

Discussion.

The President. The PRESIDENT, in moving the vote of thanks to the Author, remarked that he intended to adhere to the rule he had laid down for himself when taking office, and would avoid the temptation to anticipate the discussion; but he wished to say that it was not usual for The Institution to receive from one of its junior Associate Members a Paper of the standard of that before the meeting, dealing so efficiently with a subject of great importance to the engineering world generally. He would like, on behalf of The Institution, to congratulate the Author on the work he had put before the members that evening. The Author was apparently working in a direction which involved a great many interesting problems, and he felt sure the members would be benefited if the Author were able, as his experience ripened, to bring the subject before them again as years went on.

The Author. The AUTHOR, in describing some lantern-slides, remarked that in the test described there was bound to be a certain amount of approximation. The test had not been carried out with a view to the analysis which he had attempted to apply to it, and it was not absolutely complete for the purpose for which he had used it. He hoped that in the near future tests would be carried out on other engines, notably the one at Walton, of the Metropolitan Water Board, when perhaps it would be possible to obtain more accurate results, even though calculated by means of differences. He hoped that a too literal interpretation would not be put on the decimal figures of his losses, in view of the fact that the test was not really made *ad hoc*. The guarantee was for steam at 190 to 195 lbs. per square inch pressure and 75° to 100° F. superheat, compared with the test figures of 181 lbs. per square inch and 124° F. superheat. Those two sets of conditions, however, represented identically equal availability under the condenser conditions obtaining at Lea Bridge; and, although the results of the test had not been got under precisely the same conditions as those on which the guarantee was based, they had been obtained on equivalent conditions.

Mr. Smith. Mr. ROGER T. SMITH remarked that, as a pupil of Messrs. Hathorn, Davey & Company, who made and erected the pumping-engine described in the Paper, he had assisted in the erection of the first pumping-engine they put up at Lea Bridge 37 years ago. That

engine pumped from a deep chalk well and was arranged for both Mr. Smith. sinking and permanent pumping. While he was there it generally ran at one stroke in 3 minutes. A pump arranged in that way could not possibly be efficient as a waterworks pumping-engine, so far as its consumption of coal was concerned. The economic reason for the arrangement was that it saved pumps in the first case, and, secondly, at the moment the well was sunk, the permanent pumping was ready to begin. So far as he was aware, the Paper was the only one in the English language in which an attempt had been made—and a very successful attempt—to assign in the case of a steam pumping-engine values to the various losses which made up the differences between the efficiency of the perfect engine and the actual efficiency. By means of the entropy-diagram that analysis had been fully and convincingly worked out. It was doubtful whether the gain in steam-economy to be obtained by increasing the working range of the steam, as proposed by the Author, would be justified. He did not mean that it was not possible to improve the efficiency of the engine in that way, but it was necessary to take into consideration the troubles in the boiler-house and the extra expense in labour and maintenance on boilers working with pressures as high as 350 lbs. per square inch. He endorsed what the Author said, that *for its size* the modern triple-expansion reciprocating pumping-engine was in terms of £. s. d. easily the most economical engine for converting the heat of fuel into work. A pumping-engine of 500 HP. would be considered big, but the steam-turbine did not attain the same efficiency until it was of at least ten times that size in output. The steam turbine was the more economical the higher the vacuum, but it was doubtful if it paid to run the reciprocating engine with as high a vacuum as was maintained at Lea Bridge. It was probable that any vacuum above 26 inches of mercury was not worth the getting, partly because of the very large size of the low-pressure cylinder (and its consequent extra radiation) which was necessary in order to use so high a vacuum. On the other hand, the waterworks, or sewage, or drainage pumping-engine was unique in providing itself with ample condensing water, and the money spent in obtaining the vacuum was almost negligible. He thought the Author might legitimately have claimed, as one of the intrinsic economies of the waterworks pumping-engine, that the condensing water cost nothing. The possibility of an ample supply of water generally decided the site of a large electric power-station; and the pumping of what was the equivalent of a small river through the condensers, the necessary training works, and means of cleaning the water, were

Mr. Smith. often very costly. In Table IV the fuel charges and the capital charges on plant alone were compared for test figures—not running figures—either actual or estimated, for various sorts of pumps and pump drives. Since in most cases the figures taken were estimates, he preferred to compare the Lea Bridge pump, as it might be made for an electric drive with a higher speed and therefore smaller pumps, with the actual results of the test of the Lea Bridge engine. The Author assumed the cost of electricity to be 1*d.* per unit for a load-factor of 91 per cent. The average selling-price in 1925 for all the power-companies in this country, however, was 0·9*d.*, with a load-factor ranging about 30 per cent., and any power-company in this country, if asked to supply electricity for a load-factor of 91 per cent., would be able to do it at $\frac{1}{2}$ *d.* per unit, most of them at 0·4*d.* per unit. Assuming that at Lea Bridge there was a smaller pumping-engine driven by a three-phase motor through gearing, the average cost throughout the year—not a special test figure—of electricity corresponding to the coal per horse-power-hour would be 0·84*d.* with electricity at 1*d.* per unit, 0·42*d.* with electricity at $\frac{1}{2}$ *d.* per unit, and 0·33*d.* with electricity at 0·4*d.* per unit. Secondly, the real gain in the case of electric drive lay in just those figures which the Author had omitted from Table IV—the cost of labour and the capital charges, not only on plant but also on buildings, to which must be added rates, taxes, maintenance and management. If he understood the Author's method of calculating capital charges, which appeared to come to about 6 per cent. on the Lea Bridge engine, that pump would cost about £30,000, and the foundations and buildings about £10,000. He would be very glad if the Author could give the actual figure. With electrically-driven pumps, the plant and buildings would be little more than a quarter of that figure, and the attendance charges one-quarter of the Lea Bridge labour charges, or even less if hand-fired boilers had to be maintained at the efficiency of 70 per cent. which the Author assumed. Without the labour charges, but including the whole of the capital charges, he claimed that in the neighbourhood of any power-company's distribution-system, the power-company selling electricity at 0·4*d.* per unit for that special case, the total working-cost, taken all the year round, of an electrically-driven pump would be about the same as that of the Lea Bridge pump. Taking into account the labour charges, the electrically-driven pump would actually show a slight saving over the steam-driven pump, and there would be the advantage of getting somewhere about the same total working-cost for an expenditure of one-quarter of the capital that was necessary to install the steam-driven pump.

Mr. A. P. I. COTTERELL observed that the figure given for steam- Mr. Cotterell.
consumption per pump horse-power-hour—10·6 lbs.—was extremely low and satisfactory, and, judging the plant by the coal consumed per pump horse-power-hour, the figure of 1·3 lb. was also very good indeed. A few years ago, when he was advising a corporation on new pumping-plant, he was told it was a retrograde step to recommend, as he did, the introduction of steam pumping-plant, instead of extending the existing suction gas-plant. The installation was to be equal to pumping at least 60,000 gallons per hour, or 1,440,000 gallons per diem, a total lift, including friction, of 413 feet, of which 135 feet was lift from a borehole by borehole pumps and 278 feet the head from the surface tank to the reservoir. He made a careful comparison between the cost of steam pumping-plant, similar to that described in the Paper, and of a suction gas-plant of the same capacity. He assumed the suction gas-plant to be fitted with a rope drive to a counterbalanced borehole pump, and to work horizontal three-throw ram pumps. The annual cost of the steam plant, apart from capital outlay, per actual pump horse-power worked out at £13 10s. 10d., as against £15 12s. 9d. for the suction gas-plant. An estimate of running-costs, including capital charges and loan repayments over a period of 15 years, showed that there was practically no difference in annual outlay between the steam plant and the suction gas-plant, but, of course, the steam plant had the advantage that its life would undoubtedly be much longer. He had seen plants 50 or 60 years old still in use and apparently in good mechanical condition, but they were so obsolete so far as their consumption of steam was concerned that on that ground alone it paid to renew them. The corporation to which he had referred had adopted his recommendation and put in a steam plant constructed and erected by the Author's firm. After the plant had been in service for a few months, a test was carried out by Professor Andrew Robertson, Assoc. M. Inst. C.E. The results obtained were not as good as those given for the Lea Bridge engine, but they were more than equal to the makers' guarantee. The steam-consumption per pump horse-power-hour was 12·04 lbs. per hour, the mechanical efficiency was 91·7 per cent., and the coal-consumption per pump horse-power-hour was 1·68 lb. The superheat was 123° F., and the actual steam-temperature on the engine side of the stop-valve was 502·8° F. Fig. 3, Plate 4, showed that the high-pressure and intermediate-pressure diagrams overlapped. Was that overlapping area included, or was it regarded as lost? With regard to improvements possible by increasing pressure and superheat, he agreed with Mr. Roger

Mr. Cotterell. Smith in doubting whether it was really possible to obtain higher efficiency by increased superheat. A test¹ of the pumping-engines at Hamburg, erected, he believed, in 1922, provided an interesting comparison. Those engines were not quite of the same type as the Lea Bridge plant, but were very nearly comparable. The temperature at the stop-valve ranged from 572° F. to 662° F. The steam-consumption per indicated horse-power-hour ranged from 10.36 to 10.67 lbs. The mechanical efficiency appeared to be about 90 per cent., which would give a steam-consumption of about 11.7 lbs. per pump horse-power-hour. He would like to hear the Author's further comments on that, because his own impression had been, until he saw those figures, that improvement by reduction of loss in the prime mover in question would lie in the direction of increased superheat. With regard to the useful comparison the Author had made in Table IV, he agreed that the cost of electricity had been put rather too high. In the case of the comparison he had made between suction gas and steam plant, the cost of fuel for suction gas was 31s. per ton, and for the steam engine 23s. per ton, with a calorific value of about 14,000 B.Th.U. per pound. For large units steam still held its place and was likely to continue to hold it. There were cases where another type of plant could be usefully employed, even with a large unit, but only under special conditions. For smaller units, however, and especially for distinctly small units, the other types referred to in Table IV would be better than, or quite as good as, steam. The last had not been heard of the crude-oil engine. His own impression, however, was that the use of steam for the pumping of water was not yet by any means antiquated.

Mr. Bryan. Mr. B. W. BRYAN observed that in the Lea Bridge test the weight of coal used per pump horse-power-hour was 1.3 lb. The coal used was Nixon's Navigation Welsh large steam. He thought the price of that coal in bunker would not be less than about 38s. per ton. That would make a cost on the test of about 0.265*d.* per water horse-power-hour with an admittedly superior class of coal. The Author showed a price of £1 per ton for coal of 13,000 B.Th.U. per pound, and there was no doubt that in the vicinity of the coal-fields that would be correct. On the other hand, in London coal cost more. He had some particulars of actual running-costs of triple-expansion engines taken over a period of 16 years, finishing in 1925. The plant was a triple-expansion engine in duplicate,

¹ *Zeitschrift des Vereines deutscher Ingenieure*, vol. 68, p. 277. "Engineering Abstracts," No. 20, p. 132.

working well-pumps through gearing. The maximum power of each engine was about 190 B.H.P. There was no superheat and there were no economizers. The continuous water horse-power throughout the whole 16 years was 159 HP. For a considerable period the two engines would be running a portion of the day together. One of them might be said to have run continuously, with a few hours intermission, throughout the 16 years. Coal cost 0·397*d.* per water horse-power-hour ; wages, 0·251*d.* ; maintenance, including repairs, 0·033*d.* ; and stores of all sorts, including gas for lighting the station, 0·030*d.* ; making a total of 0·711*d.* per water horse-power-hour throughout the whole period. The average weight of coal burnt throughout the year was 1,714 tons, and the average cost, including cartage, was 26*s.* 11½*d.* a ton. The coal used per water horse-power-hour was 2·75 lbs., and the duty per 112 lbs. of coal was 80·5 million gallons. It was interesting to compare that with a 100-B.H.P. suction gas-plant over the same 16 years. The continuous water horse-power, however, was only 25½ HP. The engine ran 10 to 15 hours a day, so that conditions were not conducive to economy. The maintenance cost 0·15*d.* per water horse-power-hour, and the stores 0·12*d.* The maintenance was therefore about five times as high, and the stores about four times as high, as was the case with the steam plant. The water horse-power of the steam plant during 1925 was 136 HP., and the cost of coal for that year was 24*s.* 11*d.* a ton ; in other words, it was 2*s.* cheaper than the average for the 16 years. The reason for that was that towards the close of the war, and for 4 years after the war, the undertaking with which he was connected was buying extremely expensive coal and at the same time developing the maximum output of which its station was capable, because the war had precluded development of its other works. When coal prices were at their maximum, the pump horse-power was about 260 HP., as compared with 135 HP. for 1925—a very high load-factor thus coinciding with very high coal-prices.

Mr. H. E. STILGOE remarked that, having regard to the fact that the engine in question had been constructed for the Metropolitan Water Board, of which authority he had the honour of being the Chief Engineer, and also in view of the fact that the Author's firm were constructing other and larger engines for the Board's Walton works, he was somewhat diffident about entering upon a discussion of the Paper. It might be of interest, however, if he gave a few particulars of the operation of steam pumping-engines. The Board had one hundred and fourteen groups of engines, some containing one in a group and some two or three. He had, therefore,

Mr. Bryan.

Mr. Stilgoe.

Mr. Stilgoe. an opportunity to compare the work of various engines. In selecting a type of engine for a particular class of work, consideration had been given to the circumstances under which the engine was going to run. Some of the engines ran for more than 90 per cent. of the time, and naturally had to be selected with a view to their efficiency for work of that kind. The engines which were now being constructed by Messrs. Hathorn, Davey & Company for the Walton works were of 945 pump HP. Those engines were practically completed; in fact, they had been under steam. It had been found that the triple-expansion engine of the type at Lea Bridge was the one most suited to pumping day in and day out throughout the year, when the plant had to be of 250 HP. and

TABLE V.—OPERATING COSTS FOR YEAR ENDING 31 MARCH, 1925.

Engines.	No. of Units.	Type.	Power Per Unit.	Water Pumped Per Unit.	Cost Per Pump Horse-Power-Hour : Pence.				
					Coal.	Wages.	Repairs. ¹	Stores.	Total.
Riverdale (Hampton)	3	Triple expansion	510	9	0.47	0.15	0.06	0.20	0.70
Moreland's	2	Compound	510	9	0.46	0.22	0.17	0.04	0.89
Nos. 13, 14 and 15 (Hammer-smith):	3	No. 13, compound . . .	195	3	0.35	0.26	0.10	0.04	0.75
		No. 14 and 15 triple expansion . .	430	7 and 10	..	..	..	..	..

¹ Including wages and materials allocated to repairs.

upwards, and also when it was necessary to pump up to heads exceeding 150 feet. He thought that the Board had as complete a record of working-costs as was kept by any undertaking in this country. They had the figures of cost in respect of practically every engine. In one or two instances there were two or more engines in a group, and the cost could not very well be separated for each engine; so, being of similar type, the engines were taken together. He thought Table V would be interesting in respect of engines in operation for a great number of years. The Riverdale engines—which were constructed 27 years ago—had been running for 97 per cent. of the year. He had been told that during the war one of those engines ran for 4 years, day, night, and Sundays, without stopping. They had required very little repair, except that 2 years

ago the cast-iron entablatures carrying the cylinders showed signs of slight cracking. Whether that was due to fatigue or vibration he could not say, but new entablatures had been put in. Those engines to-day were running as well as they had ever done. The Moreland engines were built 41 years ago. A new crankshaft was fitted to one of the engines and new main bearings to both, which accounted for the higher figure (0.17*d.*) for repairs executed during the year. Complete records were kept year by year in tabular form of the performance of each engine. The various engines were classified in order of merit, by districts and by types, in order of total cost per pump horse-power, in order of actual fuel per pump horse-power, and in order of duty corrected to coal of 15,000 B.Th.U. quality, and so on. That method of keeping statistics gave a good opportunity to ascertain what type of plant was most suitable for each type of work. Whether the number of hours worked was taken into consideration, or the capital cost, or any other factors, he was able to arrive at an estimate of the best type for any particular purpose.

Mr. ARTHUR HONEYSETT observed that he had had considerable experience of the kind of engine described in the Paper, having during the last 20 years assisted in the installation of nine such engines of powers ranging from 150 to 450 water HP. and pumping against heads of 55 to 390 feet. The total power exceeded 3,000 water HP., and the combined capacity of the pumps was 88 million gallons per day. This type of engine was chosen in the first place, 20 years ago, after careful inquiry as to the merits of the different forms which were then obtainable. The result of that inquiry was that the type of engine in question was found to present advantages over all others as regarded both first cost and economy in working. Subsequent experience had fully justified the choice. The engines were still working and were apparently as good as ever. They had been maintained in repair by the ordinary engine-staff, and no events had occurred calling for the intervention of the makers. The cost of repairs averaged 40*d.* per million gallons pumped, equivalent to 1 per cent. per annum upon the capital value of the engine. The steam-consumptions guaranteed were 13 lbs. per pump horse-power-hour for the low-lift engines (55 to 70 feet) and 11.9 lbs. for the high-lift engines (188 to 390 feet). These figures had been well maintained, a consumption as low as 10.7 lbs. having been noted on some occasions with the high-lift pumps. This was in striking agreement with the Author's figure of 10.6 lbs. He had recently had the opportunity of testing the

Mr. Stilgoe.

Mr. Honeysett

Mr Honeysett. slip of some of those engines, after about 15 years of continual work, by counting the revolutions necessary to fill up a reservoir of known dimensions and comparing the quantity of water stored with the displacement of the pump-plungers. The result was a slip of 2 ± 0.3 per cent., the maker's guarantee having been 3 per cent. He was in agreement with the general result given in Table IV as to the relative economy of the various methods of pumping, but he suggested that the Table did not tell the whole story, since the load-factor of the pumping-plant was not considered. If all the machinery were to work 24 hours per diem, there would be nothing to be said against the figures, but such was seldom the case, and in pumping for water-supply purposes it was generally very far from the truth. It was, therefore, not the sum, but the ratio of expenditure upon capital to that on fuel which was of importance. As the load-factor diminished, the relative merits of a cheap but inefficient centrifugal pumping-plant came more and more into evidence, resulting in an entire superiority when the extreme case of a purely stand-by unit was reached, since this was seldom or never brought into use, and its high fuel-consumption was of but little importance. He had recently had occasion to look into this question in considerable detail, as it had become necessary, in one of the pumping-stations he had referred to, to increase the pumping power by bringing into use the engine which until then had been regarded as a stand-by. It then became necessary to install a new stand-by engine, and, on account of the improvements which had of late years been effected in centrifugal pumps, turbines, electric motors, and high-speed engines, attention was naturally directed to the employment of some such device in place of the continued use of the highly efficient but also very expensive reciprocating engines of the class which the Author had described. Careful estimates were made, based upon thoroughly reliable information, of the total cost of pumping by each of the following methods:—(1) High-class reciprocating engines; (2) centrifugal pumps and turbines; (3) centrifugal pumps and high-speed steam-engines; (4) centrifugal pumps and motors taking electricity from the public supply; and (5) centrifugal pumps and motors driven by electricity specially generated. A simple method of determining the relative merits of any scheme was to calculate the number of hours which the cheap but less effective machine must run per annum for the total annual cost to become equal to that of the dearer but more efficient machine. The higher the figure so obtained, the greater was the overall economic merit of the scheme. Thus, if the triple-expansion engine described in the Paper were taken as the standard, and

the best of each of the other combinations were taken, the result Mr. Honeysett was as follows—

2.	Centrifugal pump and turbine	hours 1,330
3.	„ „ „ high-speed engine	„ 1,030
4.	„ „ „ public electricity (a.c.)	„ 600
5.	„ „ „ private electricity (d.c.)	„ 360

Thus, when a centrifugal pump was used, a steam-turbine formed the best means of driving it, and such a combination was more economical than a high-class reciprocating engine, so long as the time which it had to work did not exceed 1,330 hours per annum. For any longer period the lower coal-consumption of the high-class engine more than balanced the greater charge for interest. The figures on which the foregoing conclusion was based were shown in the following Table—

QUANTITY OF WATER PUMPED.	
330,000 gallons per hour to	188 feet
363,000 „ „ „ „	62 „
Total W.H.P. 426·66.	
Cost of engine.	£18,000
Cost of steam	26 lbs. per penny
Steam per water horse-power-hour	11·8 lbs.
Total steam per hour.	5,100 lbs.
Cost of steam per hour	212 pence
Cost of steam for 1,330 hours	£1,170
Amortization for one year at 1½ per cent. }	1,170
Interest for one year at 1½ per cent. }	—
	£2,340
Cost of turbines	£6,000
Steam per water horse-power-hour	18·71 lbs.
Total steam per hour.	8,200 lbs.
Cost of steam per hour	342 pence
„ „ „ for 1,330 hours	£1,895
Interest for one year at 5 per cent. }	450
Amortization for one year at 2½ per cent. }	—
	£2,340

The cost of keeping the machinery in repair was omitted in both cases, as it was assumed that it would be proportionate to the work done, and therefore not materially different in the two instances. The case investigated was for machinery installed in a foreign country where fuel was expensive. In this country the comparison would be more favourable to turbines, and the result was also greatly affected by the size of the plant, since large turbines were much more economical than small ones. For instance, if the cost of fuel were one-half that which he had assumed, and if the cost of transport

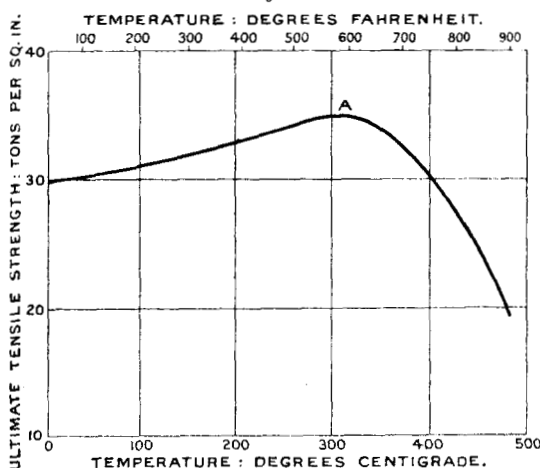
Mr. Honeysett. were deducted from the capital charge, the figure of 1,330 hours would be increased to slightly more than 2,000; and further, if the size of each unit were doubled, the figure would become 3,750 hours. The last was rather an extreme case, but not an impossible one, and it might therefore be taken that the superiority of the triple-expansion engine was always apparent when the load-factor exceeded 40 per cent., but was not likely to be apparent when it fell below 15 per cent. Increases proportionate to that from 1,330 to 2,000 would apply to the other examples, including the electrical pumping, since the cost of electricity in the locality to which the estimates applied was about double that prevailing in this country. In cases (3) and (4), however, no increase of importance would take place as a result of doubling the size of the units.

Mr. Thwaites. Mr. R. A. S. THWAITES observed that, in comparing the cost of the plant used at Lea Bridge with electrically-operated plant, the Author made certain comparisons based on electricity at 1*d.* a unit for a 90-per-cent. load-factor. The Author came from Leeds, and therefore Mr. Thwaites had taken the Leeds maximum-demand tariff and had found that for the last three examples given at the bottom of Table IV (p. 237) the price per unit, according to that tariff, came out, not at 1*d.*, but at 0·475*d.*, 0·5*d.*, and 0·375*d.* per unit respectively. That gave an average total cost, including capital charges, as compared with the figures given by the Author, of 0·544*d.*, 0·572*d.*, and 0·33*d.* per water horse-power-hour respectively. There were two matters in regard to the cost of steam on which he thought the Author had taken a somewhat optimistic view. A boiler efficiency of 70 per cent. seemed high for the conditions in question. Mr. David Brownlie had recorded¹ that tests on 88 boiler-plants with mechanical stokers and more than 300 plants which were hand-fired showed a boiler efficiency, including superheaters and economizers, of 60 per cent., which he thought would be a fairer figure. The Author also had assumed rather a low price for coal, seeing that most pumping-plants were a good distance from railway-stations or sidings; 23*s.* per ton would be a fair average price, and if a correction were made on those accounts, the total costs per water horse-power-hour for the steam plant shown in Table IV (pp. 236-7), should be 0·445*d.*, 0·64*d.*, 0·54*d.*, 0·34*d.*, and 0·47*d.* respectively. The average of those figures gave 0·48*d.* for steam plant, which was the same as that given by Mr. Thwaites for electricity; but, in addition to that, as had already been pointed out, the Author omitted the very items which were in favour of electric driving,

¹ Proceedings Inst. Mech. E., 1920, p. 263.

namely, buildings, foundations, repairs, maintenance, and labour. Mr. Thwaites. He thought, therefore, that the Author was a little sweeping in his statement that there was no real competitor with the triple-expansion engine in the field of pumping. In support of this, Mr. Thwaites might state that the power-company with which he was associated had recently made two large contracts for supplies of electricity for water-pumping, one for 24 hours a day, and the other for 8 hours a day. He was convinced that electricity would prove a very serious rival to the steam pumping-engine, whether for short-period use, or for continuous pumping. The main reason was that with generating sets of 15,000–20,000 kilowatts, the standing charges per horse-power were only a fraction of the corresponding charges for a steam pumping-plant.

Fig. 9.



The PRESIDENT observed that the Author mentioned a proposal The President. to use a pressure of 350 lbs. per square inch and a superheat of 264° F. He wished to allude to the knowledge which had been gained as to the behaviour of steel at the high temperature—approaching 400° C.—involved in boilers operating under such conditions. Taking, for example, a 30-ton steel, Fig. 9 showed that it was perfectly safe up to, but not beyond, 400° C., which was about the equivalent of 500 lbs. per square inch pressure and 250° F. superheat. Now that very much higher pressures and superheat temperatures were being adopted, engineers, in calculating boiler stresses, must realize that at point A of the diagram the strength of the material began to be adversely affected by the superheat temperature.