Discussion.

Mr D. F. J. Harricks, in continuing the discussion, said that he thought Mr Moffat's paper was very opportune, for, although "Superheat" was becoming more and more prominent, listening to a paper on the subject and seeing various illustrations portrayed on a screen, probably brought the matter more closely under the notice of members than reading articles upon the subject in the technical journals and enlightening oneself as opportunity offered.

To the lay mind a glance at a Woolf or other similar plant would very likely bring forth the remark that it was "too complicated," but to the technical mind a glance was quite sufficient to impress the fact that it was a very good example of clever engineering and heat conservation.

To a great extent the engineering world was indebted to the Germans in this matter, for their enterprise and scientific application had done much towards bringing it to its present state of excellence. He did not, of course, wish to infer that super-heating steam was a new thing, for, as far back as 1857, it was known that William Penn had adopted the practice for his marine engines, but, with the increase of steam pressures, trouble was met with in the packings and lubricants, whilst, furthermore, the adoption of compounding provided a source of economy that temporarily shut out the general adoption of super-heat. With the production of successful packings and lubricants, which remained efficient at the high temperatures due to super-heating, it was again rapidly coming to the fore, and, although engineers were not adopting super-heat for stationary and marine plants to anything like the extent that they were in locomotives, it seemed only a matter of time when a greater realization of its benefits would eventuate.

At many meetings of this Association certain members had declared themselves to be "Steam Engineers," and as this remark was usually made as the result of some claim for the economy of internal combustion engines, it must be very gratifying to them to have noticed the very high degree of economy obtained with the super-heat plants dealt with in the paper, and when it was realised that from 15/20 B.H.P. could be obtained for the expenditure of one penny worth of fuel it must be at once admitted that they were serious competitors against suction gas and other prime movers of a similar kind. It seemed evident that not a single detail of any real economical value had been neglected in the "Locomobile."

Why was it that, although British manufacturers of this class of plant were producing very economical machines their results had not seemed to reach the very high degree of efficiency that the Continental makers had? Was it because of what was often termed "British solidity" they sacrificed some efficiency for greater reliability By this remark he had not meant to infer that the Continental plants were flimsily constructed, but that in order to obtain the greater efficiency makers such as "Woolf" proportioned their super-heaters so that they were more important in relation to the whole plant than in the British designs. As the study of super-heated steam was, in some respects, more intricate than that of saturated steam, it was probably unfair to make a somewhat casual criticism of the respective merits of the plants. It seemed to him, however, that the British plants had not gained the highest results because rather less reliance had been placed on the super-heater details, and the complete outfits had been designed of such proportions that if an accident happened to the super-heat portion the boiler was still capable of producing sufficient saturated steam to keep the plant going. It would doubtless be said that the super-heater was of such simple construction that it was not likely to get out of order, but the fact remained that it was practically a second boiler, consisting of many bends and joints, which, of course, were at all times liable to cause trouble.

Could the author tell them why Woolf specially adopted the arrangement of steam cylinders over the smoke box, whilst practically all of the British makers and also well-known German makers, such as Stump & Lanz, fixed the cylinders at the fire box end of the boiler. Woolf's object was evident, viz: the surrounding of the steam cylinders with the waste gases in order to reduce the cylinder losses, but the majority of other firms had not adopted this idea. Had the author any figures to show the relative merits of jacketing the cylinders with hot gases as in the case of Woolf, as against steam jacketing as adopted by most other makers?

Mr W. Sinclair remarked that upon looking at the general design of the Locomobile the first thing that occurred to him was that the design of the plant was daring. Heat was no doubt saved greatly, and he thought it would be somewhat out of place for him to criticise too closely a machine, or rather prime mover, with which he was unfamiliar. It was comparatively new to them, and there was this to remember that the Makers of the apparatus had given years of study and consideration to the design, the mixtures of metal, and other details. He would, however, have liked more information on several matters. First, there was the important item of water. In N.S.W. they had many waters largely charged with minerals and solids, and in their ordinary Colonial type boilers, with low pressure and temperatures, they occasionally had trouble. What would occur then with high temperatures and pressures such as were employed in the super-heated locomobile type?

Then with regard to lubrication, had graphite ever been used in the cylinders, and with what results?

Had the super-heat tubes given trouble when no steam was passing through them; for instance, when steam was being raised?

In replacing parts was any difficulty brought about by the use of the ordinary metals of commerce?

How were these plants lined and set up? He thought that the high temperature would be responsible for some distortion in the long lengths of the rods and other parts, and at a time of general overhaul was it necessary to wait until the plant was hot before making the final adjustments?

It was somewhat outside the scope of the paper, but he remembered a short time ago being aboard one of the Port Line vessels which had super-heaters in the boiler tubes, and he thought then what a mass of fittings were round the tube ends, and what would happen in the event of leaky tubes. Had the author any experience of this difficulty?

Mr James Shirra said that he admitted the tests of the type of engine put before them showed very economical results, but he would have liked some further explanation as to how they had been attained. They all knew that locomotive boilers gave remarkable economy and steamed well when the engine was running on the rails, but when such a boiler was installed as a stationary one, or put in a steamship, the economy was much less evident. Apparently the vibration of the running engine improved the steaming of the boiler, it made the steam leave the heating surfaces as soon as formed, and increased the circulation and steam production. Could the peculiar construction of this overtype engine have an analagous effect. The vibration caused by the engine being mounted directly on the boiler might make the latter steam more freely. But even if it did he would not think it was a wise plan to use the boiler as a bed plate for the engine. The boiler shell had stresses enough to bear in resisting the steam pressure, which might be as much as six tons per square inch of plate section, much more than anyone would put on the engine mechanism. He thought it was unfair to subject it to further variable and scarcely calculable stresses.

The overtype engine was simply a variation of the portable engine, which latter had been brought to great perfection by British engineers, notably Clayton & Shuttleworth, of Lincoln, and Garretts & Robey, who make the type now under discussion. Their portable engine had shown great economy on short tests, such as those made at the English Royal Agricultural Society's Shows. This special economy had been largely due to scientific firing—little and often—sprinkling the fuel well, and opening the fire-door only a few seconds at a time. With similar careful firing, the boiler of the overtype should do as well, and as the engine had a condenser, feed-heater, and other refinements, the whole plant should show even greater economy.

And of course something was due to super-heat; the thermodynamic advantage of super-heated steam had long been recognised. The Great Eastern had super-heaters, and several of the old P. & O. boats of fifty years ago; but they had to be given up because of the impossibility of keeping them in repair, the decay being principally due to the use of sea-water in the boilers which would "prime" into the heaters, and gave off free chlorine from the magnesium chloride, which ate away the iron as spirits of salt would. Now, with surface condensers and mineral oil lubrication, there was a chance for the super-heater again, but it was not favoured by marine engineers on account of the extra lubricant necessary for the valves, and consequent danger of burning the boiler by greasy deposits.

The most economical marine engines the speaker had read of were those of the "Inchmarlo," of Liverpool, a five-cylinder quadruple expansion engine, using steam of 250lbs. pressure, with a super-heater of small tubes in the uptakes. These engines developed 1 I.H.P. on .95lbs. coal per hour, and "La Rance," a French cargo boat also using super-heat, which did even better, or used only .9lb. coal per hour per I.H.P. This latter had lifting valves worked by cams, and if super-heating was to be a success something of this sort would be needed instead of slide valves, or even piston valves.

The engines described by the author had piston valves, and it was well known that the small piston valve was not particularly economical; it was impossible to secure steam-tightness. Nevertheless, the engine showed great economy, but the speaker considered that it would show as much if it was on a separate foundation from the boiler, there might be a shade more steam-pipe loss of heat, but if the pipe were well lagged it would be insignificant. This seemed the sole advantage of mounting the cylinder on the boiler; it was not a novelty; they knew the early boilers of Newcomen and Watt were sometimes made thus, the cylinder in or on the boiler. When space was very limited, the arrangement might be excusable, but when one had plenty of room, there seemed no reason to submit to the inconvenience. Both boiler shell and engine were very inaccessible; and while it might be a passable arrangement with gas or oil firing, with ordinary coal the dirt, wear, and nuisance caused by ashes and dust, must be highly objectionable, and would naturally much increase the running expenses of the plant in the item of cotton-waste alone. An exceptionally careful fireman would be needed to make the job run at all for any length of time, and naturally he would expect extra remuneration.

The speaker thought that while superheated steam might well be more used in stationary engines in the future. it would need to be in installations of a more rational type than this crowded and hard-to-get-at engine-and-boiler-in-one design.

The President, Mr. Julius, said that there was much of interest in Mr. Moffatt's paper, and that although the Wolff Locomobile was an old machine, it was certainly curious how little had been heard of it, until recently, outside Germany. Furthermore it was remarkable how few of their leading text books mentioned anything about the class of plant of which the Wolff and Garrett were examples and this was the more remarkable when the results that were undoubtedly obtained, and were so notably good, were taken into consideration. Especially was this the case when it was seen that the results were practically the same for the small as for the large machines.

He would like to compare the heat efficiencies of a Locomobile such as the Wolff with other recognised prime movers, and he had prepared a diagram which he would refer to later showing general data with regard to their relative efficiencies. Before doing so, he would like to again ask Members to refer to the results obtained in actual practice with the machines dealt with by the Author and which had been obtained in practice elsewhere. To these he would like to add the results of an actual trial made by himself upon a Wolff plant, and in Sydney. It would at once be seen that the figures obtained agreed generally with those obtained in the trials referred to by the Author, but he thought they would be of special interest, having been obtained under local conditions. The results of the tests referred to are given below:—

Wolff Single Crank Tandem Compound Engine Belt Driving and Generator.

Cylinders, 10½″ x 21″.
Revolutions, 180 per minute.
Boiler Pressure, 150 lbs. sq. in., i.e., 365° F.

Two Tests.	215 B.H.P.	275 B.H.P.
Duration	4 hours	4 hours.
Coal per B.H.P. hour	1.15 lbs.	1.14 lbs.
Calorific value	13.600 B.T.U.	13,600 B.T.U.
Water per B.H.P. hr	9.4 lbs.	8.2 lbs.
I.H.P.	232	288.5
B.H.P.	218	277.5
Mechanical Efficiency	94%	96%
Supht. Temperature	540°F. *i.e*, 175° Rise	550°F. *i.e.*, 185° Rise
Vacuum	25 inches	25 inches.
Feed Water Temp.	95°F.	96°F.
Mean effec. pressures	H.P. 77.3	82
	L.P. 15.5	23
I.H.P.	H.P. 125.5	132.0
	L.P. 106.5	156.5
	232.	288.5

The remarkable economy of highly superheated steam was a well-established fact. Schmidt's engines, tested by various authorities, and notably by Professor Ewing, provided a very clear demonstration. In one of these engines was fitted a superheater and intermediate re-heater, one of which was quoted by Prof. Ewing and actually tested by him. The boiler pressure was 140 lbs. per sq. inch and the steam was initially superheated to 720° F. The steam lost approximately 190° super heat before entering the first cylinder. Under these conditions the engine developed 184 I.H.P. and the steam consumption was 10.4 lbs. per I.H.P. hour. The same engine, when using saturated steam at the same pressure, consumed not less than 17.2 lbs. per I.H.P. hour. A somewhat larger engine, a 300 H.P., but of the same type, consumed only 9 lbs. of steam per I.H.P. hour. Prof. Ewing showed that at the temperature of superheat, 9 lbs. per I.H.P. hour was equivalent to 10.8 lbs. saturated steam, so that considering it only from a thermodynamic aspect the actual steam consumption with the saturated steam being 15 lbs. per I.H.P. hour, the high economy attending the use of highly heated saturated steam was very clearly shown.

Now again referring to the diagram mentioned above, and which was shown in fig. 18, it would at once be realised what a high position the Wolff type of plant held in relation to other well-known prime movers. It would be seen that of all the steam plants the Wolff type easily held pride of place with regard to the effective output, the percentage of effective work being 16.8 per cent., while, for the 10,000 Kilo-Watt Turbine, the 250 hp. condensing engine and the 250 hp. non-condensing, the percentages were respectively 15.5, 10.5 and 9.

These figures were very striking, and when it was shown that the comparison, so far, had been based entirely upon the effective output and that no consideration had been taken of the cost of fuel, it was still more remarkable. Considering

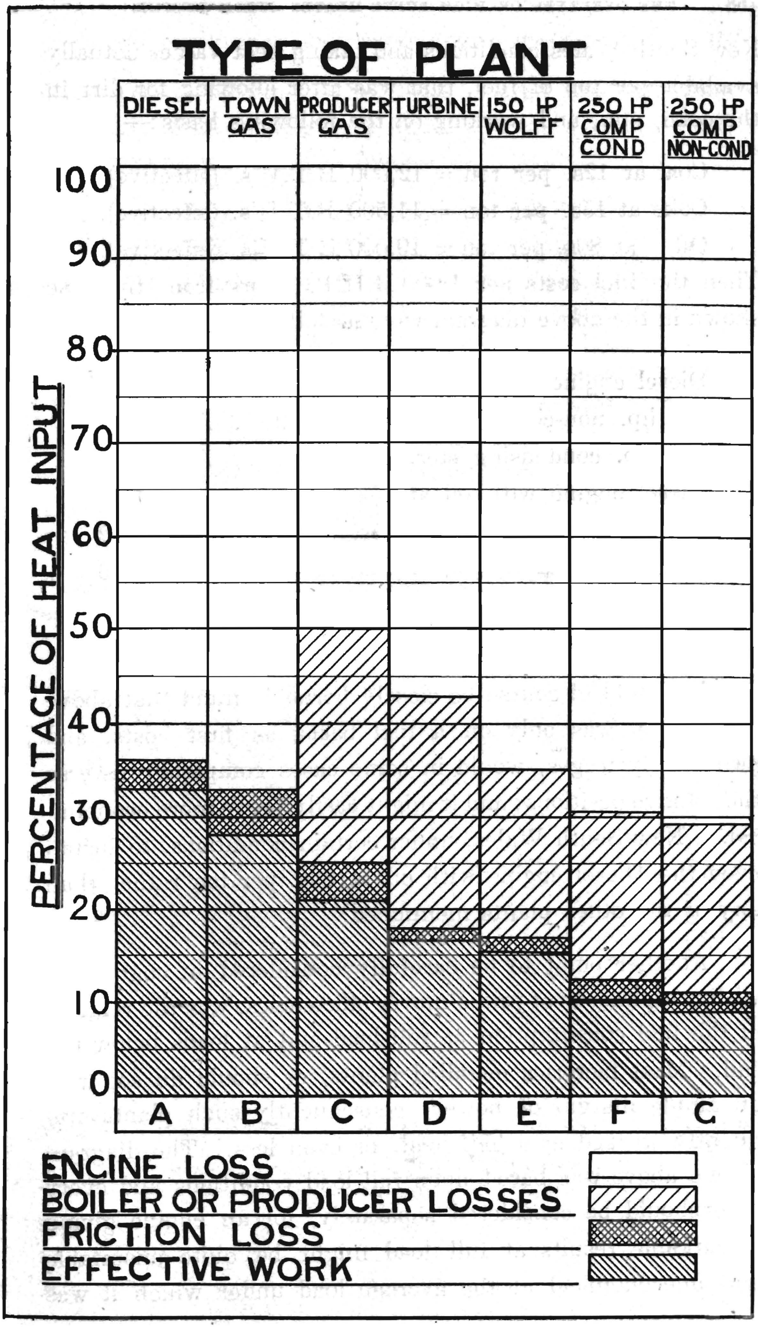
TYPE OF PLANT
DIESEL
TOWN GAS
PRODUCER GAS
TURBINE
150 HP WOLFF
250 HP COMP COND
250 HP COMP NON-COND
PERCENTAGE OF HEAT INPUT
100
90
80
70
60
50
40
30
20
10
0
A
B
C
D
E
F
G
ENGINE LOSS
BOILER OR PRODUCER LOSSES
FRICTION LOSS
EFFECTIVE WORK

Fig. 18.

New South Wales conditions and taking heat values actually available per ton of fuel, that was after allowing for dirt in the coke, etc., and working on the following basis:—

Coal at 12s. per ton = 12,000 B.T.U's. (effective).
Coke at 15s. per ton = 11,500 B.T.U's. (effective).
Oil at 80s. per ton = 19,000 B.T.U's. (effective).

Then the fuel costs per 1,000 B.H.P. hours from the case shown in the above diagram were as follows:—

	s.	d.
Diesel engine with oil at 80s.	14	6
250 hp. non-condensing steam plant	12	6
250 hp. condensing steam plant	11	0
Diesel engine with oil at 60s.	10	10
Diesel engine with oil at 45s.	8	2
10,000 hp. turbine set	7	6
200 hp. suction gas plant	7	0
200 hp. Wolff engine	6	8

It should of course be closely borne in mind that above comparison was only on a fuel basis, as first costs, and particularly wages, would in some cases completely reverse the relative positions; and it might easily prove more economical in New South Wales, under certain conditions, to install even the Diesel engine with oil at 80s. per ton rather than any of the other plants mentioned.

Another point to be carefully considered in connection with comparisons of prime mover efficiencies, was the relation of the fuel consumption at full load and at loads below the full. Most factories installed plants, or should do so, with an ample margin of power; consequently such plants frequently worked at a half load, or even less. The diagram shown above was based upon full load conditions and every case should be considered separately, for an engine giving remarkable results at full load might be quite unsuitable and uneconomical at the average load under which it was called upon to operate. The Diesel engine was somewhat remarkable in its economies at a half and three-quarter load, the average figures being as follows:—

.44 of lb. per B.H.P. hour at full load.
.46 of lb. per B.H.P. hour at $\frac{3}{4}$ load.
.51 of lb. per B.H.P. hour at $\frac{1}{2}$ load.
.72 of lb. per B.H.P. hour at $\frac{1}{4}$ load.

The percentage of increase therefore at $\frac{3}{4}$ load was only $4\frac{1}{2}$ per cent. and at $\frac{1}{2}$ load 25 per cent. It was seen therefore that at about $\frac{3}{4}$ load the loss in efficiency was extremely small. With steam plant similar results were obtained, and frequently even better than above shown. The reverse, however, was the case with producer gas plant, for, as the load was reduced, the loss in efficiency was even very much greater.

THE AUTHOR'S REPLY.

In reply to Mr. Harricks the Author said that he appreciated the kindly criticisms that had been put forward and which required but little further comment from him. He might mention, however, one question raised by Mr. Harricks with regard to the results obtained by the Continental Makers of this class of engine and which were more pronounced than those obtained by British Makers. The Author said that he hardly liked to go into this matter too deeply as it would bring commercial elements into the discussion which he thought should be avoided. Mr. Harricks' own suggestion was perhaps the nearest answer that could be given, namely, that "British solidity" had, in this instance, sacrificed a certain percentage of efficiency for greater reliability and longevity. Furthermore, Mr. Harricks had said that he would like to know why Wolff specially adopted the arrangement of the cylinders over the smoke box end of the boiler, in preference to the usual arrangement, common to most other Makers, of placing them at the firebox end.

Messrs. Wolff designed their plants to suit either arrangement, and the Author understood were prepared to supply either one. The method of surrounding the cylinders of the engine by the flue gases was not altogether a new one. The principle had been adapted some years ago, both in America and Germany, to locomotive engines, but as the arrangement had not been universally adopted, the probabilities were that considerable trouble had been met with and which had led to designers abandoning the idea. The trouble experienced with locomotive cylinders was mostly due to the unequal expansion and contraction of the cylinder walls, which frequently cracked under such conditions. Messrs. Wolff, however, were able to give the assurance that this difficulty had been overcome by designing the cylinder walls so as to readily take up the quick changes of temperature without suffering fracture.

It had also been pointed out by far-thinking engineers that in theory the principle was quite ideal, but that in practice the arrangement did not look quite so good, owing to sooty deposits adhering to the outer cylinder walls, and so forming a non-conductor of heat. It was a question he hardly liked to venture too deeply into. A subject which was at present open to much discussion was whether the outside coating of the cylinder walls, by such deposit, was a disadvantage inasmuch as it formed a barrier to the external heat finding its way into the interior of the cylinder, or an advantage in being a positive resistance and thus preventing the loss of heat units from the inside of the cylinder escaping when the same was momentarily subjected to sudden reduction of temperature probably brought about by a draught of cold air passing through the furnace during the process of stoking.

In reply to Mr. Sinclair, the Author stated that he was afraid that some of the Members had been misled by considering the design of the Locomobile engine a great departure from any other type of steam prime mover. The engine differed in no way whatsoever from the usual type of up-to-date engine on the market. The various fittings and cylinder arrangements, the packing and lubrication had been arranged in the usual way to withstand the action of superheated steam. So far as the question of water was concerned, the effects of local or any other water would make no difference in the results obtained by the superheated steam engine and the modern locomotives Power Station prime movers at present in operation. As regards the use of graphite as a lubricant, the Author believed that this agent had originally been applied for cylinder lubrication before the modern hydro-carbon variety of oils had come into universal use.

The Author said that he had already mentioned in his paper the method of assuring precise alignment of the cylinders. This was obtained in two ways. First, the original setting of the cylinder was carried out when both the boiler and cylinders had been heated up to a uniform working temperature, and, secondly, to allow for any unequal expansion of the two metals which composed the boiler crown and the cylinder, tie rods were supplied for the Wolff engine, which automatically took up any movement.

Referring to Mr. Shirra's remark, the Author said that he had little to say, for Mr. Shirra's great experience in marine work quite overshadowed his. The overtype engine was certainly in no way adaptable for marine work, and was, as had been said, an evolution of the well-known portable engine.

The Author heartily thanked the president, Mr. Julius, for his very instructive and careful criticism of the paper, and he felt that it was unnecessary for him to comment on the matter further, for Mr. Julius had really appreciated the value of the paper by adding his able contribution. Mr. Julius had pointed out to him a few moments before he had started to read the paper that one or two discrepancies were apparent in his original diagram, fig. 1. The Author had overlooked the fact in making up these thermal efficiency diagrams that they applied to the entire combination of the plant instead of to the engines only, and his remarks should have been confined to the engine itself. The Author said that he appreciated greatly the interest which the Members had shown in the discussion on the paper and he thanked those gentlemen particularly who had taken an active part in it.