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THE OVERTYPE OR HIGH SUPER-HEATED STEAM ENGINE.

BY GEO. DUNCAN MOFFAT.

Being almost an entire stranger in their midst the author said that he felt it was almost presumption on his part to have undertaken to describe to the members that evening a Prime Mover; knowing as he did that amongst his listeners were many engineers whose experience and technical knowledge of the subject he had chosen, considerably overshadowed his own. The engine in question has claimed the attention of engineers throughout the world of recent years, and is known as the Overtype or Locomobile Superheated Steam Engine. By reason of the high economy and phenomenal steam consumption results, it has brought the steam engine for smaller powers back again into general popularity, and has enabled it to compete most favourably with the internal combustion engine. To the engineer who is responsible for the cost of his power plant, a very small percentage in the saving of fuel is a most important item. The makers of this class of engine, realising this fact have endeavoured in every way to design the same with a great regard for fuel economy. A good many years ago an eminent engineer predicted that the prime movers of the future would be internal combustion engines, and certainly if we study the enormous strides which have been made during the last decade, it certainly looked as if there was some fundamental truth in this prophecy. Up to quite recently the steam engine ruled supreme as a prime mover, generating its power from heat, but was obliged to stand aside and allow the internal combustion engine to replace it in many instances, especially for smaller powers. This rivalry urged the steam engine builders to renew their efforts and re-design their steam plants, with the result that the Overtype High Superheated Steam Engine has been produced, rendering power generation more reliable and as economical as any suction gas engine plant.

Heretofore the height of economy has only been obtained by the installation of very large units such as turbines or multiple expansion engines of high power. An up-to-date power station equipped with modern boilers, superheaters, economisers, automatic stokers, and all the various items which go to make up a highly efficient power plant, could not be afforded by the smaller user of power, and could only be looked upon as luxuries which could not be indulged in.

The engine he was going to bring before their notice that night is in itself a compact unit, possessing these integral items which individually add to the economic running of the total installation, and renders the generation of power from as low as 50 B.H.P. to 60 B.H.P. as economic as the most up-to-date and elaborate power installation. The name Overtype Super Heated Engine which is applied to the particular form of steam plant with which this paper deals, but does not in itself sufficiently describe, consists of engine, boiler, superheater, air pump, condenser, and sometimes even an automatic stoker. In Germany the term Locomobile has been applied to it. In France it is called the Demi Fixe, and in Australia and Great Britain it is often known by the name of Semi-Stationary Engine. The above names do not imply that it is an engine only to be used for temporary purposes, although the great simplicity of the foundations and the arrangement generally of the plant render it an easy matter for it to be moved from one position to another, should this be desirable at any time.

Before going into any further details it is perhaps necessary here to touch lightly on the thermal efficiency of heat engines in general, and for this reason the author has sketched out the diagrams shown in Fig. 1, representing the thermal efficiency of an ordinary compound steam engine plant of normal efficiency in comparison with an engine of equal power of the overtype design. Members are, of course, aware that a very small proportion of the heat value of any fuel which is consumed is actually converted into work, the proportion varying from 35% in the best internal com-

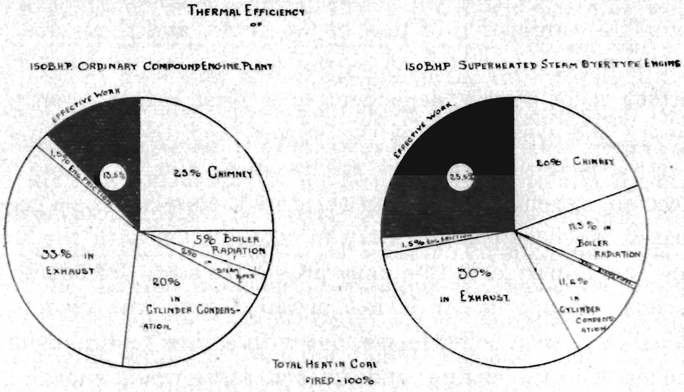

Fig. 1

bustion engine under test conditions to as low as 3% in the crude design of steam engines often applied to feed water pumps.

The diagrams show the important causes of loss in heat after generation, until passing into effective work. The entire circle represented a total percentage of 100 of the actual heat value of the coal fired, and each segment illustrated, with its corresponding percentage, the losses incurred during the transmission of heat into work, the black segments showing in each case the effective work. When it was observed what might almost be called the minute proportion of heat that is useful or effective in this diagram it would seem that there is plenty of room for improvement in the design of even the most up-to-date and modern engines. Unfortunately, however, these losses were fundamental losses; that is to say, the majority of them are inherent to this particular form of prime mover, and they could only operate on the balance between the fundamental losses and the actual losses, and which balance does not offer much room for reduction in practice.

To start with, the first segment is made up of losses occurring in the chimney; the figure given is 25%, and these losses are made up of two kinds—viz., those due to incomplete combustion of fuel in the grate, and those due to the carrying away of heat by the flue gases and air. The former is, of course, dependent to a great extent upon the energy and personality of the stoker, and the latter upon whether feed water heaters are installed; and, of course, to a certain extent upon the superheaters themselves; as a great deal of the heat passing away in combination with the flue gasses is imparted to this apparatus. He said, "of course," because a superheater is not installed with the object of doing away with boiler losses, but with a view to diminishing the losses in the engine; and, in fact, as he would show later it becomes necessary to reduce the efficiency of the boiler and recover this loss of efficiency by employing a superheater. Then of late it has been found good practice to install economisers or feed water heaters in a plant, of greater heating surface than has heretofore been practicable, ignoring the loss in temperature of the flue gasses (which would otherwise create the draught) by the installation of an induced draught fan. Five degrees is shown for pipe losses, and this figure is entirely dependent upon the efficiency of the lagging or the non-conducting composition covering them.

The boiler radiation is slightly higher in the case of the Overtype Engine, being almost entirely exposed, although well lagged under its burnished steel plates. Coming to the losses occurring in the engine itself, and which are the most important of any, if these losses can be improved upon they looked to the design of the engine to accomplish the improvement. There is no room for doubting any of the laws laid down by the science of thermo-dynamics, and there is no disputing the cycle through which the heat units pass in a heat engine, and therefore under any given set of conditions the performance of an ideal engine working under such conditions can be definitely determined.

In mentioning the term thermal efficiency it is, of course, understood to mean that ratio which exists between the total amount of heat supplied to tne engine, and the amount of heat that is actually converted into work. Naturally the ratio never reaches unity, as if all the practical losses occurring in a steam engine could be eliminated it would still fall short of converting all the heat supplied into actual work. His meaning would be better explained by briefly referring to the perfect steam engine, or Rankine engine, which has a varying thermal efficiency depending on the actual conditions under which it is operating. If we compare any ordinary engine with the Rankine engine working under similar conditions we find it falls short of the ideal result, that is to say, it is found that the ordinary engine has a somewhat lower thermal efficiency than that of the perfect engine. By these means is determined what is known as the efficiency ratio, which tells them if the thermal efficiency of their engine is good or bad. For instance, take the case of a non-condensing engine with a steam consumption of 35lbs. per I.H.P. per hour when working with saturated steam at 80lbs. per square inch and exhausting to the atmosphere. The consumption of the Rankine engine working under these conditions can be calculated out simply, with the result that its steam consumption is found to be 19.1lbs. per I.H.P. per hour. The efficiency ratio therefore between the consumption of the ideal engine and the ordinary engine would be 19/35 or 54.4 per cent. The amount by which an engine falls short of the Rankine Cycle represents the losses that can be reduced somewhat by careful attention to the design of the machine. If radiation was neglected, also friction losses, as well as leakage through the valves and pistons (which is really a matter of accurate workmanship and careful attention) there is left cylinder condensation and exhaust losses. The latter is one of the main thoroughfares by which the heat passes away. Unfortunately the greater part of these exhaust losses, as they pass away, form an integral part of the thermo-dynamic cycle which, as already explained, occurs in the Rankine engine. A few of these exhaust heat units can be recovered by carefully proportioning the cylinders so that they may utilise the expansion of the steam to its best advantage, and also by reducing clearance spaces in the cylinder to a minimum, as well as giving close attention in their design so that re-vaporation or condensation is annulled. If these important items are attended to the losses in this direction can be kept down. He would not detain them in discussing cylinder condensation and re-evaporation, as complete papers could be, and have been written on this subject alone. However, as it comprises one of the special features of the Overtype engine, without taking up too much of members' time on a subject with which they were all well familiar, he would like to say a few words regarding what actually takes place within the cylinders of a steam engine. When fresh steam enters the cylinder of an engine and comes in contact with the walls, which have previously been cooled by the outgoing exhaust, a considerable amount of heat is immediately imparted to these walls, and thus escapes doing actual work. A fine film of water is formed around the walls which acts as a ready conductor of the heat to be thus transmitted. After cut off, and during the expansion, some of this water is re-evaporated, and thus does a very slight amount of work in the cylinder, but the majority flashes into steam at the point where the exhaust valve is opened. This is, of course, due to the sudden reduction of pressure, and thus the heat is carried away without doing actual work. Then there is to be considered the fact that re-evaporation during the exhaust stroke extracts the latent heat stored up in the cylinder walls with the result that 30 per cent. of the total steam that enters the cylinder at admission is wasted. The instance given re this film of water refers, of course, to saturated steam coming into contact with comparatively cool walls. Now, if the formation of this film of water could be avoided, a considerable heat saving would be effected, although there would still be a certain amount of loss. Makers of steam engines from the beginning have realised the importance of obviating this difficulty. One method of reducing the cylinder condensation is to jacket the walls of the cylinder with a supply of fresh steam at boiler pressure. The advantage of doing this is, of course, apparent, particularly in the intermediate and low pressure cylinders of a compound engine, where the pressure and temperature of the steam in the jacket is considerably higher than that within the cylinder itself. These jackets may, however, frequently be a source of loss, owing to the condensation which occurs in them. The water must needs be drained off occasionally, carrying with it a number of heat units.

There is another method—namely, the use of superheated steam. This is, perhaps, more economical, as was realised by the earlier designers of steam engines, and almost universally adopted by them. When the cylinder is filled with superheated steam, a portion of the heat can be imparted to the walls without causing condensation. In fact, the use of superheated steam would in all probability not have been discarded if the hydro-carbon series of lubricants and oils for engines, which are at our disposal to-day had been in commercial use 50 years ago. It was mainly due to the fact that such an amount of trouble was experienced with lubricants and packing material, that the economy obtained by using superheated steam was not worth the accompanying troubles, and the system was almost entirely abandoned when the multiple cylinder high pressure engines were introduced. It will be observed that he had started to describe the losses, beginning at the furnace end, and leaving the more important losses—namely, those in the engine itself, until the last. If the steam consumption of the engine was cut down, correspondingly the size of the boiler may be reduced, and if the size of the boiler is reduced, correspondingly the losses by chimney, radiation and other losses which, to a certain extent, depend on the size of the boiler, are likewise reduced.

The Overtype High Superheated Steam Engine, or as it is sometimes called by our friends the Germans, the Locomobile, as has already been stated, is in itself a complete power station unit, comprising boiler, superheater, feed water heater, compound engine, condenser, and both air and feed pumps. This type of engine has been manufactured for a considerable number of years by Messrs. R. Wolf and Co., of Magdeburg, Germany, by Messrs. Larz, of Manheim, and later by Messrs. Richard Garrett and Sons, Limited, of Leiston, Suffolk, and Messrs. Robey, of Lincoln, both of England. Although the various engines of these makers differ somewhat in construction and design, the final results obtained by each are very similar; and they can be classed together as one type. In figure 2 is illustrated a 150 B.H.P. Wolf Tandem Compound Superheated Steam Locomobile of

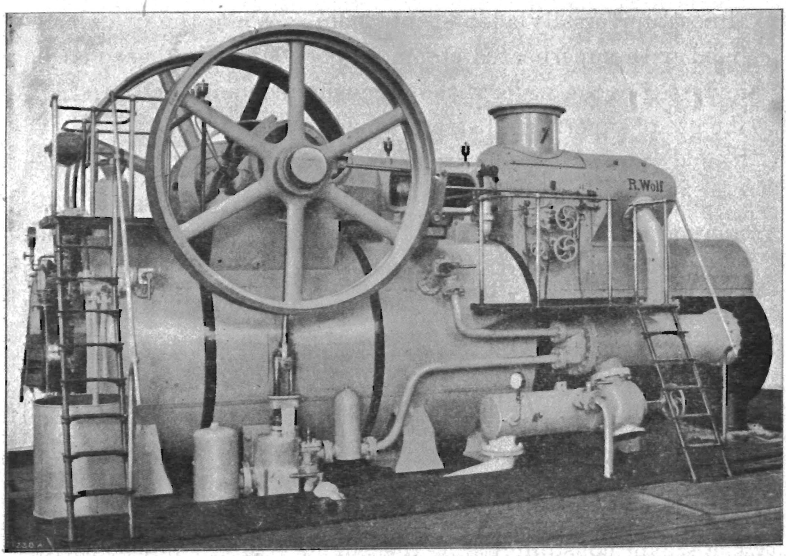

Fig. 2

ordinary commercial construction, and which is at present running in the city of St. Petersburg. The remarkably low steam consumption tests on this identical engine will be dealt with later on.

Figure 3 shows a Garrett 110 B.H.P. Standard Compound Superheated Overtype Steam Engine. Messrs. Garretts was the first English firm to manufacture this class of

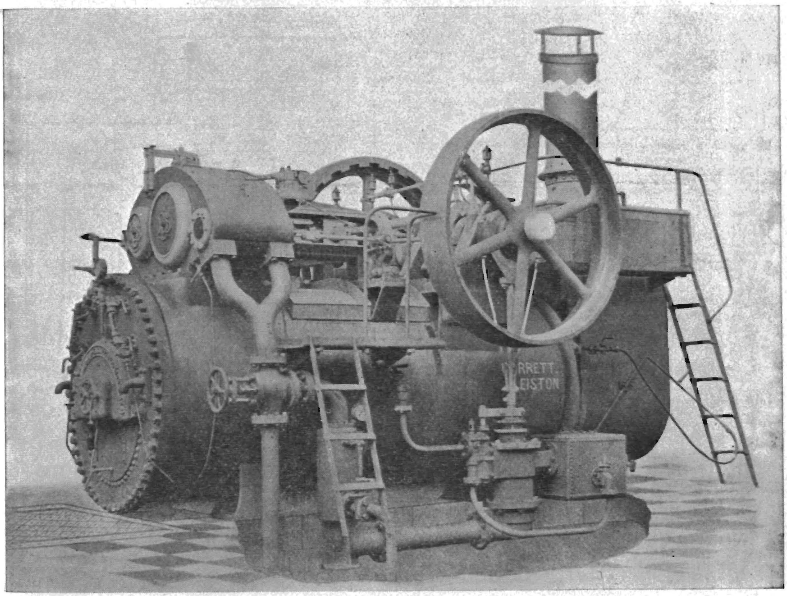

Fig. 3

prime mover, and they have been very successful in placing these engines in numerous works which have actually discarded suction gas plants in favor of the more reliable steam unit.

Figure 4 shows a sectional view of the Wolf engine which, as already stated, is of the tandem compound design, but which is by no means a standard type. The unique features are clearly shown in the figure. The cylinders are entirely surrounded by the flue gasses, thus the walls of the cylinders are kept constantly at a higher temperature even than the superheated steam admitted. It will be seen at a glance that the entire arrangement has been designed with a view of effecting even the most minute saving in heat. There is another very interesting feature in the design of this engine—namely, that the steam is not only superheated after leaving the boiler, but is again heated after passing from the

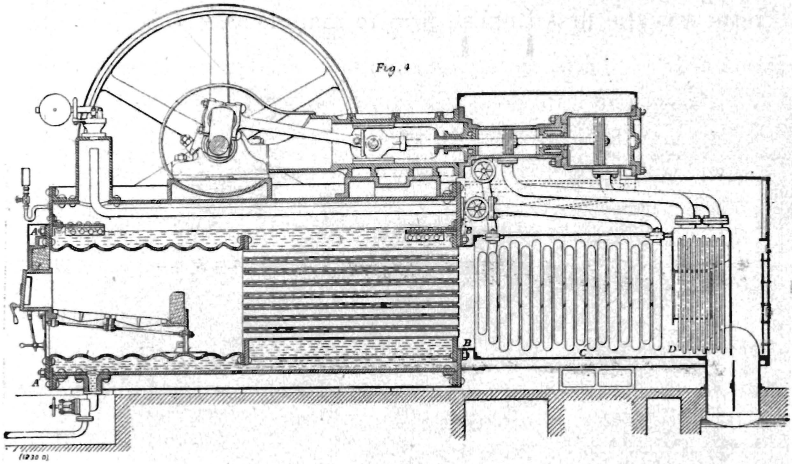

Fig. 4

high pressure cylinder and before entering the low pressure cylinder. By this method a number of heat units which would otherwise have escaped the main superheater are absorbed by the auxilliary superheater and thus recovered. The test figures which will be shown hereafter indicate that the temperature of the steam in the high pressure cylinder was 601. degrees F, and that the temperature of steam in the low pressure cylinder was as high as 431·6 degrees F. The Garrett engine is designed with a zig-zag superheater of staggered tubes, and has only one superheater. The general arrangement of the cylinders is as depicted in Fig. 5 the jackets around about the high and low pressure cylinders form a chamber with immediate access to the top of the boiler so that the jacket is continually supplied with fresh steam at boiler temperature and pressure—any condensation in the cylinder jackets immediately trickles down into the boiler, and no further heat units are lost. Both engines are equipped with circular multitublar boilers of the Cornish type and a circular corrugated fire box.

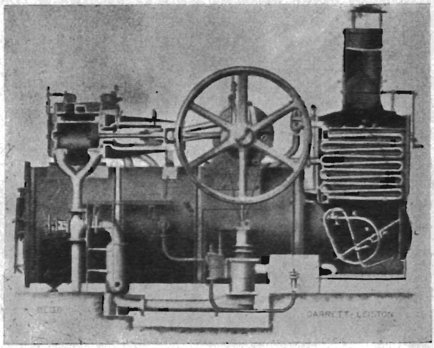

Fig. 5

Figure 6 shows that by the simple action of removing the nuts at the circular bolted joints at both ends, which joints are provided with packing rings of a special material, the complete furnace and fire box can be removed in such a

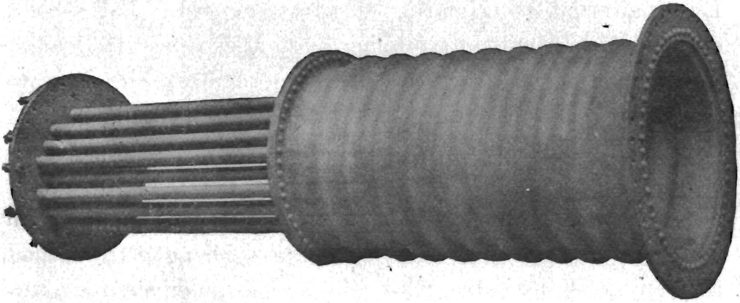

Fig. 6

way as to effect a careful scaling of the boiler tubes. Possibly if the locomotive or other similar tubular boilers were designed on this principle, scaling could be effected more simply and thoroughly. In the lower part of the boiler, pieces of longitudinal angles are riveted so as to provide guides for the back tube plate, thus simplyfying the replacing and self-centering of the entire apparatus of each type of engine boilers when so replaced. The furnace is rolled and flanged in one piece. The tubes are, of course, solid drawn steel, and are expanded into both tube plates. A few of these tubes are of thicker material and act as stay tubes, being screwed into the plates as well as expanded.

The next, Fig. No. 7, shows the dismantled boiler of the Garrett engine.

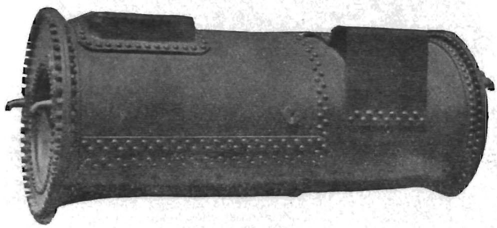

Fig. 7

Figure 4 showed a drawing of a vertical section of the tandem compound Wolf Locomobile. The superheater is made out of one continuous solid drawn steel tube placed in the smoke box directly at the mouth of the boiler tubes. Every alternate ring of the tube is staggered. The second superheater is built of a number of smaller tubes in parallel. The arrangement of placing the superheaters close up to the tube plate may be considered bad practice by some, as it renders the cleaning of boiler tubes by brushing more difficult. To get over this trouble, however, the makers provide a flexible tube from the boiler to act as a steam jet which can be inserted at the smoke box end of the tubes, and thus effect a cleaning of the tubes while the set is under steam. But when consideration is given to the design of certain types of superheaters applied to locomotives where the superheater tubes are almost inside the boiler tubes this arrangement is, after all, not so very disastrous.

Messrs. Garrett prefer to place their superheater above, or below, as the case may be, with inverted superheater for connecting with the flue, or elevated superheater for connecting with a steel chimney. The tube plate thus give an