Treasurer . . .	C. J. SHIELLS, C.A., 141 George Street.
Editor of Transactions	RICHARD STANFIELD, M. Inst. C.E., F.R.S.E., Heriot-Watt College.
Librarian . . .	E. M. HORSBURGH, M.A., B.Sc., F.R.S.E., 3 Eglinton Crescent.
Medallists . . .	ALEXANDER KIRKWOOD & SON, 9 St James Square.
Officer	FRANCIS DUFFY, 117 George Street.

Councillors.

G. H. GEMMELL, F.I.C., F.C.S., 4 St Catherine's Place.
ALEXANDER OGILVIE, B.Sc. Leith Electric Works.
JAMES PIRRIE, C.E., 135 George Street.
JAMES B. BENNETT, Assoc. M. Inst. C.E., F.R.S.E., 12 Hill Street.
R. G. HISLOP, 11 Pitt Street.
A. P. LAURIE, D.Sc., F.R.S.E., Heriot-Watt College.
HENRY O'CONNOR, Assoc. M. Inst. C.E., F.R.S.E., 1 Drummond Place.
JOHN SMITH, Engineer, Penicuik.
HIPPOLYTE J. BLANC, R.S.A., F.R.I.B.A., 25 Rutland Square.
HENRY M. CADELL, B.Sc., F.R.S.E., of Grange, Bo'ness.
JAMES D. GIBSON, Ordained Surveyor, 60 Frederick Street.
STEVENSON MACADAM, F.I.C., F.C.S., 55 York Place.

LIST OF THE ORDINARY FELLOWS AND ASSOCIATES

AS AT 15TH NOVEMBER 1905

*Those marked * are Life Fellows.*

NOTE.—Fellows may become "Life Fellows" at any time on paying £10, 10s., from which they are allowed a deduction of half the amount they may have paid previously in Annual Contributions.

1871 *Aitken, John, F.R.S.E., Ardenlea, Falkirk
1851 *Alexander, William, M.E.
1896 *Archer, Robert S., Craigleith, 5 Lowwood Road, Birkenhead
1868 *Archibald, John, M.D., Hazelden, Wimborne Road, Bournemouth
1891 Ayling, John, 22 Inverleith Place

1896 Baily, Francis G., M.A., F.R.S.E., M.I.E.E., Professor of Applied Physics, Heriot-Watt College, *Vice-President*
1895 Barron, James, M. Inst. C.E., 1 Bon Accord Street, Aberdeen
1878 *Barton, John Fraser, plumber, 11 Forrest Road
1901 Beare, T. Hudson, B.Sc., M. Inst. C.E., M. Inst. M.E., F.R.S.E., Professor of Engineering, Edinburgh University, *President*
1859 *Bell, Andrew Beatson, advocate, F.R.S.E., 17 Lansdowne Crescent
1902 Bennett, James B., Assoc. M. Inst. C.E., F.R.S.E., 12 Hill Street, *Councillor*
1879 *Black, William Galt, F.R.M.S., 2 George Square
1883 *Blaikie, Walter Biggar, F.R.S.E., printer, 11 Thistle Street
1879 *Blanc, Hippolyte Jean, R.S.A., F.R.I.B.A., 25 Rutland Square, *Councillor*
1877 *Blyth, James, F.R.S.E., Professor of Mathematics and Natural Philosophy, Andersonian University, Glasgow
1888 Boa, Peter, pharmaceutical chemist, 119 George Street
1892 Bonar, Horatius, W.S., 3 St Margaret's Road
1853 *Bow, Robert Henry, C.E., F.R.S.E., 7 South Gray Street
1868 *Boyd, James L., S.S.C., Glendouglie, Glenfarg
1890 Brebner, R. C., 28 Hermitage Gardens
1864 *Brown, Geo. Bruce, architect. (No address)
1880 *Bruce, A. Fairlie, C.E. (No address)
1868 *Bruce, C., banker, 3 Melville Crescent
1850 *Bruce, George Cadell, C.E.
1893 Buchan, Mathew, electrician, 16 Rutland Square
1893 Buchanan, James, Oswald Road
1879 *Buchanan, John, C.E., 12 Hill Street

1891 Cadell, Henry Moubray, B.Sc., F.R.S.E., of Grange, Bo'ness, *Councillor*
1879 *Carfrae, George Somervel, C.E., 1 Erskine Place
1880 *Carmichael, Neil, M.D., 23 Nithsdale Road, Pollokshields, Glasgow
1892 *Carphin, G. H., C.A., 3 Abinger Gardens, Murrayfield
1840 *Carstairs, Drysdale, merchant, Hailes House, Fairfield, Liverpool
1875 *Carter, William Allan, M. Inst C.E., F.R.S.E., 14 Queen Street *Secretary*
1872 *Cattanach, Peter Lorimer, advocate, 14 London Street

1867 *Cay, William Dyce, M. Inst. C.E., F.R.S.E., 1 Albyn Place
1879 *Clark, Alexander, Assoc. M. Inst. C.E., 8 Bright's Crescent
1878 *Clement, Adam Ferguson, telegraph engineer, Egmont, 59 Braid Road
1901 Cockburn, Alexander W., civil engineer, 39 York Place
1889 Colam, William N., M. Inst. C.E., 57 Henderson Row
1862 *Copland, Harry Y. D., 21 Manor Place
1876 *Cormack, D. Adair, marine engineer, 17 Abercorn Terrace, Portobello
1872 *Couper, Charles Tennant, advocate, 3 Charlotte Square
1888 Cowan, John, 6 Salisbury Road
1883 *Crabbie, George, merchant, 8 Rothesay Terrace
1885 Cran, John, mechanical engineer, Albert Engine Works, Leith
1876 *Cranston, The Rt. Hon. Sir Robert, K.C.V.O., Lord Provost, 33 Princes Street
1879 *Cunningham, James H., Assoc. M. Inst. C.E., 2 Ravelston Place

1892 Davidson, John, Langley Park, Wick
1882 *Dickson, Lamont, C.E., 135 George Street
1887 Drysdale, Alexander, builder, 70 Pilrig Street
1894 Dunbar, James, Elgin House, Easter Road
1893 *Duncan, D. J. Russell. (No address)

1896 Eaton, Edmond, 99 Cannon Street, London, E.C.
1892 Elgin and Kincardine, The Right Hon. The Earl of, K.G., Broomhall, Dunfermline

1878 *Farquharson, Thomas Ker, accountant, 100 Thirlstane Road.
1857 *Ferguson, R. M., LL.D., Ph.D., F.R.S.E., 5 Douglas Gardens
1895 *Ferranti, S. Z. de, engineer, Ingleside, Lyndhurst Road, Hampstead, London, N.W.
1904 Finlay, William, electrical engineer, 16 North St Andrew Street
1860 *Firth, William, Wideford, Granton Road
1894 Foulis, David, jun., 42 Shandwick Place
1850 *Fraser, Alexander, printer, 17 Eildon Street
1879 *Frazer, Alexander, M.A., optician, 22 Teviot Place

1856 *Geddes, A. C., C.E., 14 Ettrick Road
1896 *Geddes, C. D., mining engineer, 21 Young Street
1856 *Geddes, G. H., M.E., 21 Young Street
1899 Gemmell, George H., F.I.C., F.C.S., 4 St Catherine's Place, *Councillor*
1889 Gibson, J. D., ordained surveyor, 60 Frederick Street, *Councillor*
1887 Gilmour, George, builder, 19 Rosslyn Crescent
1857 *Gordon, Alexander. (No address)
1851 *Gordon, James Newall, London
1860 *Gray, Rev. W. H., M.A., D.D., 3 Carlton Terrace
1893 *Grieve, George K., 12 Cambridge Avenue

1860 *Hardie, Walter, 5 Bellevue Street
1888 *Harris, William A., F.S.S., F.I. Inst., secretary, Phœnix Fire Office, Exchange, Liverpool
1870 *Hartnell, Wilson, engineer, Volt Works, Leeds
1879 *Heath, Thomas, F.R.S.E., assistant observer, Royal Observatory
1891 *Herdman, G. W., M.A., B.Sc., Assoc. M. Inst. C.E., Irrigation Department, Pretoria
1898 Herring, W. R., M. Inst. C. E., Granton House, Granton
1871 *Hislop, George Robertson, F.C.S., gas engineer, Blackstone Road, Paisley
1898 *Hislop, Laurence, gas engineer, Uddingston
1894 Hislop, R. G., 11 Pitt Street, *Councillor*

1863 *Hogue, D. W., M.D., dentist, Roxburgh, Marlborough Road, Bournemouth
1900 *Horne, Wm. James, A.M.I.E.E., South African College, Cape Town
1900 Horsburgh, E. M., M.A., B.Sc., F.R.S.E., 3 Eglinton Crescent, *Librarian*
1868 *Horsburgh, John, Aberdour House, Aberdour
1893 Horsburgh, J. Alfred, photographer, 4 West Maitland Street
1892 Howkins, John, C.E., Granton
1897 Hume, John, 46 Torphichen Street
1888 Hume, Thomas, plumber, 2A Stafford Street
1876 *Hutchison, James T., 12 Douglas Crescent

1882 *Inglis, John William, F.R.S.E., M. Inst. C.E. (No address)

1884 Jenkinson, Alexander Dixson, glass manufacturer, 10 Princes Street
1905 Jordan, John, merchant, 17 Charlotte Square

1905 Keiller, J. D., scientific instrument maker, 1 Albion Road
1904 Kemp, Charles N., Ivy Lodge, Trinity
1872 *Kemp, D. William, Ivy Lodge, Trinity
1872 *Key, William, St Cyr, Ceres, Fife
1902 Kirkwood, Alexander, 9 St James Square, *Medallist*
1898 Knoblauch, Louis, merchant, 22 Baltic Street, Leith
1887 Knox, Patrick, plumber, 31 Crichton Place

1884 Laidlaw, Robert, engineer, 147 East Milton Street, Glasgow
1894 Laing, J. H. A., M.B., C.M., 11 Melville Street
1902 Laurie, A. P., M.A., D.Sc., F.R.S.E., Principal, Heriot-Watt College, *Councillor*
1856 *Lees, William, A.M. (No address)
1904 Leslie, James, C.E., 5 Douglas Gardens
1873 *Lewis, David, Roselea Villa, Grange
1877 *Lockie, John, engineer, 2 Commercial Street, Leith

1904 Macadam, Stevenson, F.I.C., F.C.S., 55 York Place
1882 *Macdonald, James, plumber, 3 Dundas Street
1889 *Macdonald, The Right Hon. Sir J. H. A., K.C.B., LL.D., F.R.S.S. (L. & E.), M.I.E.E., Lord Justice-Clerk of Scotland, 15 Abercromby Place
1898 M'Gregor, Walter, accountant, 32 York Place
1898 M'Hardy, Lieut.-Col. A. B., C.B., 3 Ravelston Park
1888 Mackenzie, A. Donald, 14 Greenhill Park
1905 Mackenzie, Lachlan P., iron-founder, 5 Polwarth Terrace
1867 *Maclagan, R. Craig, M.D., F.R.S.E., 5 Coates Crescent
1899 Maloney, Bernard J., 33 Frederick Street
1886 *Martin, William James, C.E., Rosario de Santa Fé, S. America
1884 *Massie, James, burgh engineer, 1 Parliament Square
1876 *Mather, Edward, Marchfield, Davidson's Mains
1881 *Maxwell-Müller, R. W., C.E.
1863 *Menzies, Duncan, C.E., 39 York Place
1858 *Mercer, James Tod, advocate
1894 *Miller, James Newlands, Broomlea, Joppa
1879 *Milne, James, Muirend, Colinton
1888 Mitchell, James D., 30 Fettes Row
1889 *Moncrieff, D. Scott, W.S., 28 Rutland Square
1872 *Morrison, James, City of Glasgow Improvement Trust, 98 Sauchiehall Street, Glasgow
1857 *Muir, John, brewer, 28 N. Back of Canongate
1866 *Muir, W. J. Cockburn, C.E.

1874 *Noble, William, millwright, 27 Rosebank Cottages

1902 O'Connor, Henry, Assoc. M. Inst. C.E., F.R.S.E., P. Pres. Soc. Eng., 1 Drummond Place, *Councillor*

1898 Ogilvie, Alexander, B.Sc., electrical engineer, Leith Electric Works, *Councillor*

1889 Ogilvie, F. Grant, M.A., B.Sc., F.R.S.E., 15 Evelyn Gardens, London, S.W.

1904 Omit, Thomas, 15 Torphichen Place

1885 Paterson, Oscar, glass stainer, 118 West Regent Street, Glasgow

1894 Peebles, W. Carmichael, Hope Lodge, Trinity

1902 Pickstone, Montague T., electrical engineer, Pilton Works, Ferry Road

1904 Pilkington, Basil A., electrical engineer, 12 Atholl Place

1882 *Pirrie, James, C.E., 135 George Street, *Councillor*

1878 *Proctor, Thomas Rodger, 21 West Maitland Street

1864 *Proudfoot, David C., City Road Trust, 10 City Chambers

1896 Purvis, George Carrington, M.D., Grahamstown, Cape Colony

1894 Readman, James B., D.Sc., F.R.S.E., 4 Lindsay Place

1902 Reis, Alphonse Louis, ophthalmic optician, The Laurels, Bright's Crescent

1890 *Ritchie, Charles, S.S.C., 20 Hill Street

1865 *Ritchie, Frederick James, clock-maker, 25 Leith Street

1866 *Ritchie, Jas., M.R.C.S., M.B., C.M., 22 Charlotte Square

1896 Ritchie, James, clockmaker, 25 Leith Street

1879 *Ritchie, John, C.E., The Knowe, Lygon Road, *Vice-President*

1857 *Rollo, Right Hon. Lord, Duncrub House, Bridge of Earn.

1904 Ross, Alexander F., engineer, 6 East Fettes Avenue

1875 *Russell, Sir J. A., M.A., M.B., F.R.S.E., Woodville, Canaan Lane

1867 *Sanderson, William, rectifier, Talbot House, Ferry Road

1878 *Scott, David A., S.S.C., 20 St Andrew Square

1900 Scott, J. Gray, A.I.E.E., Electric Light Station, Croydon

1862 *Shedden, Thomas, M.A., 47 West Cromwell Road, London

1893 Shiells, C. J., C.A., 141 George Street, *Treasurer*

1883 *Shiells, Henry Kenward, C.A., 141 George Street

1856 *Slight, G. H., Kendall, Meadfoot Road, Torquay

1902 Smith, John, engineer, Penicuik, *Councillor*

1895 *Smith, J. Ciceri, 6 Holborn Viaduct, London, E.C.

1877 *Smith, J. Turnbull, C.A., LL.D., 5 Belgrave Place

1904 Somerville, James A., engineer and shipbuilder, Glenesk Crescent, Dalkeith

1889 Stanfield, Richard, F.R.S.E., M. Inst. C.E., M. Inst. M.E., Professor of Engineering, Heriot-Watt College, *Editor of Transactions*

1850 *Stark, James, M.D., F.R.C.P., F.R.S.E. (No address)

1879 *Steuart, Robert Bromfield, C.E. (No address)

1896 Stevenson, Alexander, North British Distillery

1881 *Stevenson, Charles Alexander, B.Sc., F.R.S.E. Edin., 28 Douglas Crescent

1879 *Stevenson, David Alan, C.E., B.Sc. Edin., F.R.S.E., 84 George Street

1884 *Stevenson, Peter, instrument maker, 14 Seton Place

1857 *Sturrock, John, Peffermill House, Liberton

1899 Sutherland, Charles S., 20 Lauriston Gardens

1876 *Taylor, William, M.D., 12 Melville Street

1851 *Tennant, Sir Charles, Bart., St Rollox, Glasgow

1860 *Thomson, Alex., teacher, 40B George Square
1883 Thomson, Gilbert, C.E., 164 Bath Street, Glasgow
1878 *Thorburn, William, builder, 86 Buccleuch Street
1894 *Turnbull, William James, 16 Grange Terrace
1892 Turner, Dawson, M.D., F.R.S.E., 37 George Square

1882 *Waldie, David, coal merchant, 25 Douglas Crescent
1892 Walmsley, R. M., D.Sc., F.R.S.E., 23 Hilldrop Road, Camden Road, London, N.
1856 *Waterston, George, 10 Claremont Crescent
1866 *Watherston, James, builder, Pentland Villa, West Coates
1892 *Watson, James, M. Inst. C.E., Town Hall, Bradford
1905 Watson, William Pryde, electrician, 108 Easter Road
1892 Wemyss and March, The Right Hon. The Earl of, Gosford House, Aberlady
1879 *Westland, David Monro, M. Inst. C.E., 135A George Street
1861 *Whimster, T., gas engineer, 17 York Place, Perth
1879 *White, John, C.E., 17 E. Claremont Street
1884 *Whyte, Peter, M. Inst. C.E., superintendent, Leith Docks, 4 Magdala Crescent
1877 *Wilkins, Samuel B., 38 Wellington Street, Portobello
1898 Wilson, Andrew, Assoc. M. Inst. C.E., 14 Queen Street, *Assistant Secretary*
1898 Wilson, Archibald, A.M.I.E.E., electrical engineer, Leith Electric Works
1903 Wright, Johnstone C., F.R.S.E., Northfield, Colinton
1859 *Wyllie, James S., 21 Barnton Terrace

1890 *Yooll, W. Graham, oil refiner, 45 Stirling Road, Trinity
1893 *Young, Robert, 3 Abbotsford Park.

TOTAL ORDINARY FELLOWS, 197.

Associate

1902. Hunter, James, engineer, 23 Craigmillar Park.

INDEX TO VOL. XVI.

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