Remarks on circumstances attending the trial of certain coals at the City Electric Light Station Melbourne. Trials conducted on behalf of the Melbourne City Council by George Higgins, 11th to 21st April, 1894. The coals which were tested were: Southern, New South Wales; Newcastle, N.S.W.; Coal Creek Proprietary, Victoria; Jumbunna, Victoria. The whole of one night was devoted to testing each of the four kinds of coal. Each trial began at 5 p.m. in the evening, when the fires and ash-pit were thoroughly cleaned out. About 1 cwt. of live coal was reserved from the fire before cleaning. This was weighed and returned to the furnaces in order to start fires with fresh fuel. It was arranged that the pressure of steam in the boiler should, at 5 p.m. on each evening, be as nearly as possible 100 lb. As the pressure dropped during the process of cleaning and relighting, the lowest pressure reached was recorded and taken as the pressure at commencement of the particular trial. Steam was then raised, and at 5.30 p.m. on each evening the air and circulating pumps of the condenser were started. The engines commenced running at 2.45 p.m. The quantity of water in the boiler was ascertained, immediately before the condenser pumps started, by reading the graduated scales attached to the gauge glasses. These scales had been carefully graduated before the trial by pouring into the boiler, in succession, measured quantities of water. Each trial terminated at 6.30 a.m., at which time it was arranged that the pressure of steam in the boiler should be, as nearly as possible, 100 lb., and that the water level in the gauge glasses should be, as nearly as possible, the same as at starting. It was further managed that, at the termination of each trial, there was practically no live coal in the furnace, all that remained being clinker or ash. Throughout the ordinary working time the boiler pressure remained, with remarkable steadiness, at about 148 lb. The water level in the boiler was at all times kept well below the centre of the drums, thus reducing to a minimum the chance of priming. Considering also that the boiler was not forced—being worked to less than half its capacity—it may be assumed that very little, if any, priming occurred. Again, seeing that the conditions were practically the same during each trial, it is fair to assume that, if any priming did occur, it would affect each result to the same extent. The only departure from the normal state of things occurred on the evening of the first trial, when, owing to some adjustments which were being made in the engine room, the usual preliminary heating of the cylinders before starting did not take place. The resulting condensation after starting accounts for the greater quantity of water—and consequently of fuel—used during that trial. The warming of the brickwork, etc., and radiation have been left out of consideration as being of no practical importance for the purposes of the City Council. Such conditions as these were the same for one trial as for another. Selection of Coal for Trial:—The Southern coal tested was taken at random from a heap which was lying at the Electric Light Station, and had been supplied, under an ordinary contract, previously to the test. It was a good specimen, fairly clean. The Newcastle
coal was chosen for the purposes of the test in equal parts from three collieries, viz., the Wickham, Lambton and Newcastle. Loads were taken from heaps lying partly on the South Wharf of the river Yarra, and partly from a lighter lying alongside the wharf. It was a good clean sample. The coal from the Coal Creek Proprietary Company's mine was chosen in equal quantities from each of three heaps lying at the depot at Prince's Bridge. The coal was good and clean looking. The Jumbunna coal was taken from a stack of about thirty tons lying at the Prince's Bridge depot. It also was a good clean sample, free from any small coal.

Fires.—All the coals burned brightly and well. The fires kept fairly clean, and no difficulty was experienced in keeping up steam. Smoke.—The smoke was not dense in the case of any of the coals experimented with. [It may be remarked here that the boiler employed for the test was working far below its capacity, and that the chimney is large enough for four similar boilers, three of them being idle during the tests.] There was less smoke in the case of Southern coal than with any of the others. Jumbunna and Newcastle coals gave rise to about equal amounts of smoke, while the smoke from Coal Creek Proprietary coal was slightly denser.

Firing.—The times of firing were about the same in the case of each kind of coal. Very little stirring or raking was required. The fires were not cleaned at all during the trials. Flue Temperature and Draught.—Readings of the pyrometers placed in the flue, and of the water vacuum gauge, were taken at regular intervals. Comparisons of these ensured that the general conditions remained fairly constant throughout the series of trials. Feed-water.—The arrangements for measuring feed water consisted of two tanks in communication with the hot-well, and provided with gauge glasses having graduated scales alongside them. The scales had been graduated by marking as each two-gallon measure of water was emptied into the tank. The feed pump drew from each of the tanks alternately. The temperature of the feed water was taken from a thermometer placed in the feed-pipe, and a check on this was obtained by reading the temperature of the water in the measuring tanks as indicated by a thermometer which was immersed in them. Boiler.—The boiler employed was of the Babcock and Wilcox type, with a grate area of 50.25 square feet. The air space between the fire-bars was about 3/16 in. The heating surface was specified to 2823 square feet.

Geo. Higgins. 28th April, 1894.

COAL TESTS CONDUCTED AT THE CITY ELECTRIC LIGHT WORKS, MELBOURNE, ON BEHALF OF THE MELBOURNE CITY COUNCIL, BY GEORGE HIGGINS, M.C.E., ASSOC. M. INST. C.E., 11TH TO 21ST APRIL, 1894.

<table>
<thead>
<tr>
<th>Coal</th>
<th>Gallons</th>
<th>Pounds</th>
<th>Average Temperature of Feed</th>
<th>Average Boiler Pressure during Trial</th>
<th>Equivalent Amount of Water Evaporated from and at 212deg. Fah.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southern N.S.W.</td>
<td>6.519</td>
<td>65,352</td>
<td>114</td>
<td>144</td>
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<td>Newcastle, N.S.W.</td>
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<td>144</td>
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<tr>
<td>Coal Creek Proprietary, Vic.</td>
<td>5,688</td>
<td>56,419</td>
<td>111 1/2</td>
<td>145 1/2</td>
<td>65,058</td>
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<tr>
<td>Jumbunna, Vic.</td>
<td>5,814</td>
<td>57,762</td>
<td>105 7/8</td>
<td>144</td>
<td>66,924</td>
</tr>
</tbody>
</table>
### COAL TESTS.

<table>
<thead>
<tr>
<th>Coal</th>
<th>Water in Boiler at Commencement of Trial</th>
<th>Boiler Pressure at Commencement of Trial</th>
<th>Water Evaporated from and at 212 deg., equivalent to heat spent in raising water in boiler up to average working pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gallons.</td>
<td>Lbs. per sq. in.</td>
<td>Lbs. per sq. in.</td>
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<tr>
<td>Southern, N.S.W.</td>
<td>2,233</td>
<td>75</td>
<td>22,287</td>
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<td>Coal Creek Proprietary, Vic.</td>
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<tr>
<td>Jumbunna, Vic.</td>
<td>2,240</td>
<td>130</td>
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<table>
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<tr>
<th>Coal</th>
<th>Total Water Evaporated from and at 212 deg. equivalent to the Total Heat considered</th>
<th>Coal Consumed</th>
<th>Water Evaporated from and at 212 deg. per pound of Coal</th>
<th>Tons equivalent to 100 Tons Newcastle Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lbs.</td>
<td>Lbs.</td>
<td>Lbs.</td>
<td>Lbs.</td>
</tr>
<tr>
<td>Southern, N.S.W.</td>
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<td>8,349</td>
<td>9.11</td>
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<td>7,907</td>
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<td>Jumbunna, Vic.</td>
<td>67,413</td>
<td>8,508</td>
<td>7.92</td>
<td>108.21</td>
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</thead>
<tbody>
<tr>
<td></td>
<td>Lbs.</td>
<td>Lbs.</td>
<td>Lbs.</td>
<td></td>
</tr>
<tr>
<td>Southern, N.S.W.</td>
<td>1,163</td>
<td>Nil.</td>
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<td>13.93</td>
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<td>357</td>
<td>763</td>
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</tr>
<tr>
<td>Coal Creek Proprietary, Victoria</td>
<td>513</td>
<td>264</td>
<td>777</td>
<td>9.03</td>
</tr>
<tr>
<td>Jumbunna, Victoria</td>
<td>365</td>
<td>286</td>
<td>651</td>
<td>7.65</td>
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</tbody>
</table>
DISCUSSION ON "COAL TESTS FOR MELBOURNE CITY COUNCIL."

A Paper read before the V.I.E., on Aug. 1st, 1894, by Mr. GEORGE HIGGINS

Mr. A. C. Mountain, said these tests were of special interest at the present time, and he hoped the discussion would be prompt and succinct. Speaking in general terms so far as the test is applied, it has come out very favourably to Victorian coal, and the results had confirmed some tests made by himself some months ago, and above all, a discussion on this subject by the Institute should tend to remove that public feeling which was so manifest, and he was sorry to say supported by a section of the press, that an engineers' report, when given against the commercial interests, no matter how scientific, was condemned as inaccurate and incorrect, and unfortunate as this disposition on the part of the public is, the only conclusion to be drawn was that the engineer was a gentleman who had to be sold to the highest bidder. He wished, with regard to this particular test, which had as usual been discredited by a certain section of the public, to state that as he happened to witness the whole thing, he was sure nothing could be more fairly and thoroughly carried out within the limits of the tests applied. From start to finish Mr. Higgins had not left the boiler house for two minutes, even having his meals brought to him there. It was just about as fairly and thoroughly carried out as any test could possibly be.

Professor Kernot said he would like to know whether a chemical analysis and also calorific value (by Thompsons' calorimeter) had been taken with these tests? A chemical analysis was necessary to have a thorough test. He was a little surprised to see the Southern coal come out so well, as he always believed that Newcastle coal was superior. There was another gentleman present at these tests in the interest of the coal companies, Mr. J. T. Noble Anderson. Did Mr. Anderson agree with the results as obtained by Mr. Higgins.

Mr. G. Higgins: He agreed with the results, but differed in his interpretation of them.

Professor Kernot: It was to be regretted that the trial took place when the boiler was much underrated, as it detracted from its value when the boiler was pushed to the utmost. It did not follow that the results obtained when working at half capacity, would be the same as when working at full capacity. Was it proposed to have another test, when the boilers were working at full capacity.

Mr. A. C. Mountain: Ao.

Professor Kernot.—It seemed also strange, though he did not wish to doubt the accuracy of the test, that the coal which contained the greatest amount of non-combustible material, was the coal that evaporated the most water.

The coal that gave the least result was the one which was most entirely burned, so that it was quite opposite to what one might expect.

Mr. Phillips said there were many firms now burning Victorian coal, but most of them have confined themselves to one particular class, as Mr. Higgins had experimented with several different classes of Victorian coal, as well as Newcastle and Southern, had he not formed an opinion on the best class of firegrate to be used for the Victorian coal, and did he not
think a different class of firegrate was necessary for Victorian coal to that usually used for Newcastle coal?

Mr. A. C. Mountain—with regard to that question it was placed before the gentlemen who were looking after the interest of the coal companies at the tests, and had they expressed any objection to the type of firegrate being used, they were prepared to make any modification in the construction of the grates asked for, but no objection was raised and at the present time they were using the same grate with Victorian coal.

Mr. J. Sinclair Pirrie said he thought the committee were fortunate in having the tests carried out under the superintendence of Mr. Higgins and the results obtained by him could be taken as thoroughly reliable. He should like if possible to get the actual evaporation per lb. of coal in daily work, with this Victorian coal as now being used at the Electric Lighting Station, and compare it with the trial? With regard to the temperature of gas in the flues, he believed the gauges were fitted, and he should like to know whether any observations were taken and whether they would be found in the report. As Mr. Arnot's paper on the city lighting of Melbourne was to be read on the 15th inst., it would be interesting to know and remember these figures. He could not agree with Professor Kernot that the coal showing the greatest amount of ash and residue should give the least amount of heat, and for this reason, if they took brown coal, there was practically no residue left. The question in the long run simply amounted to this: One coal costs so much per ton, another so much what was the cost of any one coal required to do a certain amount of work, and that is the practical value of each coal per ton. As the boilers with which these tests were made would no doubt be fully described and discussed in Mr. Arnot's paper on the 15th inst., he suggested that the discussion be adjourned till that date and carried on in conjunction with Mr. Arnot's paper.

Mr. Stone would prefer to postpone his remarks on the subject till the adjourned discussion, but he should like to ask did Mr. Higgins make any test with regard to priming, and if so to what extent and with what result? It seemed to him a matter of very great importance for calorific values or chemical tests to be made, and unless these were done, it was impossible to compare these tests with tests taken of other samples of coal. Other people's tests may give slightly different results, and unless they knew the chemical composition of the coals, it was impossible to say whether the coals were different or whether the tests had been carried out differently. The figures given by Mr. Higgins could only be regarded as to the actual quantity of coal consumed in the tests, as it did not follow they could get any number of tons of coal to give the same result: the question was, was it the coals or the methods that differed. Professor Kernot had called attention to the fact that Mr. Higgins had conducted the tests with the boilers working at half power; the question then arose, what was the most suitable rate of combustion at which to conduct the tests. If the boilers worked at a full load, a less percentage of evaporation per pound would be obtained.

On the motion of Mr. Pirrie, the further discussion was adjourned till the 15th inst.
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 hardly 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 value 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 Sulzer 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, regretted 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 registered 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 flue 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 brick work 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>Commercial value per ton.</th>
<th>Commercial value per ton.</th>
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<tbody>
<tr>
<td>15s.</td>
<td>14s. 3d.</td>
</tr>
<tr>
<td>14s. 6d.</td>
<td>19s. 7d.</td>
</tr>
<tr>
<td>19s. 6d.</td>
<td>17s. 1d.</td>
</tr>
<tr>
<td>17s. 6d.</td>
<td>16s. 6d.</td>
</tr>
<tr>
<td>16s. 6d.</td>
<td>17s. 5d.</td>
</tr>
<tr>
<td>17s. 5d.</td>
<td>19s. 3d.</td>
</tr>
<tr>
<td>19s. 3d.</td>
<td>14s. 3d.</td>
</tr>
<tr>
<td>14s. 3d.</td>
<td>15s.</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></th>
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<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>15s. 8d.</td>
</tr>
<tr>
<td>Jumbunna</td>
<td>108</td>
<td>15s. 10d.</td>
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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 incombustible 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
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, to 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.
COAL TESTS AND ELECTRIC LIGHTING.

lbs. of water per lb. of coal, or 11030 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 boiler on the next night. If this be so it will pay to keep the cylinders hot. My remarks have been made with a view of 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 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 idiosyncracies 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 engineersubjects 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 a paratus 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 15th and 14th of April with Newcastle Coal:

- 10 p.m. — Flue temperature machinery 100° — Draught same place, 50°
- 3 a.m. — Flue temperature machinery 150° — Draught same place, 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 gases 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 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 conscientious 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 combustion, 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 interesting 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 unfortunate 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 priming? 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. Considering 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
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 overestimated. 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
ELECTRIC LIGHTING.

the Metropolitan Board of Works require that their plant shall give the
stipulated duty with coal having a given calorific value, and that they pro-
pose 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 care-
less 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
\( \frac{1}{100} \) 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 \( \frac{1}{100} \) 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 prac-
tical 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 effi-
ciency 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 sur-
prised to find that Mr. Arnot had adopted the Thomson Houston dynamo
for Melbourne. It certainly stands, on suffranc, 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
deidedly 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. Alcock Electric Light Company. Dynamos of this type have the
advantage, both theoretically and practically, over the open coil type at
every point, with exception of the mechanical simplicity of the commutator. 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 an e.m.f. as high 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 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 voltmeters 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 obstruct 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
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 advantages 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 some 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: "Considerable 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, with-
out 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 dis-
cussion 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 this carefully
LLECTEIC LIGHTING.

9

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 same 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 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 navi-
gators 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.
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