I HAVE divided this paper into three sections, viz:—1. Description of system. 2. Reasons for adoption. 3. Five months experience of same. The City of Melbourne Electric Light Station has been erected to supply arc. and series incandescent lamps for the illumination of the public streets and markets; also 8000 eight candle-power incandescent lamps, for the lighting of corporation premises and private supply. The station has been erected upon the corporation property in Spencer street, at the corner of Little Bourke street, where there is an area of two acres allotted by the Council for electric lighting purposes. The work was subdivided under several contracts as follows:—The buildings were erected by Messrs. Smith and Upton, and the chimney stack by Mr. Beck, both of these contracts being under the direction, and supervision of the City Surveyor, Mr. A. C. Mountain. The boilers were supplied and erected by the Babcock and Wilcox Co.; the engines, steam piping and pumps by the Austral Otis Engineering Co.; the shafting by the Langland's Foundry Co.; the dynamos and lamps were supplied by the Thomson Houston International Electric Co.; the vulcanised india-rubber cable by the Okonite Co. of Manchester; all the poles in the streets have been dressed by Messrs. G. and C. Hoskins, and the lamp pillars by Messrs. Monteath and Son. The buildings consist of an engine and dynamo room 138 ft. by 78 ft., boiler house and stokehole 84 ft. by 37 ft., coal bunkers, testing-room, stores, offices, fitters shop, and apartments for resident engineer. The system adopted for lighting the streets of Melbourne is known as the continuous current series, arc, and incandescent, favorably known and well tried in America and in some parts of Great Britain. The streets to be lit are those within the city limits, which embraces an area of 4,700 acres. Arc lamps of 1,200 nominal candle-power, are used in the main thorough-fares while incandescent lamps of 20, 25, and 32 candle-power are erected in the lanes. The generating station is situated at a point nearly equidistant from the two main extremities of the city. The site is high enough to be well out of the reach of floods, and at the same time not too far from the River Yarra to prevent its water being used for condensing purposes, and is also conveniently situated to wharf and railway for the delivery of coal. A plan of the generating station is attached of which the following particulars may be interesting:—The plant is laid out in four sections, each complete in itself. Three of these are sufficient to light the whole of the city, the fourth being at all times a stand-by in the event of any part of one section
NOTES ON ELECTRIC LIGHTING.

failing. A section consists of one 250 horse-power boiler, one 300 indicated horse-power engine, one 30 ft. length of shafting, five 50 light arc dynamos, and one 2,000 eight candle-power incandescent lamp dynamo (this last to be erected). The boilers consist of 4 water tube Babcock and Wilcox manufacture. The heating surface of each boiler is 2,823 sq. ft., and the grate surface 51 sq. ft. These boilers are now so generally and favorably known amongst engineers, that a description of them from my pen would be out of place. They are fed by steam pumps of the direct acting duplex type two in all, each of 3,000 gals. per hour capacity; one pump being, therefore, sufficient to feed three boilers. There are two independent delivery pipes, each boiler being connected to both of them, and the connections to pumps are so arranged, that by a manipulation of valves either pump may be connected to either delivery pipe. The suction pipe may be fed from three distinct sources. 1st. hot well, 2nd. storage tank of Yan Yean water, capacity 48,000 gals., situated under the coal bunkers, 3rd. from Yan Yean direct. The feed water is forced through an economiser situated in the flue, having a total heating surface of 3750 square feet, or may if necessary be forced direct to the boilers. The economiser is divided into two parts, so that either half, or whole, may be used. Before the flue gases enter economiser, and after they leave same, the temperature is recorded by pyrometers. A draught gauge is fixed in the flue, as is also a test tube connection for sampling the gases. On the feed water pipes on either side of the economiser, thermometers are attached. The main steam pipe is on the principle of the ring of steel, 10 in. and 8 in. diameter, cast iron flanges, copper bends and expansion pieces. Branching into the main pipe on the boiler side are four supply pipes and on the other or engine side are four connections to high pressure cylinders. Each branch has its own valve. The ring has two valves between the supply steam and delivery steam connections, for use in the event of a part of the steam pipe service becoming unusable. The exhaust main, which consists of a 12 inch cast iron pipe, runs the whole length of the building under the floor as shown by sectional drawing. Branching into it are the exhaust pipes from the four engines. This main exhaust is connected by valves to two surface condensers, each capable of condensing the steam of three engines. The main exhaust is also led into the smoke stack, when by the opening of a valve should necessity arise the steam may exhaust into the atmosphere. The condensers are situated below the engine room floor. Alongside each condenser is a separate circulating and air pump. The circulating pumps take their supply from two large tanks underneath the dynamo room, each tank being capable of holding 125,000 gals. of water. This water is pumped up from the river Yarra by a compound duplex direct acting pump of 50,000 gals. per hour capacity. The pump is situated in the corporation fish markets, taking steam from the refrigerating plant boilers, and is attended to by the engine driver in charge of that plant. The distance from the lighting station to fish market is 900 yards, and the difference in elevation of low water mark and level of tank is 39 feet. The depth of water in storage tanks is indicated by floats connected to electric alarms, which ring when tank is full or contains only two feet of water. The overflow from surface condensers is into the main drain in Spencer Street, which to the station is gas tight, as are also the walls of...
NOTES ON ELECTRIC LIGHTING.

Storage tanks. The storage tanks are ventilated by pipes in outer wall of building. The air pumps deliver into a hot well situated over the flues. The engines which are four in number, are of the horizontal compound surface condensing type, fitted with the Rowland Richardson's patent trip valve gear. The high pressure cylinder is 15 inches, and low pressure 26 1/2 inches diameter, the stroke being 3 ft., and the number of revolutions 82 per minute. The fly wheel is 14 feet., in diameter, and weighs 10 tons. Each engine drives on to its own section of 6 in. shafting by seven 6 1/4 in. ropes. The receiving pulley on shaft is 5 ft., 7 in. in diameter. Between each section of shafting is a patent friction and claw clutch combined, so that should occasion arise, any engine may drive any section of shafting. There are at present ten dynamo pulleys on each set of shafting, five being fast and five loose. These pulleys are 5 ft., 7 in. diameter with 8 in. face. Double leather belts 7 in. wide are used to drive the arc machines. On each section of shafting space is left for 100 horse-power high tension alternating current dynamo, for which tenders are now about to be called. These alternators will be sufficient for the present demand for light, and it is proposed, with an increased demand, to extend the building for alternating plant, and then erect engines and alternators coupled direct for incandescent lighting, and the spare 400 horse-power on the arc light plant could be used for further extensions or increased lighting in the streets, when the cost of maintenance will permit of it. The arc dynamos are of the well-known Thomson Houston type, of 50 arc light, or 250 20 candle power series incandescent. The armature is of the new type lately introduced by the manufacturers known as the sectional coil armature and is a great improvement on the old style of spherical armature. There are 30 coils on each armature, 10 being coupled together in series. The dynamos, 20 in all, were bedded on top of the large storage tanks used for condensing purposes. The roof of these tanks consists of 4 1/4 in. brick arches with a layer of concrete varying in thickness from 4 to 18 inches. It was found necessary in drilling the 80 holes (through this roof) required for the holding down bolts, to use a vertical electric drill, patented by the writer, which did the work expeditiously and well, preventing any disturbance to the brick work, which might have been occasioned by jumping these holes. The cables from the dynamos are led beneath the flooring in compo pipes which are filled in with bituminous compound to the controllers on the wall opposite each dynamo, and from these controllers along the wall to the switchboard. The switchboard is at an elevation of eight feet from the floor, access to which is by a two way staircase. The cables to the street lamps are led out from the back of the board through the wall in porcelain tubes to the carrying poles. The system of arc switching calls for special mention. The principle is an old and very simple one in telephone work but it has only lately come into use in arc light installations. In America I noticed only two of these in operation which had recently been erected by the Thomson Houston Co. The base is of slate. The holes of each horizontal line are all coupled together, each of these lines representing a dynamo. Six inches behind (air insulation) the holes of all the vertical lines are coupled together, these represent the circuits. So that by inserting a plug in any one of the front holes, and forcing it in far enough to reach
the circuit connection behind, contract is made between\textsuperscript{3} dynamo and lime; and thus you will readily understand any circuit can be connected to any dynamo by the simple insertion of the necessary plug. Supposing the board described represents the positive, a duplicate of the above represents the negative. On both sides of the plug board are 10 amperemeters, and one Lord Kelvin electro static vol meter. Above the plug board the lightning arresters are arranged, 40 in all. The switchboards for the alternating plant will be erected on both sides of the present one. As is too well known by all present the overhead system of conducting the cables has been been adopted throughout. The great cost of undergrounding the whole of the reticulation was prohibitive, although in the near future I look forward to the placing of both the electric light leads, and telephone wires underground in the principal streets. There is no doubt that from an electrical engineer's point of view this is very desirable, several systems having proved a great success in the old countries. The poles used for the carrying of the cables are all of box, or red iron bark, of two sizes 30 and 35 ft. long. The 30 foot poles are fitted with 5 arms in some cases and 2 in others, the 35 ft. poles having generally seven arms, with the exception of a few close to the lightning station which have nine and ten. The arms are morticed into the pole. The poles are all machine dressed. The rough logs weighing about a ton are placed in a large lathe and caused to rotate on their axis at the rate of of 50 to 100 revolutions per minute, and moved at the same time at the discretion of the attendant in a longitudinal direction. A cutter revolving 2800 revolutions per minute suspended above the pole in bearings, adjustable vertically, revolves in a direction at right angles to the direction of rotation of the pole. With this tool it is possible to dress the rough log in one hour, to the sizes required viz:—10\frac{1}{2} inch octagon seven feet up from ground line, and tapering circular in section from that to the top which is seven inches in diameter for 30 foot; and 12\frac{1}{2} in. octagon 8in. at top for 35 foot. The maximum distance between the poles is 53 yards. At all intersections of the telephone circuits a long arm on both sides of the intersection takes all the corporation and companies cables through the telephones on one plane, a clearance of two feet being made by the telephone authorities for this purpose. Six foot wooden battens are served on all the electric cables at these points of intersections to prevent contact of falling telephone wires. At this stage I might mention that some 120 of the telephone circuits are considerably affected by induction, but we hope in a few weeks to eliminate this, as we are now erecting and crossing return cables in the affected districts. Oil insulators have been used throughout. The placing of the lighting pillars in the city proper has been one of the most difficult features of the whole installation, considering that in the main streets 99 feet wide the tram lines occupy the centre, and the telephone poles and wires one kerb line, and the electric carrying poles and cables the other. The spanning of the streets by steel cable and suspending the lamp in the centre was objected to by the Electric Light Committee as unsightly; the erection of wrought iron girder work as too costly; and the use of extension brackets as undesirable, owing to the necessity, if that system were adopted, of placing all the lights on one side of the street to prevent contact with the telephone wires. The system adopted was the only one left
that was possible, viz., the placing of the arc lamps on top of lighting pillars on alternate sides of the street. The pillars on the telephone sides being always at intersections of cross streets, in which generally no tram line existed, were erected in the centre of the cross street 3 feet back from the telephone wires. The lighting has been found to be all that was necessary, although the effect looking down the street is not good, owing to so many of the lights being hid behind telephone and electric carrying poles. The actual candle power per sq. foot of area equals .048, which is considered to be sufficient for a well-lit street. Where, however, the tram lines do not exist and a less number of arc lamps are erected per square foot of area, the effect is all that could be desired, the pillars being in the centre of the roadway. Wherever possible only every alternate lamp is on the same circuit. The height of centre of arc lamp globe is 25 feet from ground level. The pillars used in the city proper are a combination of iron and wood. The base extending 9 feet out of the ground is of cast iron, and the extension piece, to which the cast steel steps are attached, are of grey box. The wood extension passes down the centre of the casting to the ground level, where it enters a conical-shaped seat. An inch and a quarter hole runs right up the centre of the pole to permit of the carrying of the leads to feed the lamp when the cables are placed underground. The incandescent lamps which are chiefly placed in lanes and small streets are of the Sawyer-Man type, taking in all cases the arc current of 6.8 amperes. They are so constructed, that should the filament break, the current may pass on by either the fusing together of the platinum wire of the lamp, or the burning through of a thin piece of paper inserted between the two poles of the lamp within the socket. The height from the ground of the incandescent lamp is 14 feet. Some circuits in the city have as many as 120 thirty-two candle-power incandescent lamps and 10 arc lamps in series. I will now offer some of the reasons of my committee and self for adopting this system of street lighting. In the first place, the whole of the lighting of the streets by the new illuminant had to cost no more per annum for maintenance, including all charges, than the previous installation of gas. This was a potent factor in the equation, and necessitated the greatest care in designing and carrying out the work, while considering at the same time the necessity of improving the lighting of the streets. Considerable discredit has fallen on the fair name of electric lighting, owing to the expense as compared with gas. Electrical engineers are greatly to blame for this in many ways. In England and in several cities on the continent too much light has generally been wasted in the streets, the idea being simply to give a grand illumination without any consideration as to the quantity of light required for all practical purposes, hence the too well-known cry, “costs three or four times gas.” Not so, however, in the United States. In most of the cities which I visited in 1892, the arc lamps have been erected with a greater view to economy, giving perfect satisfaction, utilising the light to the utmost advantage, and not obstructing 40 or 50 per cent. of it by thick ornal globes, or lanterns, as is the practice in many English cities. The Babcock and Wilcox boiler was recommended by me, and approved of by the Council for the following reasons:—In the experience of the writer in electric light installations, this boiler has given better evaporative results than any other he had used.
NOTES ON ELECTRIC LIGHTING.

That as compared with boilers of the shell pattern it is safer from serious explosion. That the readiness with which steam may be got up when required, such as when a sudden and unexpected increase of load is thrown on, a circumstance peculiar to electric lighting, especially private lighting; also on account of the durability of this class of boiler. In support of these contentions I beg to submit the opinions of a few leading electrical engineers at home. Mr. R. E. Crompton, M.I.C.E., and vice-President of the Institute of Electrical Engineers, in his paper, read before the latter Institute, on the 26th April, 1894, on the cost of electrical energy, makes the following statement:—"My experience in the use of Babcock's boilers, has been altogether satisfactory, and I believe that the best evaporative efficiency, yet obtained in supply works, has been with these boilers. . . . I believe these boilers stand quite at the head of the list, not only as regards economical working on full load, but also in the small use of fuel when standing banked. These are my observations, but, I understand that the experience of others has been equally satisfactory, at least, wherever Welsh anthracite, coke, or other smokeless fuels are used. . . . A long and interesting series of articles has recently appeared on water-tube boilers in the Engineer, in the course of which, the writer more than once, states, that it is impossible to force any of the existing types of water-tube boilers, as any such forcing invariably results in the production of wet steam, and consequent loss of economy. Is it difficult to know how the writer could have formed such an erroneous impression. My own experience is, that the works where the best results have been obtained, are those where the Babcock and Wilcox boilers have been forced the hardest. At works W., the boilers, which are nominally supposed to evaporate 11,000 lbs. of water per hour, have frequently been forced to 16,000, or about 50 per cent. in excess of the duty guaranteed by the makers, and at such times of heavy forcing there has never been any trace of priming or wet steam." In the discussion of this paper the following statements were made.—Mr. Raworth: "I find it a very pleasant task to be able to notice to-night that Mr. Crompton has taken some of the advice I gave him on a former occasion, viz., to throw up Lancashire boilers in favor of Babock boilers." Mr. Mark Robinson: "With regard to the dryness of steam from water tube boilers, his own company had lately taken up a water tube boiler, from which they hoped great things, and from which they knew they got dry steam. They had had one under test there with really extraordinary results, there being about $\frac{1}{2}$ per cent. of moisture only." Mr. W. Geipel: "The reserve power afforded by the forcing capabilities of the Babcock boiler was of enormous importance." Professor Unwin: "Believe that the Babcock boiler was an excellent one, as good as any made." The evaporative results at a test of coal carried out by Mr. G. Higgins, at the Council's Electric Light Station, are certainly not excellent, viz., 9·11 lbs. of water evaporated from and at 212 degrees per lb. of Southern N.S.W. coal. But it must be remembered that the boiler used was only working up to 150 horse power, while its normal working horse power is 250. The compound surface condensing engines were adopted in this undertaking on account of economy in the consumption of fuel, coal costing the corporation at the time the scheme was formulated 17s. per ton, and water being fairly convenient for
condensing purposes. The small unit high speed engine coupled direct to arc dynamos is now being discarded by many electrical engineers for arc lighting. In Milan, 1892, the engineer of the arc light plant showed me similar engines to the type adopted by the Melbourne corporation, and of the same horse power, being erected to take the place of the high pressure high speed engines which they were then using, each engine driving direct on to two dynamos by belting. The 6-8 ampère lamp was adopted after careful consideration of the advantages and disadvantages of the two usual class of lamps used, viz., 6-8 and 10 ampères. In the discussion on General Webber’s paper at the Institute of Electrical Engineers, on the lighting of London Streets, it was pointed out by several eminent engineers that the more extensive use of small candle power lamps was more suitable for street lighting than the larger candle powers. A 10 ampère lamp I admit gives a slightly better light immediately round the base of the lamp, but surely the art of lighting a street is not the brilliant illumination of various points, while the intermediate spaces are left in total darkness. Better far that more lights should be used of a less candle power, giving a more uniform system of lighting, at the same cost of maintenance. At any point in the Melbourne streets where the arc lamps are used, one can comfortably see his way, and be able if necessary to read directions, or look at his watch without as in the old system of gas, waiting until you arrive at the next lamp post. The following is a table of costs of lighting the streets of sixteen cities in America, by 1200 candle-power, and 2000 candle-power nominal arc lamps. The prices given are these which the ... pay for supply by contract. These contracts all existed in 1891; some of them may have expired since then.

<table>
<thead>
<tr>
<th>Name of City</th>
<th>No. of Ares.</th>
<th>System.</th>
<th>Candle Power.</th>
<th>Price per lam per annum.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado Springs</td>
<td>32</td>
<td>Thomson Houston</td>
<td>2000</td>
<td>43 6 8</td>
</tr>
<tr>
<td>Trinidad</td>
<td>30</td>
<td>do</td>
<td>2000</td>
<td>31 5 0</td>
</tr>
<tr>
<td>Newhaven</td>
<td>146</td>
<td>do</td>
<td>2000</td>
<td>35 14 9</td>
</tr>
<tr>
<td>Bath</td>
<td>31</td>
<td>Brush</td>
<td>2000</td>
<td>31 5 0</td>
</tr>
<tr>
<td>Baltimore</td>
<td>587</td>
<td>Thomson Houston</td>
<td>2000</td>
<td>38 0 0</td>
</tr>
<tr>
<td>Worcester</td>
<td>170</td>
<td>do</td>
<td>2000</td>
<td>41 13 4</td>
</tr>
<tr>
<td>Norwich</td>
<td>22</td>
<td>do</td>
<td>2000</td>
<td>20 6 0</td>
</tr>
<tr>
<td>Saugus Marie</td>
<td>15</td>
<td>do</td>
<td>1200</td>
<td>18 15 0</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>150</td>
<td>do</td>
<td>1200</td>
<td>20 10 0</td>
</tr>
<tr>
<td>Newburg</td>
<td>97</td>
<td>do</td>
<td>1200</td>
<td>23 2 0</td>
</tr>
<tr>
<td>St. George</td>
<td>92</td>
<td>do</td>
<td>1200</td>
<td>16 3 4</td>
</tr>
<tr>
<td>Balnigh</td>
<td>50</td>
<td>do</td>
<td>1200</td>
<td>15 12 6</td>
</tr>
<tr>
<td>Norfolk</td>
<td>162</td>
<td>do</td>
<td>1200</td>
<td>18 15 0</td>
</tr>
<tr>
<td>Biddeford</td>
<td>140</td>
<td>do</td>
<td>till midnight</td>
<td>30 16 8</td>
</tr>
<tr>
<td>Winchester</td>
<td>80</td>
<td>do</td>
<td>1200</td>
<td>16 3 0</td>
</tr>
<tr>
<td>Montpelier</td>
<td>80</td>
<td>do</td>
<td>till midnight</td>
<td>30 6 8</td>
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<td></td>
<td></td>
<td></td>
<td>40 of 2000</td>
<td>15 12 6</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>18 of 2000</td>
<td>15 12 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>till 11 p.m.</td>
<td>8 12 0</td>
</tr>
</tbody>
</table>

The continuous current was preferred to the alternating system, in consideration of the many arc lamps required for the street lighting, the former being considered the most satisfactory from an economical and
NOTES ON ELECTRIC LIGHTING.

lighting standpoint. The city proper having now been lit up for five months, a few notes may be of interest. The lamps lit every night, and all night, in this section are 132 arcs and 320 incandescent chiefly of 32 candle power, also 59 arcs in the two markets. In the boiler, engine and dynamo rooms everything has run well and given complete satisfaction. Three rather warm bearings is all that can be recorded against the plant, which however put us to no material inconvenience. I regret (on account of the plant not yet working up to full capacity) being unable to place before you exact figures as to the efficiency of same, but I shall be glad to do so if I am permitted at a later date. At present, however, a pound of coal gives 129 watt-hours, which is 37 above the average return of 800 electric light companies in America, according to the Engineering News, of 15th March, 1894. This however is to be expected, on account of the high load factor obtained in a plant, used wholly for street illumination. The copper coated carbons now used in the arc lamps, we find unsatisfactory; our present stock will be finished in a few months, when we hope to replace them by a better and more suitable type of carbons. The vulcanised indiarubber, cable 7-18 copper, of which we have some 60 miles now erected, has so far proved satisfactory. The insulation resistance which is tested by dial pattern Wheatstone's bridge, Thomson reflecting galvanometer of 7000 ohms-resistance, and 100 Leclanche cells every day gives in dry weather, about 8 megalohms per mile, and in wet, 3 megalohms per mile. This, considering the nature of arc and incandescent lamp attachments in the streets is all that could be expected. The life of the incandescent lamps I consider very remarkable, some 320 of them have, now been installed for five months, and have run every night, and all night, during that time making a total of 1600 hours. The number which have burnt out in that time is only 28 a percentage say of 9 which have not exceeded 1600 hours. These lamps were guaranteed for 600 hours. In conclusion I might say that the extension of the public lighting to the boundaries of the city is now being rapidly completed, considerable delay having been occasioned in connection with the boundary lighting and the supply of poles. Great credit is due to the chairman, and members of the electric light committee for the painstaking manner in which they have entered into all the details of the scheme, and to my assistant, Mr. W. Nimmo for the careful execution of the necessary drawings, and general attention to details of this important undertaking.
DISCUSSION ON THE PAPERS ON "COAL TESTS,"
BY MR. HIGGINS, M.C.E., A.M.I.C.E.

AND THE
"ELECTRIC LIGHTING OF THE CITY OF MELBOURNE,"
BY MR. A. J. ARNOT, A.M.I.C.E., M.I.E.E.

WEDNESDAY, 15TH AUGUST, 1894.

Professor Kernot said as he was to some extent interested in electric lighting, he would make a few remarks upon the paper. He must say, that speaking apart from the paper, he was pleased with the result of their visit to the City Lighting Station that afternoon. Everything seemed to be excellently arranged and worked admirably. Mr. Arnot had the advantage of not being stinted for cash, and it could be seen that the policy adopted was one of doing things well. In the arrangement of building he had been struck with the great advantage of having a series of vaults running under the machinery, giving convenient and perfect access to all pipes, valves and connections which could not very well be placed on the floor of the engine house. This gave an advantage in many ways, while the easy accessibility of all the pipes and connections was a matter of great importance, as if they were put in an inaccessible position it was found they were continually going wrong. There was something to be said under the several headings into which the paper was divided. The boilers were of the well-known water tube type which had always caused considerable discussion. This type of boiler had been warmly advocated by some of the greatest and most eminent engineers. The trials lately conducted were singularly perplexing in their varied results, but being interested in the same boilers, he received very great comfort from these results. In England, America, and on the Continent this type of boiler was almost exclusively adopted, and from inquiries he had made when on a recent visit to those countries, he found that they worked extremely well and satisfactorily. It seemed, therefore, that the fact of their being used by such a large number of people was the most powerful evidence that they were the most suitable kind for this class of work. After an experience of four years working, he could speak very favorably of them; the boilers he referred to had been rarely and almost cruelly treated and pressed far beyond their rated capacity, and at present were in perfect order. He knew there were other forms of boilers used for electric lighting work, and he had no special complaint against them, but nevertheless the water tube boilers were to say the least second to no other make. With the engines they had two lines of thought. Electrical engineers were very much divided in opinion between the advantages of what are called low speed and high speed engines. What they now considered as low speed would have been regarded as high speed some 20 years ago; what he meant by low speed was 70 to 100 revolutions per minute, by high speed engines was meant...
driving at such a speed convenient for coupling direct. Upon this there had been a very great controversy and it was unwise to dogmatise very strongly on the point, but from his own experience he would certainly prefer the low speed engine. At the same time it was an open point, and he had known some high speed engines having done excellent work which were regarded by those who used them as very successful. One good argument in their favor was the saving of space, and where space was excessively valuable, it might be perfectly wise and right to use these engines, but circumstances in each case differed. The type of engine used by Mr. Arnot is perhaps a little interesting. Corliss, in America achieved a great success in replacing the old fashioned slide valve by four separate valves to each engine, and it was claimed that with these valves they got theoretical perfection combined with the best possible results. He thought Sultzer deserved the credit of the invention of the class of engines at the City Lighting Station. Engines of this type and size made by Robey & Co., were purchased and put down by The New Australian Electric Company four years ago; they had been working ever since and were now running under very severe conditions. They never got hot but were always perfectly cool; this he attributed to the large bearing surfaces which were fitted to them. Another point is the extraordinary perfection of their governing gear; the engines were placed under very severe tests, as much as 60 I.H.P. being thrown suddenly on them without notice, with the effect that only a variation of half a revolution in speed could be detected. The engines at the City Lighting Station were of colonial make, and he had every reason to believe they would prove equally as efficient as their prototypes made in England. Mr. Arnot had adopted rope-gearing on the separate rope system, which he noticed was without means of tightening. There was no reason to fear any difficulty, and it had this in its favor, that the pull was on the right side of the rope. He had always found that rope drive was far more economical and efficient than belt drive. With respect to the system of dynamos, he was not prepared to object to it, considering his company had adopted them for their arc lighting. He considered them as good a form of machine for lighting purposes as any. Mr. Arnot had gone in for condensation. The difference between a condensing and non-condensing engine was quite sufficient to justify the little extra cost in condensing the water. On the whole, he did not think there could be any serious criticism with regard to the station; it seemed to be quite up to date in every respect, and he doubted if the changes in electrical matters would be so rapid in the future as they had been in the past. It would be a good thing if Mr. Arnot could give them another paper at a later date when the station had been loaded to its full intended capacity, and when the machinery had had sufficient time to develop any little peculiarities it was going to develop. He should then like to have a test of the quantity of the coal burned, water evaporated, indicated horse-power, and the output of generated electricity. Mr. Arnot had fitted up gauges, thermometers, pyrometers, and all the other attachments necessary, so that a scientific investigation should be as easy at the City Lighting Station where its load was always uniform and steady as it was difficult in a private station with its sudden variation of loads.

Mr. Geo. Higgins said they had a very interesting contribution to the discussion from Professor Kernot, who had touched upon the subject of
the engines, boilers, and dynamos, but there was the matter of arrangement of air and circulating pumps which he thought worthy of notice also. He observed Mr. Arnot had adopted the now general practice of having the air and circulating pumps working independently of the main engine; but while he thought the principle a good one, he did not, from experience, favor this particular type of horizontally-acting air pump. A type of air and circulating pump, which had been adopted by the Harbors and Rivers Department in New South Wales, was that with the air pump at one end and the cylinder at the other end of a beam, both working vertically, which he found to give much better results. There were several objections to the former type. The valves being placed above the plungers, were also sometimes placed above the bottom of condenser; in this case he believed about 2 feet 6 inches. This being the case, it was absolutely impossible to get as good a vacuum as if the pump and its suction valves were placed lower, their being always a loss due to that difference in head. He spoke from experience, as one of these air pumps had been fitted to a condenser of his own at too high a level, and, consequently, a good vacuum was not obtained. Another objection was owing to the excessive amount of clearance at the ends of each stroke and in the valve chambers and passages. The weight of the suction valves was also objectionable, as they required a pressure in the condenser to lift them. With reference to the type of engines referred to by Professor Kernot, he remembered 15 or 16 years ago examining carefully the drawings of the Sultzer engine, and if he was not mistaken, an engine with the name of Robey on it was exhibited here in 1880, the details of valve gear of which were practically the same as those used with the Sultzer engine.

Mr. G. A. Turner wished to confine his remarks to the subject of the coal tests, and must say he considered their value detracted from on account of their incompleteness. Speaking of the Southern coal, from his experience, he would say the coal used in the test must have been of exceptional quality, even much better than Newcastle, but, owing to not having a chemical analysis of the coal before him, it was impossible to say what was really the composition of that coal. The proportion of fixed carbon in each coal determined its evaporative efficiency. There was another matter, viz., no heat balance was taken. Had this been done, it would have been possible to check the figures obtained by Mr. Higgins.

Mr. Geo. Higgins wished to make an explanation. Several of the speakers had referred to the incompleteness of the tests. The facts of the case were these:—The City Council had a certain type of boiler working under certain conditions, and there were certain coals offered at certain prices, and he was instructed to see which was the most economical coal to use with their boilers under these conditions. He had read his notes before the Institute, giving particulars of how the tests were conducted, and, consequently, the reference to their incompleteness was unnecessary.

Mr. G. A. Turner: That puts a different light upon it, and, under the circumstances, he had nothing further to add.

Mr. J. S. Pirrie, regretting not being able to be present at the visit to the City Council lighting station. He quite coincided with Professor Kernot in his favourable criticism on the installation, and he might say that two eminent American Engineers, who had lately visited the station with him, had remarked that it was most undoubtedly the most complete municipal light-
COAL TESTS AND ELECTRIC LIGHTING.

ing station they had ever visited. With regard to the type of engines he fully endorsed Professor Kernot's remarks, as from personal experience, in 1876, he had erected a Sultzer engine, connected with an ice factory in Bombay, the working drawings of valve gear of which were practically the same as those of the Robey type, with the exception of detail in the governor. He was satisfied that this installation would prove the undoubted economy to be obtained by condensation, even after making every allowance for the increased cost due to water supply, condensers and air and circulating pumps. Referring to Mr. Higgins' remarks, he could not agree with him as to the inefficiency of the duplex horizontal air and circulating pumps, as from practical experience, he had been able to obtain as good a vacuum under ordinary working with this type as that obtainable in other types. In the pumps referred to special attention had been paid to minimise clearance and when it was considered that a steady vacuum of 27 inches could be maintained with the engines working under light load, he thought it would be hard to beat. Certainly he agreed with Prof. Kernot in his preference for rope driving over belts, but he would have preferred a continuous rope system with tension gear as usually supplied by the Otis Company, as, for example he instanced the very complete rope driving installation erected at Dights' Falls flour mills, where all the motion from the turbines to the upper floors of the mill was on this system, and it had now been working some seven years without the slightest hitch or difficulty. As the firm with which he was connected had constructed the engines under discussion, he preferred to say nothing about them, excepting that they were perfectly satisfied with the results being obtained in actual work, the indicator diagrams leaving nothing to be desired. Referring to the boilers, and at the same time continuing his discussion on Mr. Higgins' paper on the coil tests, and being a strong advocate of feed water heaters and economisers, he was pleased to notice the favourable results obtained, especially when taking into consideration the fact that the boilers were working at considerably less than half their rate capacity. He found from Mr. Higgins' report and other observations made during these tests that the average increase of temperature of feed water was from 114 deg. to 206 deg., showing an increase of 92 deg. and a consequent economy in fuel of 10 per cent. He thought there must be something wrong with the readings of the pyrometers in the flues, as if they were correct, showing an average of 439 before the economiser and 164 after leaving same, it would be difficult to account for the good draught obtained, which he believed registerer on the water gauge '5 of an inch. If the pyrometers were correct, the equivalent gauge pressure of this temperature at the base of a chimney 150ft. high assuming the temperature of air to be 62 would be 36 in. However, there was no use discussing this subject as Mr. Arnot had just informed him that the pyrometer in the slide behind the economiser was not recording correctly owing to its position behind the damper. It had been also stated that these tests were incomplete because calorimeter tests had not been made of the coal nor chemical analysis taken of flue gases, but he failed to see the necessity for these being made on a test as to the commercial value of certain coals in a certain boiler generating steam for engines at a fixed load. Had Mr. Higgins been instructed to test the evaporative efficiency of the boilers, no doubt it would have been necessary to have made an analysis of the flue gases so as to have prepared a complete heat balance-
sheet, showing what proportion of heat units given off by the coal was used in evaporating water, and what proportion was taken up by the brickwork in the furnaces and flues. Confirming the correctness of the system adopted by Mr. Higgins, he had before him a report published in the Engineering News, May 31st, 1894, on testing the commercial value of some coals by Mr. Hague, M.A.M. Soc. M.E. From this report on eight different coals, a trial was made of each coal for four working days of ten hours each, the boilers being handled by their usual attendants and treated under regular conditions of daily work. Indicator diagrams were taken repeatedly to determine the power developed. One coal was taken as a standard of comparison, it being that most commonly used and recognised as the standard in the market, then as the other coals varied above or below they were given a corresponding percentage. That was practically the method adopted by Mr. Higgins. To show the great variation in the commercial value of different coals, the results obtained by Mr. Hague were as follows. Transferring dollars into our currency the value of the standard coal was 15s. per ton.

<table>
<thead>
<tr>
<th>Per cent. burned</th>
<th>I.H.P. per hour</th>
<th>Commercial value per ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>100</td>
<td>15s.</td>
</tr>
<tr>
<td>No. 2</td>
<td>105</td>
<td>14s. 31.</td>
</tr>
<tr>
<td>&quot; 3</td>
<td>77</td>
<td>19s. 7d.</td>
</tr>
<tr>
<td>&quot; 4</td>
<td>87</td>
<td>17s. 5d.</td>
</tr>
<tr>
<td>&quot; 5</td>
<td>78</td>
<td>19s. 3d.</td>
</tr>
<tr>
<td>&quot; 6</td>
<td>81</td>
<td>16s. 6d.</td>
</tr>
<tr>
<td>&quot; 7</td>
<td>86</td>
<td>17s. 5d.</td>
</tr>
<tr>
<td>&quot; 8</td>
<td>72</td>
<td>20s. 10d.</td>
</tr>
</tbody>
</table>

If they took the results obtained by Mr. Higgins and worked them out on the same method, they found the four different coals come out as follows, taking Newcastle as the standard and its market value at 13s per ton.

<table>
<thead>
<tr>
<th>Relative Value</th>
<th>Market Price</th>
<th>Commercial Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newcastle</td>
<td>100</td>
<td>13s.</td>
</tr>
<tr>
<td>Southern</td>
<td>94</td>
<td>13s.</td>
</tr>
<tr>
<td>Coal Creek</td>
<td>1.2</td>
<td>17s. 8d.</td>
</tr>
<tr>
<td>Jumbunna</td>
<td>108</td>
<td>15s.</td>
</tr>
</tbody>
</table>

Without desiring in any way to dispute the correctness of the results obtained by Mr. Higgins in these tests, he could not help thinking that better results would have been obtained with the Jumbunna coal, had it been used under more favorable conditions as to fire grate area. This was a quick firing coal, giving out an intense heat, and, in his opinion, based upon some experience he had had with it, it would be an advantage to have reduced the fire grate area and kept heavy fires. This, however, was not a matter to do with Mr. Higgins, but more for those looking after the interests of the different coal companies. Of course, it might also be claimed that Newcastle or Southern coals would also give a better result had the fire grates or condition of draft been altered to suit their peculiarities. This is a point where calorimeter tests as to value of the coal would have been of interest to engineers so as to have compared the actual results obtained in the practical tests with their values as shown on the calorimeter. It was well-known that with water-tube boilers, high initial temperature in the furnaces was essential, owing to the large
amount of heat-absorbing surface in close contact with the product of combustion. One matter in connection with these tests he thought worthy of notice, viz., the great excess of water evaporated on the first night as against that of the other evenings. It could not be accounted for by condensation in the pipes and jackets, as he understood this was most carefully measured, and showed that while 5390 lbs. of water was condensed in them during the first night; the quantity condensed on the other three evenings was only 3740, 3630, and 1430 respectively, showing that the extra condensation only accounted for a proportion of the increase. Referring to the criticisms on water-tube boilers, he was glad to hear the very favorable opinion expressed by Professor Kernot after four years' experience under exceptional conditions. From personal experience, he had been able to form a most favorable opinion of water-tube boilers. Whether the Babcock and Wilcox, Hornsby, or other makers was the best, experience could best determine. So far the Babcock and Wilcox type had the benefit of many years of practical hard work, and the continued demand for these boilers was a complete answer to the adverse criticisms so often heard, but generally from interested parties. One heard it often stated that the Babcock and Wilcox boiler primed excessively, and was constantly giving wet steam; but the results of the tests made by Mr. Bryan Donkin, M.I.C.E., at the Frankfort Exhibition, 1891, hardly bore out these assertions, as the results of these tests, as recorded in the Engineer of 8th and 15th June, show that the percentage of moisture in steam evaporated in a Cornish boiler was 0.76 per cent., while that from the water-tube boiler was 0.85, thus showing anything but an excessive moisture in the latter. He sincerely trusted that Mr. Arnot would be in a position to adopt Professor Kernot's suggestion, and give them at a later date the results obtained in actual working of the station after the plant had been fully loaded. They were very much indebted to Mr. Higgins and Mr. Arnot for the two valuable papers which these gentlemen had contributed. Mr. Stone said:—I desired first to say a few words with reference to the subject brought before us by Mr. Higgins and then to add a few remarks on the subject of fuel testing generally. I was very pleased to hear Mr. Higgins' paper (which will well repay careful study) and find with what characteristic care he had carried out his duties. I however, regret to find that Mr. Higgins has given us no data which will enable us to compare the coals which he has tested with those tested by others. Although Mr. Higgins was very careful to obtain (as far as an eye estimate could inform him) a fair sample of each kind of coal tested, still I think it must be admitted that others obtaining samples of coal in a similar manner would probably find their samples differ appreciably from his and differ from each other if taken at different times. Such variations may be due to the different proportion of combustible matter contained in the coal taken from various parts of the seam in any given mine which frequently amount to four per cent. or five per cent. of the fuel or they may be due to comparatively small variations in the composition of the combustible portion of the fuel. All engineers who have had experience with the use of coal for steam raising purposes will be familiar with the complaints of the firemen, "that they had a lot of trouble with the fires last night could hardly keep steam and had to clean the fires three times" and so on. These complaints occur even though the coal is obtained from the same mine. If then variations in the
COAL TESTS AND ELECTRIC LIGHTING.

of the quality of coal obtained from one and the same mine occur to such an extent that the fireman's biceps is a sufficiently delicate analytical machine to detect them, surely we should adopt some more rigorous method of selecting average samples than an eye estimate. If we cannot be sure of obtaining a true average sample some other factor must be introduced into our tests with a view to eliminating this difficulty. In the absence of reliable data concerning the intrinsic value of the coal itself we can readily imagine that some months hence the city authorities may be in a dilemma should they find the evaporation value of their fuels less than that obtained by Mr. Higgins. How are they to determine whether the discrepancy is due to a difference in the quality of the coal obtained by them, or less skilful firing and dirty tubes &c? The question of firing is a very important one, as widely different results can be obtained from the same fuel by simply altering, the thickness of the fire, the method of distributing the fuel when firing, the quantity of and method of admitting air above the fire and so on. These remarks will also apply when different coals are used, the conditions which are most favorable to one are not necessarily equally favorable to the others. A test to be considered thoroughly satisfactory should include data which will indicate how far the conditions of combustion were suitable to the respective coals. The fact that representatives of the various coal interest were present and did not object to the treatment which their fuels received is no criterion that the conditions of combustion were equally favorable to all for no man can tell, without suitable tests whether combustion is being efficiently effected or not by an ocular examination of the fire and chimney. Some other interesting, and I think very valuable data, although taken during the tests are not given in Mr. Higgins paper, I refer to the flue temperature and draught. It would be very interesting to know at what temperature the furnace gases leave the boiler when steaming at half its rated capacity, and compare these values with those obtained when the boiler is working at its maximum. When we know the normal rate of evaporation for a given coal when consumed under what may be regarded as the normal conditions of combustion in the furnace, a knowledge of the actual rate of evaporation and corresponding flue temperature will enable a rough idea to be formed as to whether any discrepancy in the results obtained is due to the quality of the fuel used, or the treatment it receives at the hands of the fireman. A high rate of evaporation and low flue temperature indicate either a good quality of fuel or clean heating surfaces and attentive firing; whereas a lower rate of evaporation and high flue temperature indicate dirty heating surfaces and careless firing. From the figures given, the rate of combustion in the case of Newcastle coal was about 12 lbs. per square foot of grate surface per hour, and 8:57 lbs. of water were evaporated per lb. of coal. If we take 14 lbs. of water per lb. of coal as the theoretical maximum evaporation per lb. of this coal, which is a reasonable value, we have a useful absorption efficiency of only 60 per cent., which is a low value with such a slow rate of combustion. If we look at the matter from another standpoint, and assume that the heated chimney gases carried off 20 per cent. of the heat developed, and 5 per cent. is lost, due to incomplete combustion and radiation, the total loss would be 25 per cent., or an equivalent evaporation of 2:85 lbs. of water, thus the theoretical heating value of the fuel would be 8:57 + 2:85 = 11:42.
lbs. of water per lb. of coal, or 11090 B.H.U., which is a very low value to suppose that class of coal to have, especially as very liberal losses have been allowed when we take into consideration the slow rate of combustion. Would Mr. Higgins kindly give us details of the path of the hot gases through the boiler in question, such data would be interesting. From the results above stated I should conclude that the hot furnace gases are too quickly brought into contact with the comparatively cool surfaces of the water tubes, to allow complete combustion to be effected. However, we are given no data which will permit us to form any definite or certain conclusions on this subject. With reference to the apparently abnormal consumption of water during the first test to which Mr. Higgins alludes, I should like Mr. Higgins to give us some further explanation if possible.

In passing it is a somewhat curious fact that the actual quantity of water evaporated on the different nights varied inversely as the quality of the fuel used. The highest two consumptions of water occurred on the first two nights. If we take the equivalent evaporation from column I. of table III. the quantities are 76,058 lbs. and 67,776 lbs., the difference being 8,282 lbs. evaporated from and at 212°. Taking the lowest value of the latent heat as 856, the total number of heat units extra used on that night was 7,089,392. Then taking the specific heat of iron at 13, and assuming the parts of the engine to have been at a temperature of 63 deg. Fah., the above quantity of heat would be sufficient to raise 81 tons of iron from a temperature of 63 deg. to 363 deg. Fah., or the temperature of steam generated. Or stating the fact in another way the assumed heating of the cylinders represents 12-2 per cent. of the whole work done by the boilers on the next night. If this be so it will pay to keep the cylinders hot. My remarks have been made with a view to pointing out how much more valuable an already valuable series of tests would have been, had one or two simple tests been added to the number, and not in any way with a desire to detract from the value of Mr. Higgins’ results, or the credit due to him for the able and thorough manner in which the work was done. I would now, if I have not already trespassed too much on your time and patience, like to make a few remarks on fuel testing generally, and point out how some of the weak points, which I have alluded to, may be eliminated. If, however, Mr. President, you should consider my further remarks irrelevant, I hope you will stop me. When we have to carry out a series of tests for any given purpose, the first point to be settled is, what are the exact data that we need to determine? In coal testing, the question may be similar to that asked by the City Council, viz., what are the relative values of different fuels when consumed in given furnaces? Or the question might have been, what are the relative values of the different fuels to the City Council? The answers to these two questions may be regarded as representative of the results which the engineer may be called upon to give. To answer each of these questions in a proper manner, necessitates a widely different series of tests being made, and may involve an immense amount of labor on the part of the engineer, to whom the work is entrusted. To answer the first, no matter what sort of work is required from the fuel, we must show the relative amounts of this work, which each of the fuels submitted to us is capable of performing under the given conditions. We must then prove that the samples which we use are true average samples of the various fuels; or if this be as it would in most cases an impractic-
able question to answer, we must give exact data with reference to the quality of the actual samples of the various fuels which we have employed for our tests. That is, we must give data which are readily obtainable from any fuel; which will enable us to compare the value of any fresh sample of the same fuel with that which we employed in our tests without having to go through the whole process of testing again. Further, we must prove how far the conditions of combustion which obtained during our tests were favorable or otherwise to the various fuels submitted to us, and demonstrate that they have all received fair treatment from the fireman, who is the most important officer in fuel testing, and who has it in his power to bring out almost any results that he may desire. That we may be in the position to give such data as I have just pointed out as necessary, we must be capable of measuring within a practical degree of accuracy the quantities of work done by the respective fuels, no matter what that work may be. I shall, however, confine my remarks to the use of fuel for steam raising purposes for use in engines. For steaming purposes the only work the fuel has to perform is the evaporation of water. This, then, is the quantity which we have to measure. But we must remember that it is not the quantity of water which leaves the boiler which is alone of importance. What we want to know is the number of heat units per lb. of steam as it leaves the boiler and the number of pounds of steam generated per lb. of fuel. The steam may be either wet or superheated, hence the simplest method of determining the true evaporative value is by means of the steam calorimeter. As the percentage of incombustible matter and chemical composition of any coal are very appreciably variable quantities, it is evident that at least in the case of coals a true average sample cannot be obtained in any reasonable time, and we could never be sure without testing that the quality has not altered. For this reason I think the only satisfactory procedure is to determine the chemical composition of the various fuels submitted, or what is much simpler, we can determine their calorific values by means of a fuel calorimeter. The latter, viz., the determination of the calorific values, is an extremely simple test when carried out to a practical degree of accuracy, and the data obtained from coal used at any other time can be quickly determined, and its value compared with that of the coal originally tested. The only other point of importance is to prove that the fuels have received fair treatment during the process of testing. If we can prove that the same, or approximately the same, proportion of the total heat in the different samples of fuel submitted for test has entered the boiler, and is made available in the steam generated, we have proved for practical purposes that the conditions of combustion were equally fair to all samples, and that a want of familiarity on the part of the fireman with the idiosyncrasies of the respective fuels or carelessness in firing has not acted detrimentally to any. If we have determined the calorific values of the fuels we have all the requisite data, and should the heat per lb. of steam expressed as a percentage of the calorific values in the case of each fuel be approximately the same, we have given the requisite proof. In order that the process of testing to which I have alluded should give reliable comparative data, it is imperative that the total rate of evaporation per unit time shall be as nearly the same as possible through the whole series of tests so as to eliminate errors due to radiation, various rates of combustion, etc. To indicate the process of
testing requisite to enable an intelligent answer to be given to the second form of question would. I am afraid, make my remarks take the form of a supplementary paper on the subject, which is out of place. I will, therefore, content myself by calling your attention to the very great importance of testing the flue gases, or products of combustion. An analysis of the flue gases is to the furnace what the indicator diagram is to the engine, each giving a clear, graphic description of the processes at work by which defects, their locality, causes, and possible remedies can be determined. Engineers are in the habit of working by rigorous processes to effect small economies in the use of steam. High rates of expansion, subdivision of expansion in a series of cylinders, steam jacketing, and super-heating, are all employed to effect economy in the use of steam, and engineers are required to build engines that will develop power at stipulated rates per lb. of steam used. We regard a waste of 2 or 3 per cent. in the use of steam as important, and yet very largely disregard the enormous waste of heat due to the temperature of the chimney gases, seldom, if ever, try to ascertain what losses are taking place due to the escape of unconsumed gases from the chimney, and this mainly because they are not visible to the physical eye; and, worst of all, we purchase the source of all this energy on an eye estimate or its value, or, what is nearly as bad, on the results of a crude test which does not give us any idea of the true nature of the articles we are purchasing. Wool, corn, cheese, and the thousand and one things used in daily life are subjected to a more thorough test than the average engineer subjects the fuel which is the source of all his power. Is this a credit to the profession?

Mr. J. T. N. Anderson said:— On the afternoon of the 11th of April we were full of confidence that the trial which Mr. Higgins was about to conduct would be more thorough and conclusive than anything of the kind that had yet been done in Melbourne. He had gone to immense trouble, and had taken the most elaborate precautions with gauges and measures of all kinds. The chief engineer had done all in his power to make the trials complete and the results conclusive, and, as he expressed it, "had provided sufficient apparatus to enable us to check 'Joules equivalent.'" That we might be able to prepare a balance sheet to show how the heat was expended, he had gone to the trouble of designing an excellent gas-sampling apparatus, and had given instructions that a barrel steam calorimeter should be attached to the boilers at the steam valve. I had undertaken to have the calorimeter value of the fuels taken by a Thompson fuel calorimeter, with special attachments of my own. As representing one of the Coals, I felt called on to express my satisfaction with the preparations that had been made, and my confidence that as the engines were of an unusually steady type, and were required to develop the same power hour after hour, and night after night, the results should be conclusive. Unluckily events proved that I had formed and expressed my opinion in too great haste. The engines, which would have given excellent results as far as duty is concerned, had they been required to do twice as much work, did not prove so very satisfactory when working at half-power, and even more fatal was the attempt to work the boilers at a rating of only half their capacity, and at less than a sixth-part of what the flue and chimney had been designed for. To illustrate how hopeless would have been the attempt to determine the proportion of heat which went to
waste in the flues and chimney, it will be necessary to only cite one example of many. Take trial of 16th and 14th of April with Newcastle Coal:-

At 10 p.m.—Flue temperature machinery 100°—Draught same place, 50°

3 3 a.m. " " " 150° " 45°

The record of the tests show these discrepancies as the rule and not the exception. Now it is unnecessary to remind the meeting that unless the flue gas are determined not only in quality but also in temperature and quantity, it is impossible to determine whether the coal has been completely consumed or not, or, in other words, to tell whether the conditions have been favourable to the coal or the reverse. The hopelessness of the task along with insufficient preparation prevented me from taking such chemical tests as I had intended to take, and consequently the results given are without this very important information, and we cannot say conclusively that the stoking was best suited to each coal. With reference to the Newcastle coal, I am quite satisfied, as the result of several previous tests with it and the other coals (excepting Jumbunna coal, which I never tested), that it did not get fair play, and the records of all the tests conducted by the Victorian Railways, and by similar bodies in New South Wales, will bear out this statement. Then, again, until the last two trials, I was unable to get satisfactory steam calorimeter tests, and in consequence cannot say whether the boiler primed. It is obvious from Mr. Higgins' published results that there must have been considerable priming on the first night, since the quantity of water apparently used was 654 gallons, or more than 11 per cent, greater than that used on any other night. Mr. Higgins explains this by stating that the steam cylinders were cold before the trial that night, and consequently more water was condensed therein. I would like to ask Mr. Higgins how long he thinks it would take to heat the steam cylinders, and further if his theory is consistent with the fact that the water consumption as in his own log, was excessive all through the night, showing no easing off until 4 a.m., and also showing the greatest consumption of water between 8 and 9 p.m.; also if he is aware that there been such condensation the temperature of feed water would have been proportionately higher. Mr. Higgins also remarks that such priming would be very noticeable, and that it would be unlikely when the boilers were working at less than their capacity. In this connection I would like to ask him if he knows that the workmen, when trying these boilers, several times found serious priming to take place, and that without any sign of priming in the boilers or gauge glasses, also that the water tube boilers are unlike other boiler in that they invariably make dry steam when forced and are rather inclined to prime when working very much under their true capacity. If he has not worked with these boilers before, I would request him to refer to the report of the American Government trials of these boilers at the International Exhibition when he will find that while they made dry steam under pressure, at their economy trial they prime and to the extent of 2'6 deg. Further I would like to ask Mr. Higgins if he is still satisfied that there was no priming, how he accounts for the extra horse-power, more or less, that the engines should have developed with the extra 55 gallons an hour of water he says was evaporated on this evening. Failing the calorimeter checks, and not being able to make up an accurate balance-sheet, I was compelled to send in a report of the duty obtained with each trial. This report was printed in
part by the Coal Creek Proprietary Company, and is at present on the

II'

table. The results are such as might have been taken by any engine-driver,

and must seem very bald and unsatisfactory to engineers such as are here
to-night; but I know that they will see that these results are all which
could fairly be drawn from the tests. In calling attention to the fact that
these trials were barren of results, such as could be relied on, I do not wish
to imply any blame either to Mr. Higgins or to the very careful and con-
scientious gentlemen who represented the City Council. The failure of the

trials was chiefly due to the complete insufficiency of the engines to take

so much steam as the boilers were capable of developing. To the large

proportions of flues and chimney, which no matter what precautions could
be taken in limiting grate area, or flue area, must cause irregularity in com-
bustion, and, finally, it would be of little use to repeat the trials until the

engines are capable of doing at least twice as much work.

Mr. I. Tipping said he did not think Mr. Higgins was called upon to
take the calorific value of the coal. The City Council did not want to

know anything about evaporation of the boilers, but simply to know what
was the cheapest coal to be used with their boilers.

Mr. Geo. Higgins, said he would but briefly reply to the criticisms that
night, as he possibly might not be present at next meeting. The result of
having read his paper was, that it had called forth one of the most interest-
ings discussions they had ever had. Mr. Stone had contributed a very valuable
addition to the discussion, but most of the other speakers had been under
a misunderstanding regarding these tests. He had undertaken to do
certain things, and the speakers had assumed he was wrong in not
performing that which he had not undertaken to do. Mr. Stone said if he had taken a calorific test, they would then be able
to see the total heat value, and could also determine whether certain coals
had been treated more fairly than others, in using the one class of grate
for all. Mr. Stone did not recognise that his object was to try to comply
with the wishes of the Council, which he had stated earlier in the evening.
Nothing would have given him greater pleasure than the opportunity of
making a scientific investigation, and to have taken the calorific values
and a chemical analysis of the gases in the flues, but as he had simply
been called upon to see what coal was the most economical in a certain
boiler, he thought the members would agree with him, that, under the
circumstances he was right in not making these tests. It was very un-
fortunate that the warming of the cylinders had not been done previous to
the using of the southern coal. It had been asked was there any pri-
ming? If there was any priming it would be the same in each test. In
his report he said: “the water level in the boiler was at all times below
the drums, thus reducing to a minimum the chance of priming. Con-
sidering also that the boiler was not forced—being worked at less than
half its capacity—it may be assumed that very little, if any priming
occurred”! Consequently he thought he was justified in assuming there
was no priming. A boiler, provided there was no priming, afforded really
a calorimeter test on any large scale. It was agreed that Mr. A. J.
Arnot should reply to the discussion on his paper at the next meeting.

This terminated the discussion, and the Chairman declared the meeting
closed.
DISCUSSION ON THE
ELECTRIC LIGHTING OF THE CITY OF MELBOURNE.

WEDNESDAY SEPTEMBER 12TH, 1894.

Mr. Stone said:—I have read Mr. Arnot's paper on the Electric Lighting of Melbourne very carefully, and desire to thank him for bringing so interesting a subject before us. The first impression left on my mind, after reading the paper, was that Mr. Arnot had all through been afraid that we should regard his paper as too tedious if he went more into detail. Such a feeling is perhaps not unnatural, for when we have been engaged for a considerable time on any work, and the constant attention to details has become irksome to ourselves, we cannot help feeling that these details must be tedious to others. Such, however, is not the case; those very details which to the man who is engaged upon the work ultimately appear to be trivial, or but the suggestions of one's common sense, have often the greatest interest for those who are listening to the description for the first time. From what I have seen of the plant on the two occasions on which I had the privilege of looking over the installation, and the description given by Mr. Arnot in his paper, I feel sure that it is very complete, and a credit to all engaged on it and to the city in which it stands. The selection of the system which will be best adapted to meet the requirements to be demanded of the installation is a matter on which considerable differences of opinion may exist. Undoubtedly the selection and arrangement of a system which is to be used mainly for municipal lighting is one of the simplest problems of this class. The question most open to debate is probably the relative claims of slow speed v. high speed engines. The claim made by the advocates of the small unit high speed engines for the high load factor, economy does not in this case come in, for it is just as easy to arrange matters so that the engines running at any time shall be working approximately at their most economical rate when large slow speed engines are adopted. This is especially true when compound condensing engines are used for, as Professor Kennedy says, the indicated power of such engines is almost proportional to the weight of steam used, provided the load does not fall below one-half the normal maximum, conditions very easy to maintain in a municipal lighting plant. The other claim for the small unit high speed engine, viz., the comparatively small inconvenience caused by the failure of one of these engines, is perhaps more worthy of consideration. With the large slow speed engine and its attendant counter shaft, where each bearing may be the cause of trouble, even necessitating the stoppage of that section of the machinery, the loss of time in stopping the faulty and starting a fresh section and switching over the dynamos would be much greater than the time required to perform a similar set of operations with a small high speed engine and its one or two small machines. The claim for small space for a given output in favor of high speed engines
ELECTRIC LIGHTING.

is one, the nature of which is entirely dependent on the circumstances attending the location of the plant. There is, however, another method of dealing with the problem which Mr. Arnot has brought before us, to which he does not allude in his paper. I refer to the use of comparatively large dynamos having a high e.m.f., and capable of generating a considerable current. Such machines can supply a number of separate circuits, the number of lamps in each circuit depending on the e.m.f. of the machine. The machines can be either directly coupled to moderately high speed engines running from 200 to 400 revolutions per minute, or may be driven by rope or belt gearing direct from the fly-wheels of slow speed engines without the intervention of a counter shaft. This system appears on the surface to combine some of the advantages of each of the other systems, at least for municipal lighting. Its more general adaptability will largely depend on the efficiency of the means adopted for controlling the current passing to the respective circuits on any machine when the number of lamps on any one circuit is altered. This system is, I believe, used by Siemens Bros. Although the advantage of the small space occupied by the high speed direct coupled plants may not from the value of the space be important, still a compact plant, provided it is not crowded, is more economical to run. More attendants are required for a given output from the station when the power is transmitted first by ropes to a counter shaft, and then from the counter shaft to the dynamos, than when the dynamos are directly driven by high speed engines. In the latter case the whole plant is easily accessible, there are no ropes or belts to run round or jump through, and the engineer has everything more directly under his eyes and requires less assistants.

The Boilers.—Whatever may be said, and a great deal has been said and is being said, concerning the evaporative efficiency of this class of boiler, still there is a fair uniformity of opinion with reference to the suitability of the boiler for electric light requirements in other respects. The comparative immunity from serious breakdown is a feature the value of which cannot be over estimated. The ease with which it responds to a sudden demand for an increased supply of steam is a point of great importance in the private lighting installation, or any installation in places where dense fogs occur with very little warning. The former is I think the more important advantage for such a purpose as our city lighting, and might I think be regarded as of sufficient importance to make the use of water tube boilers compulsory within city boundaries. I cannot help thinking that the very diverse results obtained and opinions expressed by various engineers regarding the evaporative performance of these boilers must be mainly due to differences in the treatment which the boilers have received from them. I have never had any experience with these boilers, but from their construction I should say that, with usual arrangements of furnace, their performance would be more affected by the nature of the fuel used and the stoking, than is usual in the older forms of boilers. Looking at the usual method of erecting these boilers and arrangement of furnace, which is I believe adopted in the city plant, we find that the air has as usual two ways of ingress to the furnace—one through the fire bars, and the other through the door. The gaseous products of combustion rise almost vertically from the surface of the fire and at once pass into the spaces
between the staggered tubes. The very feeble inrush of air through the door is not capable of causing its rapid intermingling with the furnace gases before they reach the tubes; nor has it energy enough to cause that thorough mixing of the furnace gases before they pass into the tube spaces, and rapidly lose the high temperature which is requisite to maintain combustion. In the majority of the older types of boilers, the furnace gases roll along over the glowing fuel and brick arch, thus effecting the thorough mixing of the air which enters above the fire with the furnace gases before they reach the combustion chamber, where there is a chance for combustion to be completed before the gases enter the cool tubes. We must not overlook the fact that the first section of the tubes in these water tube boilers is admirably arranged to take up the heat from the furnace gases passing between them. Hence probably when they reach that triangular space above the tubes called the combustion chamber their temperature is probably below that which is requisite to ensure the completion of combustion with such dilute gases. At all events, a large portion of the gases which have come into fairly intimate contact with the tubes, will have been so reduced in temperature that some of the carbon will have been thrown out in the solid state, and as is well known its combustion afterwards can only be effected with difficulty or at a high temperature. The second section of the tubes through which the furnace gases pass, will not be nearly so effective in taking up heat as the first section; nor in the first place, the difference of temperature between the gases and tube surfaces is much less, and secondly, the gases pass downwards between the tubes, and thus impinge on that surface of the tubes which will collect, and rapidly become covered with, a thin sheet of beautifully non-conducting ash or dust. The highest temperature of the furnace gases, which I have personally observed, taken at a height of about one foot above the surface of the glowing fuel, was about 1,600 deg. Fah., and this was obtained with a high rate of combustion and good coal. If we assume the furnace gases to leave the boiler when working at the normal rate at a temperature of 500 deg. Fah., we have a fall of 1,100 deg. to account for, two-thirds at least of which is probably taken up by the first section of tubes, which would thus reduce the temperature of the combustion chamber to about 900 deg. Fah., a temperature not very likely to promote the combustion of such gases as usually leave the furnace. If my above supposition is at all correct, it would follow that this type of boilers would give the best results when fired with fuels such as, anthracite coal, or coke, which give out the greater part of their heat of combustion in the radiant form. My experience with the fuels which Mr. Higgins recently tested at the lighting station and the results which he obtained appear to me to support this view; the smokeless coals had the advantage, and Mr. Crompton’s remarks quoted by Mr. Arnot seem to imply the same.

**Furnace Accessories.**—I am very pleased to find that Mr. Arnot is one among the few in Melbourne who have sufficient faith in their belief that a chain is no stronger than its weakest link, to cause him to so arrange his testing apparatus that no link in the chain of transformations of energy which his plant is erected to effect shall pass untested. He has arrangements by which everything from the coal which is thrown into the bunkers, to the light in the streets can be tested and measured. I believe also that
the Metropolitan Board of Works require that their plant shall give the stipulated duty with coal having a given calorific value, and that they propose to purchase their fuel on its calorific value also. These are healthy signs. Indeed, I regard these accessories which are fitted in the city lighting station furnaces, as a standing material protest against the careless use of the expression "scientific tests," which we have heard so frequently at our recent meetings. As far as I can see, the expression can only have been used in antithesis to the expression "practical tests," and with a desire to discount the practical value of the so called "scientific tests." All sound practical tests must be carried out on a scientific basis, and the processes selected are those which will enable the desired data to be obtained most readily and with the degree of accuracy which is required. One of the most important duties of the engineer and physicist alike, consists in the taking of physical measurements. We might, therefore, say that their duties are to some extent alike in kind; but how widely different in degree. The engineer may measure a diameter of his engine cylinder correct, to say \(\pm\frac{1}{2\alpha}\) part of an inch, whereas the physicist must determine the dimensions with all the accuracy attainable by modern refined processes. The difference in the two cases lies within the \(\frac{1}{2\alpha}\) part of an inch—not a very large quantity, truly; nevertheless the difference in the skill required in the two cases makes the difference between the engineer and physicist. We might with as much reason call the indicating of a steam engine a "scientific test" as the approximate determination of the calorific value of a fuel or the loss due to incomplete combustion. If these tests are to have a practical value, they must be carried out on a scientific basis. I should like to ask Mr. Arnot to give us particulars of his apparatus for collecting flue gases, as I notice that Mr. J. T. N. Anderson speaks very favorably of the arrangement adopted, and also of the construction and placement of the pyrometers. *The Dynamos.*—I should like Mr. Arnot to give us full details, magnetic and electrical, of his arc lighting-dynamos. The Thomson Houston, like the Brush, is an exceedingly interesting form of machine. The virtues of these two machines consist largely of the vices of other types. Would Mr. Arnot tell us whether he has tested (either before he purchased them or since they have been erected here) the efficiency of these dynamos, and, if so, what results he obtained. I am aware that a very high commercial efficiency is claimed for these machines, but I should like to see the results of independent tests. I was very much surprised to find that Mr. Arnot had adopted the Thomson Houston dynamo for Melbourne. It certainly stands, on sufferance, in the list of continuous current dynamos; but I think it is the very worst on that list, as far as producing disturbances in adjacent circuits is concerned. Its three-coil armature, even though steadied by the field magnets, must produce a very decidedly pulsating current, the hum of which most of us have heard through the telephone by induction. Can Mr. Arnot tell us what the loss would be if conductors carrying such pulsating currents were put in metal pipes under ground? There are several designs of continuous current dynamos now in the market, which give a current practically continuous in strength as well as direction, e.g., the Woods's dynamo, which is used here by the A.U. Alock Electric Light Company. Dynamos of this type have the advantage, both theoretically and practically, over the open coil type at
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The old electrical difficulties of insulation with the Gramme type of commutator have entirely vanished, so that machines with this class of commutator are made to generate as high an e.m.f. as those of the open coil type. Such machines produce little or no disturbing effect on adjacent telephone circuits, and can be constructed to give a higher efficiency than their open coil competitors. Mr. Arnot refers to the induction trouble with the telephones in his paper, and says, "but we hope in a few weeks to eliminate this, as we are now erecting and crossing return cables in the affected districts." I do not understand whether Mr. Arnot means that he is duplicating the electric light circuits or putting up a metallic return for the telephones in the affected districts, will he kindly explain? In any case it appears to me that a dynamo generating a smooth nonpulsating current must be more suitable where telephones are so numerous, no matter whether the wires be overhead or underground. In other respects the dynamos which Mr. Arnot has selected appear to be beyond criticism, they are solid and well made, at least as far as can be seen from the outside. Will Mr. Arnot, if he has no objection answer the following questions? What is the composition of the bituminous compound which he uses to fill the compo pipes through which his conductors run from the dynamos to the controllers? Are the compo pipes protected against rats in any way? What method has he adopted for connecting the various dynamos to the volt meters whilst the plant is running.

Street Illumination.—We are told "The actual candle power per sq. foot of area equals 0.048 which is considered sufficient for a well lit street. Will Mr. Arnot kindly tell us how he arrives at this figure. I think that he has erred on the side of keeping all his lamps too low down and that more pleasing results would have been obtained if the lamps had been kept higher up. The reflected light from buildings would have been just as good and the direct illumination at about half way between the lamps would have been greater. Of course the illumination of the street at the foot of the poles would be less but this I think can be spared if a better illumination could be obtained at the intermediate points. A bright light at or near a lamp pole is decidedly objectionable from a lighting point of view; it simply fatigues the eye and thus makes the less brilliantly illuminated part of the street appear worse than it really is. Are the globes which Mr. Arnot uses on his arc lamps similar to those which he speaks of as being used in America and which he says do not obstruct 40 or 50 per cent. of the light. I should judge from the comparatively bright illumination on the buildings above the projection of the globe line that the Melbourne globes do stop from 40 to 50 per cent. of the light produced. Although I fully endorse Mr. Arnot's statements that the art of street lighting lies in effecting a uniform illumination it must not be forgotten that uniformity of illumination depends primarily on the ratio of the height of the lamps to the distance between them, and not on the candle power of the lamps. All other conditions remaining constant the actual illumination at any given point varies directly as the candle power of the lamps employed, but the distribution of light will not be affected. Efficiency of Plant.—We are told that "one pound of coal, gives 129 watt hours, which is 37 above the average return every point, with exception of the mechanical simplicity of the commutator.
of 800 electric light companies in America, according to the *Engineering News* of 15th. March 1894*. Is it not strange that engineers should go to the trouble of working out, and journals give space, for such useless figures? The evaporative value of the coals tested by Mr. Higgins differed by roughly 16 per cent, and the evaporative values of different black coals differ by as much as 30 per cent. What, then, is the use of talking about the result obtained per pound of coal when the value of the coal may not be known to within 30 per cent. of the total. Evidently even—electrical engineers—are reluctant to give up such practises of the "good old days," as measuring the height of a door in terms of the length of the fore-arm. If we are to give data which will be of any real value, we must state the ratio of the electrical units obtained per some stated number of heat units represented by the fuel put into the furnace, or what is equivalent, we may give the number of electrical units obtained per pound of coal, provided we give the calorific value of the coal used. *Insulation of Circuits.*—Insulation testing is a somewhat vexed question. Considerable differences of opinion have been expressed by electrical engineers as to the requisite voltage to use in order to ensure reliable results. Two very different kinds of insulation faults have to be dealt with. The first may be considered to be due to a diminution of the insulation properties of some portion, or portions, of the insulating materials, resulting either from the deterioration of the insulating material itself or the formation of a slightly conducting film of moisture, or dirt, over some parts of the insulating surfaces. The second kind of insulation fault may be looked upon as due to mechanical conditions, such as the too close approximation of portions of the circuit between which a considerable difference of potential exists. The first class of fault may be detected by the process of testing which Mr. Arnot describes in his paper, although it by no means follows that the seriousness of the fault can be estimated by such a process. The second class of fault is in most cases entirely beyond detection by such a test as that described by Mr. Arnot. Indeed, the circuit may appear to be perfectly insulated when so tested and yet break down immediately on starting the dynamo. The first fault depends on the conductance of the insulation; the second on the disruptive power of the currents employed. A simple hydraulic analogy will illustrate the difference in the two cases of insulation fault to which I have alluded. Let a water main which is intended to carry water at 100 lb. per square inch be tested for the first time at a pressure of 10 lb. per square inch, and let the rate of breakage be determined at this pressure. Then, assuming the law of water flow to be, the velocity varies directly as the pressure, we might assume that the leakage at 100 lb. per square inch would be ten times as great as that measured under the 10 lb. pressure. This is an analogous process of testing to that described by Mr. Arnot. He uses an electro-motive force of from 140 to 150 volts to test his circuits, whilst the normal electro-motive force of the machine is about 3000 volts, or twenty times as great as the pressure used in testing. The utter absurdity of testing the water main at a pressure of 10 lb. per square inch is apparent, for on applying the full pressure a faulty joint may blow out or faulty pipe burst, and these faults may occur even though the pipe...
showed no indication of leakage at the low pressure test, the faults in this
case being caused by the disruptive force of the higher pressure. I have
repeatedly found similar results in electrical testing apparatus which
appeared perfect when tested with a battery having an e.m.f. of 300 volts,
and a reflecting galvanometer, has broken down at once on being subjected
to an electro-motive force of 1500 volts. I think that all insulation tests
should be carried out with an electro-motive force at least as great as that
of the machine to be used on the circuit tested, and of a similar kind, i.e.,
either direct or alternating, according as the machine used is a direct
current or alternator. I should like to ask Mr. Arnot what are the advant-
ages which he considers are to be derived by the use of high insulation
cables, for I believe he uses cables which have an insulation resistance of
two thousands of meg. ohms per mile. Of course, whilst the insulation
is sound it may be regarded as an element of personal or material safety.
But the question is—how long will it remain perfectly sound? What is
the effect of 10 years—or even five years—exposure to the weather on the
insulation? As far as personal safety is concerned, the supposed, and
trusted, high insulation may soon become a snare.”

Mr. K. L. Murray said he was sorry at not having been present to hear
the paper read, and he had only been able to hastily glance over it. He
congratulated Mr. Arnot upon having had an opportunity of so thoroughly
well equipping the station, and was pleased to see it fitted throughout in
such a complete manner with testing instruments, by which Mr. Arnot
would be able to take tests which should prove of great value. The test
which Mr. Arnot placed on the insulation of the leads was practically valueless.
It was similar to a boiler constructed to work at a pressure of 100 lbs. to
sq. in. being tested at one pound. Any faults existing in the boiler could not
be detected by the test. Mr. Arnot had stated in the paper, “The great cost
of undergrounding the whole of the reticulation was prohibitive, although
in the near future I look forward to the placing of both the electric light
leads and telephone wires underground,” but he did not give the
estimate of cost, nor the figures upon which he based that estimate, nor
say what was the cost of fixing the leads in the way he had done. If the
overhead leads are “in the near future” to be undergrounded, it
appeared that all the expense of fixing these leads and poles in their
present position would be thrown away, so he should like to be in a
position to say whether the extra cost of fixing these leads in position was
a suitable and proper one to incur! Mr. Arnot further said: “Con-
siderable discredit has fallen on the fair name of electric lighting owing to
the expense as compared with gas. . . . In England and in several
cities on the continent, too much light has been wasted in the streets, the
idea being simply to give a grand illumination, without any consideration as
to the quality of light required for all practical purposes, hence the too-
well-known cry, ‘Costs three or four times gas!’” He (the speaker)
had never yet heard arc lighting described as “costing
three or four times gas.” Incandescent lighting, certainly, they found
sometimes to be more expensive than gas lighting. Mr. Arnot continues,
“Not so, however, in the United States. In most of the cities which I
visited in 1892, the arc lamps have been erected with a greater view to
economy, giving perfect satisfaction utilising the light to the utmost
advantage, and not obstructing 40 or 50 per cent. of it by thick opal globes, or lanterns, as is the practice in many English cities." He (the speaker) must say that his observations had been directly the opposite, for in America he found the arrangements of some of the electric light plants simply abominable, and the arc lights were placed generally so low as to be a regular nuisance; while certainly he could point to a few stations in England which were eminently satisfactory. Referring to the engines, Mr. Arnot says that the big engines which he had adopted are very much more suitable than high speed ones. He states, "The small unit high speed engine, coupled direct to arc dynamos, is now being discarded by many electrical engineers for arc lighting. In Milan, 1892, the engineer of the arc light plant, showed me similar engines to the type adopted by the Melbourne Corporation and of the same horse power, being erected to take the place of the high pressure high speed engines they were then using," but he gave them no reason for this alteration being made, leaving them to imply that the engineer at Milan was impressed with the belief that the engines Mr. Arnot has described in his paper, were very much better, without any evidence as to what had induced him to make the alteration? In his younger days he (Mr. Murray) had been taught to believe that low speed engines were proper to use, as being the most efficient, and although he still held that belief, yet he was decidedly of opinion that for certain lighting purposes, high speed engines coupled direct to dynamos, were the most efficient for practical and lengthened service. When he travelled in 1890, he saw in Italy, Germany, France and England that the central lighting stations were mostly driven with high speed engines direct coupled to dynamos, and therefore his observations were directly in opposition to Mr. Arnot's statement that "the small unit high speed engine coupled direct to arc dynamos is now being discarded by many electrical engineers." He was glad to learn that Mr. Arnot intended supplementing his paper at a later date, after the plant had been working up to its full capacity, when he would be in a position to place before them the exact figures of its efficiency, as electrical engineers wanted all the information possible, with regard to the methods of arrangement for central electric lighting stations, and the result of those arrangements; he hoped therefore Mr. Arnot would give them some data which would enable them to tell what was the pound shillings and pence question connected with this station, also the efficiency of plant, indicated horse power of engines, the loss between them and the dynamos, and the loss in the lead between the dynamos, and the lamps, as also any other information at his disposal.

Mr. A. J. Arnot said he was very pleased to hear the interesting discussion that this paper had evoked. Professor Kernot had very favourably criticised the paper and approved of the class of engines adopted, and also stated that they were really a copy of the engines driving electric lighting plant at Richmond. This was so, and it was these very engines that had brought him (Mr. Arnot) out to this country, and in adopting this class of engine for the city lighting, he was adhering to the same type he thought most favourable then. The air and circulating pumps had been referred to by Mr. Higgins, who stated that the level of the suction valves was 2 ft. above the bottom of the condenser, pointing out that we lose at least 1 inch of vacuum thereby. He (Mr. Arnot) had had this carefully
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... dynamos instead of the Brush, he had considered the satisfactory regulation of the former, although now he believed that the regulating device of the latter was as good; but when he was at home he could not get an opportunity of testing this, and preferred to adopt the dynamo, the measured, and found that there was not an inch difference in level between the suction valves and the bottom of condenser, and that a steady vacuum of 27 inches was obtained. Referring to Mr. Murray's remarks, and to the testing of the leads, Mr. Arnot said that these tests were those made every day. The cables had been carefully tested by himself before leaving the manufactory, the test being a very severe one. It was not actually necessary to have such a high insulation resistance as 3000 meg ohms per mile, but in specifying so much it insured first class rubber and material being used in the manufacture of the cables. It would neither be wise or necessary to test the leads every day up to the full pressure. What engineer using a boiler would run it up to 400 or 500 pounds per square inch every day before use. It was the same with the testing of the leads. A battery test of 100 volts was sufficient to ascertain and locate any serious fault on the line, and faults had been detected with this test and remedied before starting the plant. The insulation resistance of the circuits had always proved very satisfactory. As to the cost of the erection of poles, this was a matter of 4s. 6d. per pole, while their removal to outlying districts when required would not cost (contract price) 10s. per pole, and it must be admitted that this was a small item when compared with the advantage of having the light at once, instead of waiting for such time as the leads could be placed underground. Mr. Murray had objected to the statement that in some municipalities electricity had cost three or four times as much as gas. The cost of lighting the city of London with electricity was £26,000 per annum as compared with £7000 per annum previously for gas, and numbers of other instances could be cited, though he was not prepared to do so, not anticipating that the question would be disputed. Referring again to the engines, Mr. Murray had objected to his statement as to the slow speed engines; but it was a well-known fact that at the present day electrical engineers generally were adopting slow speed engines for arc lighting and high speed for incandescent. He would never approve of connecting the small unit dynamos with small high speed engines. High speed engines for incandescent lighting were used in some parts of America, but the system generally adopted throughout America and England when he was there in 1892 was slow speed compound-condensing engines for arc driving, and high speed coupled direct for incandescent lighting.

In answer to questions, Mr. Arnot said that his paper was not intended to be a scientific treatise, but a simple description of the plant—that the installation was too recent yet to give any data as to the efficiencies of the boilers, engines, and dynamos, but he looked forward with much pleasure to making complete tests in that direction, and would be most happy to give all technical details of the plant and of these experiments at some future time. His estimate of the cost was £75,060, of which £72,000 had now been spent. All the necessary plant was purchased, and further expense was only that required for labor, so that he did not doubt that his estimate would not be exceeded. In adopting the Thompson Houston...
factory working of which he knew by personal experience.

To Mr. Stone: The arc lights should rather be higher than lower. The height of the arc depended directly on the distance between the lights, taking into consideration that the greatest illumination was between 40 and 60 degrees from the horizontal.

The Chairman announced that Mr. R. Foster Smith had kindly presented the Institute with a recording compass, and had pleasure in calling on Mr. Smith to explain the working of the instrument.

In giving a short explanation of the working of the instrument Mr. Smith said that he was induced to undertake the invention of this instrument by reason of the great difficulty at present experienced by navigators in ascertaining the true average compass course pursued by the ship. This was an instrument having a magnetic needle, attached to which is a card having the “points” cut in raised letters. Under the card is a train of clockwork so arranged that every ten or five minutes a flat disc of metal placed round the needle pivot, and parallel to it, shall be carried up until it first lifts the card off the pivot and then presses it up against a metal table in which is cut an opening to allow those points of the compass indicating the direction of the ship’s head to be shown through the plate. Then, by means of an ink ribbon and a strip of paper, an impression or print of the raised metal figures or letters on the card is taken on the paper. This paper strip can be examined, or removed, for reference, and enables the master to make out with great exactness the actual course the ship has made.

A hearty vote of thanks was accorded to the donor.

Mr. Tipping spoke regarding Mr. Higgins’ paper on “Coal Tests.” He moved—“That the Secretary be instructed to forward copies of the paper, and discussion thereon, to the London Engineering Journals.” The motion was seconded by Professor Kernot, and carried.

This concluded the discussion, and the meeting closed.
Author/s:
Arnot, Arthur James

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