# HIGH SPEED STEAM ENGINES.

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BY

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BEN. H. MORGAN, Editor "Engineering Times.

WITH ONE HUNDRED AND FIFTY-SIX ILLUSTRATIONS.

SECOND EDITION.

ENGINEERING TIMES LIBRARY

LONDON:

P. S. KING & SON,

2 & 4, GREAT SMITH STREET, WESTMINSTER.

1902.

BRADBURY, AGNEW, & CO. LD., PRINTERS,
LONDON AND TONBRIDGE.

# PREFACE.

In preparing this work the authors' object has been to provide a useful guide and reference to the best known practice in this branch of Steam Engineering, and one that will be of practical utility to designers, makers, and users of High Speed Steam Engines.

The first edition of this book was issued in September, 1900, and it is a matter of gratification to the authors that another issue has become necessary so soon following. The opportunity has been taken to correct several errors which appeared in the first issue, and two important sections have been added dealing with the High Speed Engines exhibited at the Paris and Glasgow Exhibitions respectively.

As stated in the preface to the first edition, the authors have not set forth herein their pet theories, or the exclusive practices of any individual firm, but an accumulation of knowledge gained by years of study and much experimenting by men whose success places them among the foremost of our most eminent engineers. This work is based purely on practical experience, and to-day the high pressure at which we have to take life does not allow of too much mathematical research; but by collecting results from actual practice much time and labour may be saved, and with a surer certainty of final success. Not that the authors for a moment disparage the use of mathematics or accurate calculation, but formulæ are only applicable within certain limits, for apart from the risk of error in calculation, a comparison of the results from the formulæ of one writer with those of another will often show great discrepancies between them.

With the idea of making the work as exhaustive as possible, the results of tests have been given, where reliable ones could be obtained.

To the names of Mr. Tom Scott King and Mr. G. Hives Dawson, whose assistance we gratefully acknowledged in the first edition of this work, we add the name of Mr. E. H. Judd, who has placed some valuable data at our disposal, and made several suggestions which we have adopted.

THE AUTHORS.

# CONTENTS.

# LIST OF ILLUSTRATIONS.

and not because its piston speed is greater than that of any engine running a slow rate of speed with a longer stroke, or that the power developed piston for piston and speed for speed is any different. We are in no degree claiming that a high rotation makes something out of nothing. What we do say, and what is common knowledge amongst makers of high speed steam engines, is, that higher rates of rotation than those formerly used have become necessary, through the exigencies of modern requirements. The experience which has been had, and tests which have been made, have proved indisputably that within certain limits short-stroke engines at a high rate of rotation develop economies in many ways which are more than a set-off against increased clearances. Their larger clearances cause a loss, but their decreased cylinder losses on other points quite balance the former, with a result that, for about half the money formerly spent on any given amount of power, you can have an engine in which the steam economies are quite equal to the average best quality of long-stroke slow rate rotation engines: and not only do the engines cost less, but the buildings also in which they are contained in an even greater ratio. In addition to these very obvious advantages to the capitalist, in many cases of manufacture, the speeds are much more convenient, while for electric light and similar work it would be idle to discuss their absolute superiority.

The better understanding of the conditions developed by high rates of rotation which experience has given to those steam engineers who during the past twelve or fifteen years (or, we may say, even during the last eight or ten years) spent their time and brains on the subject, has enabled them to produce engines which are not only as economical in steam, easier to govern, cheaper to produce, cheaper to house, and cheaper to attend, but are machines much more reliable, less liable to accident, and less dangerous in case of failure than the more ponderous types of former days. In a word, for what they have to do they are vastly stronger; and, moreover, are easily made so. To give the same margins in larger engines is impracticable. In regard to the term "small engine," it is hardly necessary to say, this is "relative." The more correct designation would perhaps be short engine. You cut the long engine in two, metaphorically, and let it turn round twice in the time instead of once.

The introduction of high speed single-acting engines on sound mechanical lines is unquestionably due to the late Mr. P. W. Willans. His famous single-acting engine has been the subject of most exhaustive trials and experiments, the results of which are published in the "Proceedings of the Institute of Civil Engineers,"[1] and form classical studies on steam engine performances and economy.

It was not until Mr. Morcom designed the "Belliss" double-acting engine with *forced lubrication* that the single-acting engine had any serious rival. We have had considerable opportunity of watching the behaviour of four "Belliss" engines for the past two and a half years.

The steam Turbine with its ideal rotary motion, *one moving part*, dispensing, as it does, with what most engineers have a sneaking regard for, viz., the innocent crank and connecting rod, has for more than a quarter of a century been assiduously developed by the Hon. Charles Parsons. Messrs. Parsons & Co. have made a large number of this type of engine up to 1,000 H. P. These turbines run with as small amount of steam as the best reciprocating engines.

Any radical departure from a well-beaten track requires no small amount of courage, and such an engine as Mr. Parsons', coupled with the many years of practical success it has met with, places the designer in the foremost rank of pioneers.

We must not lose sight of the sterling work accomplished by American engineers. Was it not Charles T. Porter who in 1860 first proposed to develop double or triple the power from the same weight of material for the same weight of engine, by increasing the number of its power-producing elements per minute from 50 strokes, as was the practice, to 250? Then we have the "Westinghouse" single-acting engine, and the "Ideal" double-acting engine, both of which are engineering triumphs.

[1] "Proc. Inst. C.E.," Vols. xciii., xcvi., and cxiv.

There have been vast strides in steam engines as in other things during the last decade, and the lines on which these have been entirely brought about can be expressed in two words, " high speed."

## Lubrication.

It is a notorious fact that strict attendance to lubricating and cleanliness has been sadly neglected by many English makers of high and slow speed engines.

It is a common practice to use a number of drop feeds to lubricate the various bearing surfaces. Each of these feeds, which must be adjusted to a very small opening to get a drop by drop feed, requires constant watching, and is liable to become choked. The varying temperature of the engine room is also responsible for erratic supply.

When using oil or any other lubricant it is absolutely essential that the oil should be evenly distributed, and at a fixed rate over the whole of the bearing surface.

It is well known that to efficiently lubricate a machine running at a high speed there is great difficulty in ensuring an even distribution of oil, and when moving parts are subjected to heavy pressure the difficulties are considerably intensified. Since engines of the high speed type are so very largely used for driving dynamos and continuous running is a *sine qûa non*, the lubricating of the moving parts must of necessity be constant, if the maximum duty of the engine is to be maintained for any length of time.

*Forced Lubrication.*—It has been proved by several makers of high speed engines that the pressure of the oil as supplied need not by any means be equal to the pressure of journal on the bearing, as it is only required to put the oil between the rubbing surfaces when the pressure on the bearing is reduced on the return stroke, and when the pressure of the shaft on the brass is set up there is not time for the filling oil to be entirely squeezed out in a high speed engine before the pressure is again reduced to admit of the supply being reinforced.

By arranging a suitable oil pressure, metallic contact between the surfaces is avoided, as there is always a film of oil under them.

Forcing oil under pressure to each bearing by means of a simple oscillating valveless pump driven off the engine shaft is a system which leaves little to be desired.

The density of the oil used in any type of engine plays a very important part as to its behaviour. Thin oil with little body will allow knocking to take place, while a thicker oil would reduce the *knock* considerably.

A novel system of lubricating and making stroke by stroke a close-up adjustment of the brasses is used by Mr. Dales on high speed engines. This method consists of a hydraulic "stop" or support to such brasses.

A well-known American system of lubricating is that used on "Ideal" high speed engines. In this arrangement the crank discs dip in the oil contained in the chamber beneath them, and none of the parts are submerged. The oil clinging to the surfaces of the discs is raised, and cast off in a shower of drops by the action of the centrifugal force. A constant and abundant supply of oil is thus delivered into pockets placed with the hood, wherein it flows in streams to the crank shaft bearings, and from the bearings back into the oil chamber under the discs.

## Governors.

Governors used on steam engines are mechanical combinations in which the centrifugal force developed is balanced and opposed by dead weights, springs, or other resistances, and are mostly arranged to run at an average speed, determined by the conditions under which the engine is employed, with a margin of variation usually allowed in the design, generally ranging from 2 per cent. for engines when great steadiness is a desideratum, to 5 per cent. for ordinary purposes. In a well-designed governor disturbing action may be neglected, since the object of the governor should be to signal to a separate part of the engine to perform the work, such performances being carried out without interfering with the governing proper. When shaft governors are used to vary the cut-off, the valve spindle should not pass through an ordinary stuffing box ; if this is permitted, then a disturbing action must of necessity take place, and "hunting" as a natural consequence will follow. It is possible even now to find steam engines which are used for driving dynamos with the governor out of action, and the steam regulated to suit the load.

Shaft governors consist essentially of an excentric which fits loosely on the hub of the governor wheel and which is connected by means of weight arms or springs through links in such a manner that the excentric is moved round the hubs of the governor, forward or backward as the weights change their position. This forward or backward movement through the excentric should be communicated in such manner as to give a straight line across the shaft, thus maintaining a constant "lead" for all points of cut-off. This movement across the shaft is always in the direction of reducing the excentricity of the excentric, consequently reducing the travel of the valve.

When the weights are at the inner position, the throw of the excentric is at its maximum. When the weights are at their extreme outer position the throw of the excentric is at its minimum. Between these two extremes any number of positions of the weights and corresponding angular position of the excentric may be had, and as the steam is thus adapted to the load in each position it follows that a slight increase or decrease in speed must make a change in the cut-off, and so bring the engine again to its normal speed.

Many English makers of high speed engines use a shaft governor regulating the quantity of steam admitted to the high pressure valve box by means of an equilibrium or throttle valve. A well-known type is where the centrifugal force of the governor balls is mainly met by springs applied to them, but a part is carried by the adjusting springs by means of which the revolutions can be varied, whilst the engine is running through a considerable range.

"Dale's" governor, which we have tested with highly satisfactory results, differs from any other of the shaft type, and is known as a fly wheel radial governor, on the centrifugal principle, in which the centrifugal force generated by opposite and duplicate parts is so balanced and arranged that it acts upon and moves the cut-off excentric in performing its functions, without any friction caused by such centrifugal force; and thus reducing the work to be performed by the governors to such as is necessary to overcome the friction and inertia of the governing parts, which is a very small item as compared with the larger centrifugal force of such an arrangement of governor. The friction and inertia of the arrangement are so low that the governor can be made practically isochronous, and can therefore be adjusted to work through its whole range with a 1 per cent. variation of speed without "hunting." This governor acts on the cut-off valve, and by means of a very ingenious arrangement the usual stuffing box is dispensed with, and so the disturbing action is eliminated.

It is well known to engineers in this country that most American engineers have pinned their faith to the shaft governor acting direct on the admission valve, whilst English practice is somewhat conflicting as regards the advantages of the direct cut-off over the "strangling" process. As already explained, the disturbing action, which undoubtedly exists in some types of shaft governors, is responsible for purchasers preferring the throttle valve centrifugal type.

"Rites'" shaft governor is very largely used in America. This governor embodies the centrifugal and inertia principles in a single weight. The inertia principle of the governor regulates all sudden changes in load, and the centrifugal principle takes care of any changes in speed which might occur from a gradual change.

## The Action of the Reciprocating Parts of the Engine.

When using a single cylinder to obtain a given power at a slow speed we must employ moving parts of great strength, and a heavy fly-wheel must of necessity be used to take the crank through the negation parts of the cycle. Now if we use a cylinder of say half the area, keeping the stroke the same and double the number of revolutions, we obtain the same power, but with double the number of impulses in the same period ; and although we have only the same number of impulses to each revolution of the crank, yet a much lighter fly-wheel and moving parts can be used, since there will be only one-half of the pressure on the piston. Therefore a steadier movement is obtained, and less vibration and shock to the engine, and to whatever it may be attached. In designing high-speed engines these facts must have been well borne in mind by the designer as described and illustrated some five years ago.[1] "When the force of inertia of the moving parts is shown to act as a regulator and modifier of shock in the transmission of the force to the crank, a point which, though well known, is much overlooked; while in virtue of the high speed, this force of inertia is utilised to the fullest extent, and instead of being an evil, it becomes a distinct gain."

"No amount of testimony," said Mr. John Hick, after he had come every day for a fortnight, and watched a "Porter-Allen" engine in the Paris Exposition of 1867, running with a 24 in. stroke at 200 revolutions per minute, "no amount of testimony would have made me believe that a steam-engine could be made to run at such speed, with such absolute smoothness." The secret of it was the inertia of the reciprocating parts between the steam and the crank.

The action of these parts is highly interesting. On every centre they are at rest. At the middle of each stroke they have a velocity equal to that of the crank. This velocity is all imparted to them in the first half of each stroke, and taken from them in the last half.

A little thought will enable one to see that the force exerted must vary as the square of the motion imparted or arrested within a known distance. For example, if a double

[1] W. Norris. "Practical Treatise on the 'Otto' Gas Engine," Longmans, Green & Co.

velocity is imparted, it must be imparted in one-half of the time, and so requires the exertion of four times the force.

It has long been established that the inertia of the reciprocating parts of an engine culminates on the dead centres, the point at which their motion in one direction is finally arrested, and that in the opposite direction begins to be imparted; and that it is there equal to, or rather is identical with, the centrifugal force, which these parts would continually exert if they were revolving in the path of the crank; and that at every other point in their stroke it is equal to the horizontal component of this centrifugal force at the corresponding point in the revolution of the crank.

The unit of centrifugal force, or the centrifugal force of 1 lb., making 1 revolution per minute in a circle of 1 ft. radius is ·000341 of a lb.; and this force varies directly as the weight revolving, and as the length of the crank, and as the square of the number of revolutions per minute. So the simplest computation enables one to find, in any case, what this final retarding and initial accelerating force is.

For example, in an engine of 2 feet length of crank, making 50 revolutions per minute, it is 1,705 times the weight of the reciprocating parts; for $50^2 \times 2 \times 000{\cdot}341 = 1{,}705$. That is, they are being put in motion 1,705 times as rapidly as gravity would do. We have then only to multiply the weight of these parts by 1,705, and we have the total force; and then by dividing this by the number of square inches on the piston, we have the pressure of steam per square inch that will furnish it. At the above speed it will be insignificant, probably 7 or 8 lb. per square in. But it increases as the square of the speed; at 100 revolutions it is 4 times as much, at 200 revolutions it is 16 times as much. The first is 30 lb., something to be considered; the second is 120 lb., something to be avoided.

The force on the square inch having thus been found for the dead centres, we have only to measure, at the commencement of the diagram, a height representing it—as, for example, *a*, *b*, Fig. 1—and from the point *b* to draw a diagonal, crossing the line of counter-pressure at the middle of the diagram, and continue it to the end, and we shall have enclosed two triangles, the first representing, at every point, the force exerted to give to these parts their velocity, which they must have to keep up the crank, and the second the precisely opposite force exerted to stop them.

At the mid-stroke acceleration passes insensibly into retardation. The curved end of the lower triangle shows the extent to which the motion of these parts is arrested by the compression on the opposite side of the piston, and not by the crank.

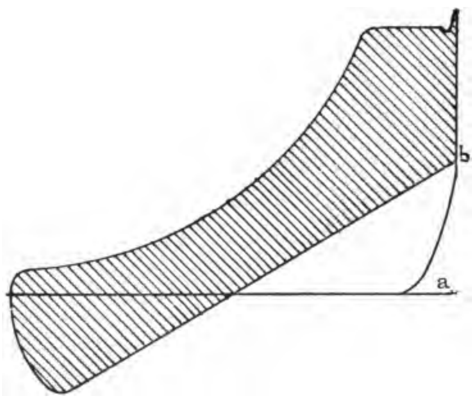



FIG. 1.

We see at a glance what a useful action this may be made when judiciously applied, which high speed enables us to do.

In a variable cut-off engine the pressure on the piston is enormously different at the opposite ends of the stroke, and when, as is the case in all slow-speed engines, the pressure on the crank is nearly the same with this, the engine is rotated by a succession of separate impulses, which are certainly in the highest degree unfavourable, either to quiet and steady motion, or the permanent good condition of the running parts.

But let the weight and speed of the reciprocating parts be so adjusted that their initial acceleration shall require about one-half the initial pressure of the steam, and what a magical change is effected.

The crank is relieved of one-half of the pressure at the commencement of the stroke; the force given out to the crank by the reciprocating parts, in being brought to rest, supplements the falling pressure of the steam towards the end of the stroke, and, as shown by the shaded portion of the diagram, the pressure on the crank is approximately equalised throughout, giving a smoothness of running and a steadiness of motion, with a small fly-wheel, which cannot be too much admired.

These parts, when their inertia is thus utilised, may very properly be termed "the reciprocating fly-wheel," since they act to equalise the motion by alternately absorbing and imparting force.

The most trying office of the fly-wheel is that of compensating for the varying angles, varying from 0° to 90°, at which force is applied to the crank, so as to maintain approximately uniform rotation under a constant load. This inequality in rotative effect, which has to be corrected, is enormously increased when most of the force is applied at the commencement of the stroke. The resulting irregularity of motion is seen in the vibration of belts, and is heard in the pulsation of gearing. This function of the fly-wheel is performed by the reciprocating parts in a superior manner.

The fly-wheel does nothing to save the crank and shaft from shocks, but these parts act to equalise the application of force to them also.

The fly-wheel acts only to the comparatively slight extent to which its speed is varied, but these parts act to equalise motion to the extent of their momentum, being on every stroke brought to rest. Above all, their action does not involve the least change in the rotative speed of the engine, while the fly-wheel, imperfect regulator, acts only by absorbing force as the speed of the engine is accelerated, and giving it out as the motion of the engine is retarded.

The ideal conditions of smooth running are better realised in throttling engines than in automatic cut off engines. By keeping down the space between the throttle valve and slide valve the initial pressure in the cylinder can be made to closely approximate to the pressure at the stop valve, and as the piston speed increases the pressure in the cylinder will fall, as shown in Fig. 2, the aperture through the throttle valve being so restricted that the pressure in cylinder is not maintained, although steam up to full pressure is fed into the inter-valve space during the period when the steam port is not open to cylinder.

In comparison with an ordinary arrangement of throttling this modification presents economic advantages, and does practically equal the more elaborate engine fitted with automatic cut off gear.

The high initial pressure helps to maintain the average temperature of the cylinder walls, and provides re-evaporation during expansion. Hence the line *a* can be made more nearly parallel to *b* by careful designing than *c* can.

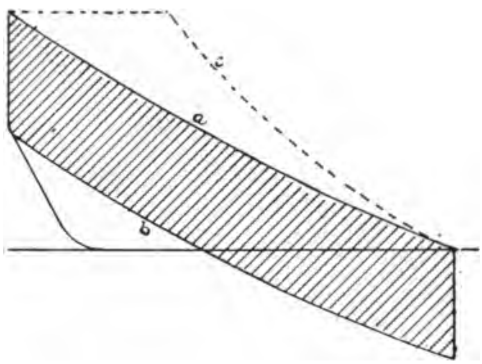


FIG. 2

The pressure on the crank pin is therefore more nearly constant with throttling engine *a* than with automatic engine *c*. The reversal of stress arising from the reciprocating parts is equally well effected in both cases. The aim of the high-speed designer should be not only to produce an engine which can be run quietly, but go further, and produce an engine in which the constancy of pressure on revolving crank necks and pins does maintain absolutely equal wear and give an engine which, when old and worn, can be still run quietly instead of degenerating into noisiness owing to untrue necks and pins.

## The "Willans" Engine.

This famous engine is the design of the late Mr. P. W. Willans. It has been the subject of most exhaustive trials and experiments. The "Willans" Central Valve Engine is a single-acting engine, whose working-stroke is the down-stroke, the piston or pistons having equal pressures on both sides during the up or return stroke. The arrangement of the engine will be understood from Figs. 3 and 4.

Fig. 4 shows a standard pattern engine, simple, compound, or triple-expansion in section. In the triple-expansion form

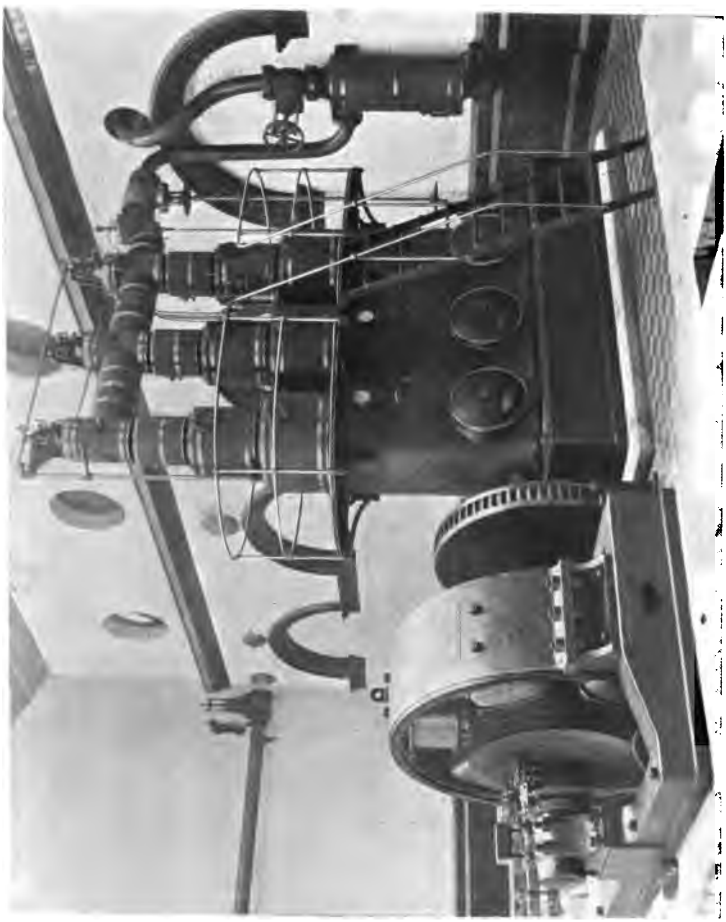


FIG. 3.—700 H.P. "WILLANS" HIGH SPEED ENGINE AND DYNAMO.

of these engines what is usually called the "Intermediate Cylinder" is called the "High-pressure," or H.P. cylinder, because it is virtually the H.P. cylinder of the compound form of the same engine, "tripled" by adding a still smaller cylinder above it; the latter is called the "H.-H.-P." cylinder.

It will be noticed that a compound, or even triple-expansion engine, may be run as a simple engine without removing the upper cylinders, by merely removing the upper pistons and the piston-valves corresponding with them; in fact, either the steam-pistons or the valves might be left, were it not for the useless friction of the rings; the upper cylinders in such a case become mere extensions of the steam-chest.

Starting with a simple engine, the steam passes from the steam-chest into the cylinder through the hollow piston-rod 21, which moves through the gland 11 L.P. in the cylinder top, which forms also the bottom of the steam-chest (or receiver, if the engine be afterwards compounded).

Referring to the left-hand line of pistons (which has completed one-fourth of the down-stroke), it is seen that steam is entering the piston-rod or "trunk" by the ports 7, and passing out again into the cylinder by the ports 8. At about three-quarter stroke the piston-valve $V^8$ will close the last-named ports, but cut off will take place earlier than this by the ports 7, entering the gland 11 L.P., and so leaving the steam-chest. The point in the stroke at which cut off takes place is governed by the height above the cylinder top to which the gland-rings are raised, by the distance piece W.

The cut off is fixed with reference to the steam pressure and other circumstances. When a very late cut off is required it is effected by the ordinary valve-motion. In this case there is no valve-piston above that which actually closes and opens the ports, *i.e.*, above $V^8$, $V^5$, or $V^2$, as the case may be, the latter being constantly exposed to the pressure in the steam-chest.

The piston-valve $V^8$ (which commences to uncover the ports 8 at top-stroke) is now nearly its lowest position relatively to the ports.

Shortly before the piston reaches the bottom of the stroke the valve $V^8$, then moving upwards, again uncovers the ports 8, and places them in communication with the ports 9, through which the steam commences to pass from the upper to the under side of the piston.

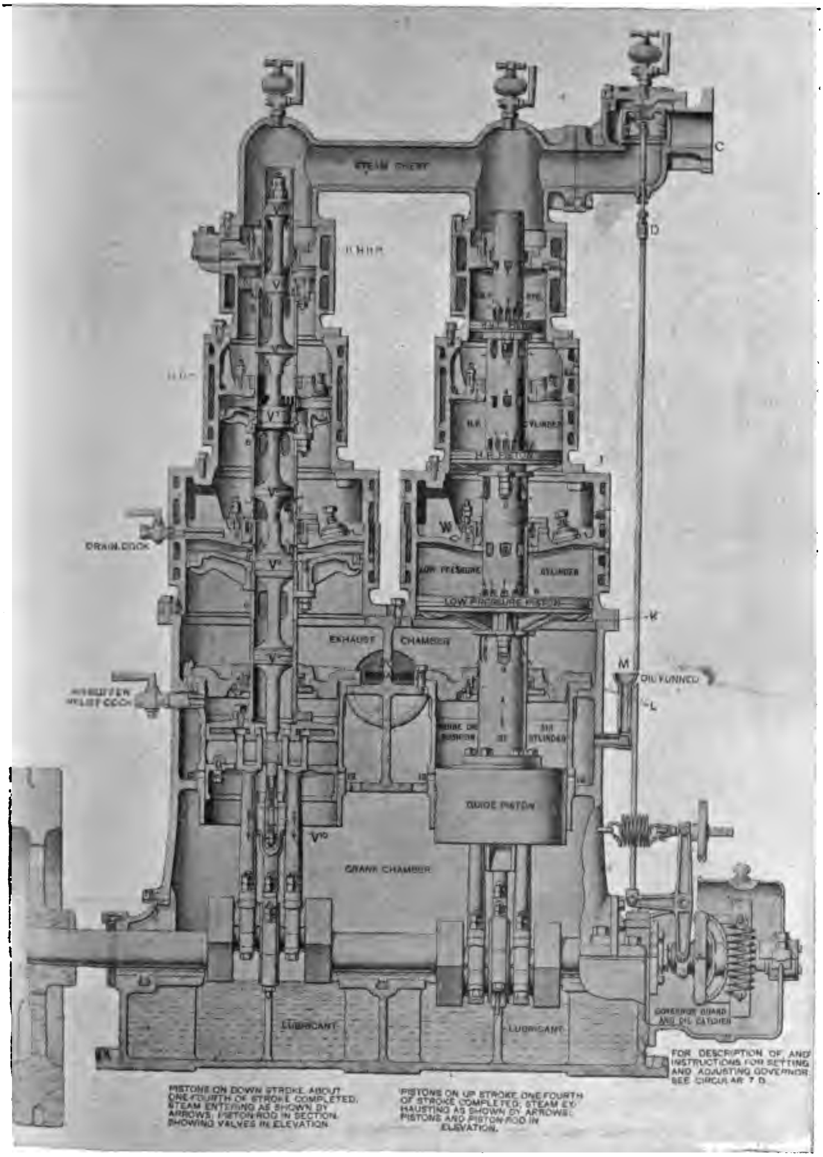



FIG. 4.—SECTIONAL VIEW OF THE "WILLANS" STANDARD PATTERN ENGINE.

The space below the piston communicates with the exhaust-chamber and the exhaust-pipe, the steam passing away (through 8, 9, and the exhaust) during the whole of the upstroke.

*Compound Engine.*—The above description is applicable to the second stage (*i.e.*, to the low pressure cylinder) of a compound engine, the word "receiver" being substituted for "steam-chest." The description of the first stage of expansion is, however, but little different from that of the second. The steam enters the H.P. cylinder by the ports 4 and 5, until cut off by the passage of 4 through the gland 11 H.P., the point of cut off depending, as before, upon the height to which 11 H.P. is raised above the cylinder cover. $V^5$ is the valve, shown fully open (like $V^8$ in the cylinder below); it will shortly rise, close the ports 5, and still rising will open them to 6; the steam will then pass from above the H.P. piston to the space below it, which, this time, is not an exhaust-chamber, but a receiver. The receiver may also be regarded as the steam-chest of the cylinder below it.

*Triple Expansion-Engine.*—The addition of a third (or "H.-H.-P.") cylinder above the others only involves a repetition of the foregoing paragraph, substituting the ports 1 and 2 as the channel by which the steam passes from the steam-chest to the cylinder, the cut off being given by the passage of the ports 1 through the gland 11 H.H.P., and the exhaust (into the receiver below) by the passage of the valve $V^2$ above the ports 2.

It will be noticed that in the simple engine the steam remains in the engine from the commencement of admission to the end of exhaust, for one revolution, as in ordinary engines. But in the Compound Engine the steam remains for two. and in the Triple Expansion Engine for three whole revolutions. In this way the economical advantages of the well-known Cornish cycle are obtained.

*Triple Expansion Transfer Engine.*—For very high pressures, and where economy of fuel is of great importance, an additional receiver is used between the low-pressure and the exhaust. It is known as the transfer-chamber, and its action is precisely the same as that of any of the upper receivers.

The steam during the up-stroke of the engine is merely transferred from the upper to the lower side of the low-pressure piston, instead of being discharged direct to the exhaust, to which it only passes during the succeeding down-stroke. By this arrangement the upper or hot end of the low pressure cylinder is never placed in direct communication with the condenser, and the range of the temperature in it is divided into two parts, reducing initial condensation. The L.P. cylinder and the transfer-chamber combined constitute in effect an ordinary Cornish engine.

The brasses are arranged to be constantly in compression; that is to say, the piston-rod is kept pressing in the same direction (downwards) against the connecting-rod, the latter against the crank-pin, and the crank against the main bearings, not only throughout the working-stroke, but through the return stroke as well. There being no reversal of pressure there is freedom from knocking, which is usually the initial cause of wear.

In order to secure that the condition of *constant thrust* is maintained, an amount of compression must be provided which shall always cause a downward pressure in excess of the upward accelerating force. In the "Willans" engine, the requisite compression is obtained by means of an air-chamber above the guide-piston—the lowest on the rod. This piston on the up-stroke compresses the air contained in the chamber above the piston, and thus any amount of compression can be obtained according to the clearance allowed. The work expended in compressing the air is given out again by expansion on the succeeding down-stroke. The engine is usually governed by a throttling governor, but often by a variable expansion governor.

A disadvantage of all *single-acting* engines is that for a given power the cylinder capacity must be twice as great as in a double-acting engine, or else the engine must run twice as many revolutions per minute.

The high economical performance of the "Willans" engine is shown by the following table:—

### Test of "Willans" Engine.

*Duration of Tests: 1st,* 4·2916; *2nd,* 3·5166; *3rd,* 3·55; *and 4th,* 3·05 *hours.*

*Effective Area of Cylinders—three of each: High-pressure,* 90·836 *square inches; Intermediate,* 345·44 *square inches; Low pressure,* 587·175 *square inches.*

*Stroke:* 10·24 *inches.*

| | |
|---|---|
| Number of Boilers in use | One. |
| Total length of Boiler | 28 feet. |
| Diameter of Boiler | 7 feet 6 inches. |
| Diameter of Furnaces (two)......... (Purvis mean diameter) | 2 feet 11 inches. |
| Heating Surface of Boiler | 904 square feet. |
| Grate Surface of Boiler | 32 square feet. |
| Ratio of Heating Surface to Grate Surface | 28 : 1 |
| Mean Boiler Pressure above the Atmosphere | 190 lb. per square inch. |
| Mean Admission High-pressure Cylinder | 169·5 lb. per square inch. |
| Mean Effective Pressure on Low-pressure Cylinder | 28·918 lb. per square inch. |
| Mean Vacuum | 25·925 inches. |
| Mean Revolutions per minute | 299·8. |
| Mean I.H.P. | 394·775. |
| Mean total Feed-water per Hour | 5,050 lb. |
| Mean Deductions for Separator and other Drains per hour | 117·1 lb. |
| Mean total Steam to Engine per hour | 4932·9 lb. |
| Mean Steam used per I.H.P. per hour | 12·49 lb. |
| Temperature of Feed to Economiser | 113 degrees. |
| Temperature of Feed to Boiler | 243 degrees. |
| Coal burnt per hour | 457·6 lb. |
| Coal burnt per square foot of Grate Area per hour | 14·3 lb. |
| Coal burnt per I.H.P. per hour | 1·185 lb. |
| Pounds of Water evaporated per lb. of Fuel | 11·1. |
| Pounds of Water evaporated per lb. of Fuel from and at 212° F. | 12·83. |
| Pounds of Water evaporated per square foot of Heating Surface per hour | 5·58. |

## THE "BELLISS" ENGINE.

Messrs. Belliss & Morcom, Ltd., in 1890, introduced what is known as forced lubrication to the moving parts of quick

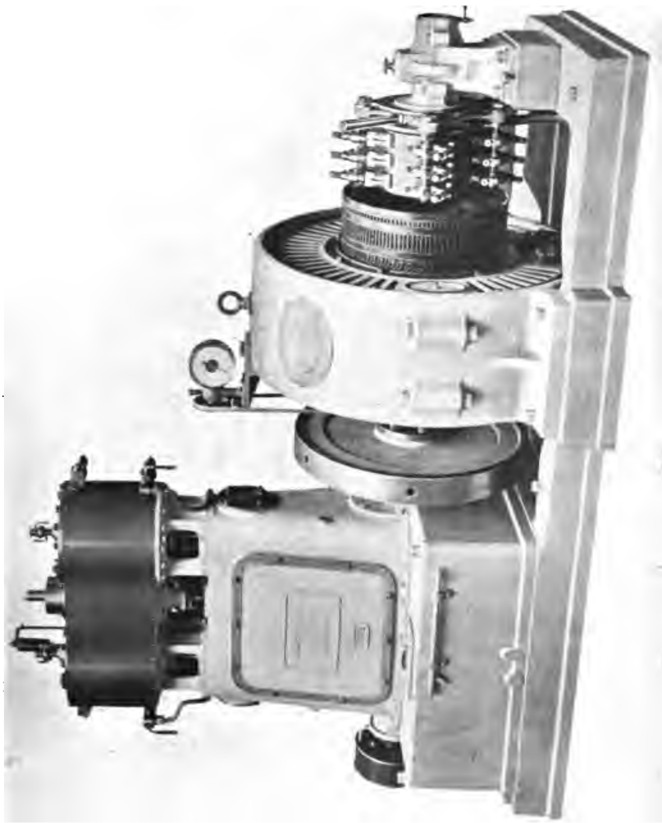


FIG. 5.—"BELLISS" PATENT SELF-LUBRICATING TWO-CRANK COMPOUND QUICK-REVOLUTION ENGINE AND DYNAMO.

revolution steam-engines, which at once gave to the double-acting engine all the advantages of quiet running at high rotative speeds which had hitherto been claimed for single-acting engines, with the additional power. As already pointed out, a high speed does not necessarily mean a high rotative speed. The "Belliss" engine is in reality a low piston speed engine with a quick revolution. Some years ago we pointed out that the misleading terms, nominal and I. H.P., should be abolished, and that engines should be sold on their B.H.P.—*i.e.*, brake, effective, or actual horse power.

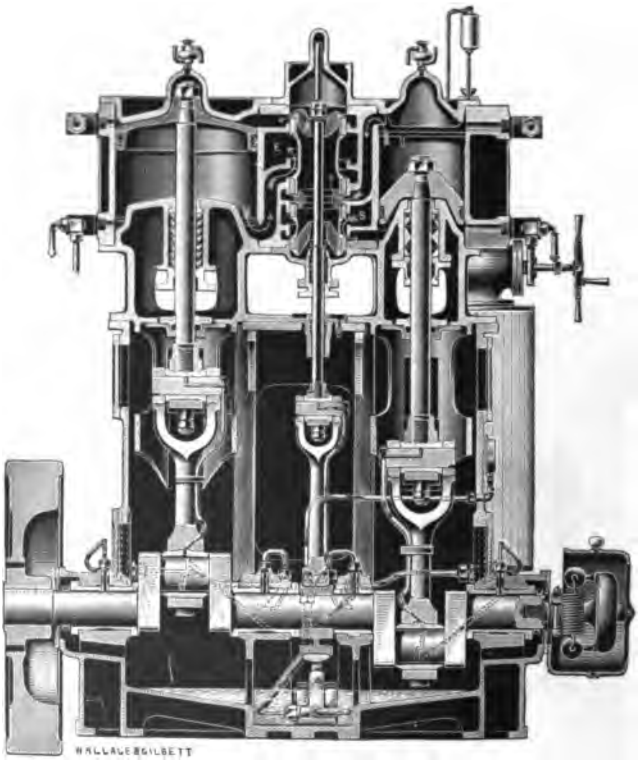


FIG. 6.—"BELLISS" ENGINE. SECTIONAL ELEVATION.

Messrs. Belliss & Morcom make a point of rating their engines on the B.H.P. for continuous running; this is as it should be.

With forced lubrication oil is supplied to all the bearings by means of a simple pump without valves or packing, discharging the oil at a pressure of about 15 lb. per square inch, through a specially arranged system of oil channels.

Fig. 5 is an external elevation of a "Belliss" compound quick revolution engine coupled direct to a dynamo.

Fig. 6 is a sectional elevation, and Fig. 7 is a sectional end elevation of the same engine.

Referring to Figs. 5, 6, and 7, it will be seen that only one piston valve is used, arranged between the high and low

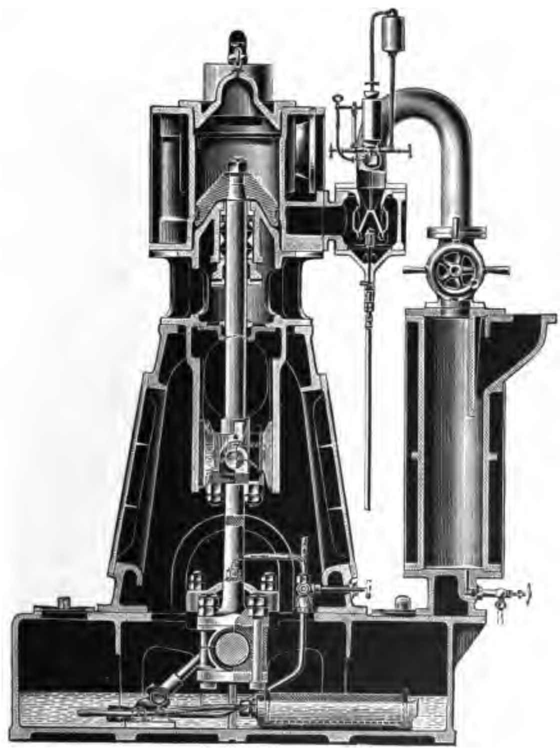


FIG. 7.—"BELLISS" ENGINE. SECTIONAL END ELEVATION.

pressure cylinders, operated by an excentric. The cranks are set opposite to each other, the steam being admitted simultaneously to the top of one cylinder and the bottom of the other; by this arrangement the reciprocating parts are to a great extent balanced, the strains on the bearings much reduced, and a high speed of rotation made possible without setting up undue vibration.

Messrs. Belliss's governor is of the centrifugal type working an equilibrium throttle valve, and is adjustable by hand while the engine is running. In this governor the centrifugal force of the governor balls is mainly met by springs directly applied to them, but a part is also carried by the adjusting spring by means of which the revolutions can be varied, whilst the engine is running through a considerable range. By way of showing what the throttle valve form of governor

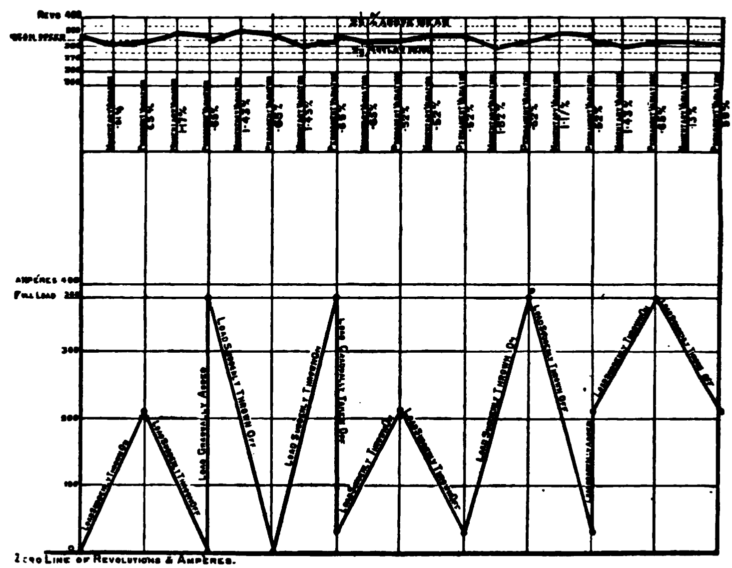


FIG. 8.—"BELLISS" PATENT SELF-LUBRICATING ELECTRIC TRACTION SET, FITTED WITH THROTTLE VALVE GOVERNOR DIAGRAM SHOWING GRAPHICALLY THE RESULTS OF SWITCHING ON AND OFF VARIOUS LOADS. IT WILL BE SEEN THAT WHEN THE LOAD IS SUDDENLY THROWN OFF OR ON, THE VARIATION OF SPEED FROM THE MEAN DOES NOT EXCEED 3 TO 4 PER CENT. PERMANENT, AND 2 PER CENT MOMENTARY.

as applied to these engines is capable of, Fig. 8 was selected from Messrs. Belliss's test house records.

In the case of central stations, situated in the midst of residential neighbourhoods, the necessity of reducing the vibrations, set up by the working of the machinery, to a minimum becomes of paramount importance. Messrs. Belliss, with this fact before them, have designed a three-crank tandem compound quick revolution engine, having the three cranks disposed at equal angles, each crank having a


FIG. 9.—VIEW SHOWING SIX SETS OF THREE-CRANK TANDEM COMPOUND "BELLISS" ENGINES AND DYNAMOS INSTALLED AT THE WATERLOO AND CITY ELECTRIC RAILWAY GENERATING STATION.

complete engine. Fig. 9 shows an external view of a "Belliss" three-crank tandem compound quick revolution engine coupled direct to a dynamo. In such a combination, whilst rocking couples are not wholly eliminated, there is no vertical displacement of the centre of gravity of the working parts as a whole; and, in practice, this type is found to work without setting up appreciable variations.

The soundness of Messrs. Belliss & Morcom's system is admitted in the most practical manner by the large number of firms who have waited sufficiently long to see the market value of forced lubrication before adopting it.

## "BELLISS" 300 H.P. QUICK-REVOLUTION, SELF-LUBRICATING ENGINE,

FITTED WITH THROTTLE-VALVE GOVERNOR, FOR WATERLOO AND CITY ELECTRIC RAILWAY.

### RESULTS OF GOVERNOR TESTS AFTER FINAL ADJUSTMENTS.

*Variation in speed above and below general mean speed,* load being switched off or on as suddenly as possible.*

| Change of Load. | Non-Condensing. | | | | | Condensing. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Revolutions per min.* | | | Percentage of Variation in Speed. | | Revolutions per min.* | | | Percentage of Variation in Speed. | |
| | From | To | Settle | Momentary. | Permanent. | From | To | Settle | Momentary. | Permanent. |
| | Revs. | Revs. | Revs. | Per cent. | Per cent. | Revs. | Revs. | Revs. | Per cent. | Per cent. |
| None to Half - - | 387 | 381 | 382 | 0·91 | 0·65 | 387 | 380 | 382 | 0·78 | 0·26 |
| Half to None - - | 382 | 389 | 387 | 1·17 | 0·65 | 382 | 388 | 387 | 1·30 | 1·04 |
| Full to None - - - | 382 | 390 | 387 | 1·43 | 0·65 | 379½ | 392½ | 387 | 2·48 | 1·04 |
| None to Full - - - | 387 | 379 | 382 | 1·43 | 0·65 | 387 | 377 | 379 | 1·56 | 1·04 |
| 1–15th to Half - - | 386½ | 382 | 382½ | 0·65 | 0·52 | 385 | 381 | 381 | 0·52 | 0·52 |
| Half to 1–15th - - | 382½ | 386½ | 386½ | 0·52 | 0·52 | 381 | 386½ | 385 | 0·91 | 0·52 |
| 1–15th to Full - - | 386½ | 377½ | 382½ | 1·82 | 0·52 | 385 | 375 | 379 | 2·09 | 1·04 |
| Full to 1–15th - - | 382½ | 389 | 386½ | 1·17 | 0.52 | 379 | 389 | 386 | 1·56 | 0·78 |
| Half to Full - - - | 382½ | 379 | 382 | 1·43 | 0·65 | 381 | 377 | 379½ | 1·56 | 0·91 |
| Full to Half - - - | 382 | 384 | 383 | 0·13 | 0·39 | 379½ | 382 | 382 | 0·26 | 0·26 |
| Emergency to none. | — | — | — | — | — | 379½ | 392½ | 387 | 2·48 | 1·04 |

* Steady Speed { Non-condensing, Full load 382 No load 387 Mean 384½ } Revolutions per minute.
{ Condensing, " " 372½ " " 387 " 383 }

## TRIALS OF "BELLISS" 200 H.P. QUICK-REVOLUTION, SELF-LUBRICATING ENGINES, CONDENSING.

*Cylinders 12¼ and 20 in. diameter, with 9 in. stroke. Working pressure 120 lb. per square inch above atmosphere.*

| | Station.—Sunderland Electric-Supply Engine. Tested by Professor Kennedy. (Fig 12.) Load. | | | | | | Station.—Cheltenham Electric-Light Engine. Tested subsequently. (Fig. 14.) Load. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum. | Normal full. | Three quarters. | Half. | One quarter. | Only exciting. | Normal full. | Three quarters. | Half. | One quarter. |
| Mean effective pressure per sq. in. reduced to low pressure cylinder | 42·3 | 37·6 | 28·6 | 20·0 | 9·7 | — | 36·1 | — | 20·6 | 10·4 |
| Mean revolutions per minute. Revs. | 364·6 | 365·0 | 364·5 | 363·9 | 363·8 | — | 365·5 | — | 361·0 | 361·5 |
| Mean indicated H.P. - - I.H.P. | 217·5 | 193·6 | 147·1 | 102·7 | 49·8 | — | 185·7 | — | 104·8 | 53·1 |
| Mean brake H.P. - - - B.H.P. | 209·5 | 186·0 | 140·6 | 97·0 | 44·5 | — | 176·8 | — | 97·4 | 44·2 |
| Mechanical efficiency $\frac{\text{B.H.P.}}{\text{I.H.P.}}$ p.c. | 96·3 | 96·1 | 95·2 | 94·4 | 89·3 | — | 95·2 | — | 93·0 | 83·2 |
| Water per hour - - - Total lbs. | 3772 | 3383 | 2628 | 1920 | 888·5 | — | 3301 | — | 1939 | 987·9 |
| Water per hour, per B.H.P. - lbs. | 18·0 | 18·2 | 18·7 | 19·8 | 20·0 | — | 18·6 | — | 19·9 | 22·3 |
| | Coupled to Continuous-Current Dynamo. (Fig. 13.) | | | | | | Coupled to Alternator. | | | |
| Mean effective pressure per sq. in. reduced to low pressure cylinder - - - - - - - lbs. | — | 36·0 | 24·2 | 19·2 | 10·5 | 2·2 | — | 28·4 | 23·0 | — |
| Mean revolutions per minute. Revs. | — | 367·6 | 365·3 | 362·6 | 365·2 | 364.8 | — | 350·2 | 351·0 | — |
| Mean indicated H.P. - - I.H.P. | — | 186·7 | 129·4 | 98·2 | 54·1 | 11·6 | — | 144·8 | 114·4 | — |
| Mean electric H.P. - - - E.H.P. | — | 168·6 | 115·1 | 83·8 | 40·9 | — | — | 126·8 | 98·5 | — |
| Combined efficiency $\frac{\text{E.H.P.}}{\text{I.H.P.}}$ - p.c. | — | 90·3 | 88·9 | 85·3 | 75·6 | — | — | 87·5 | 86·1 | — |

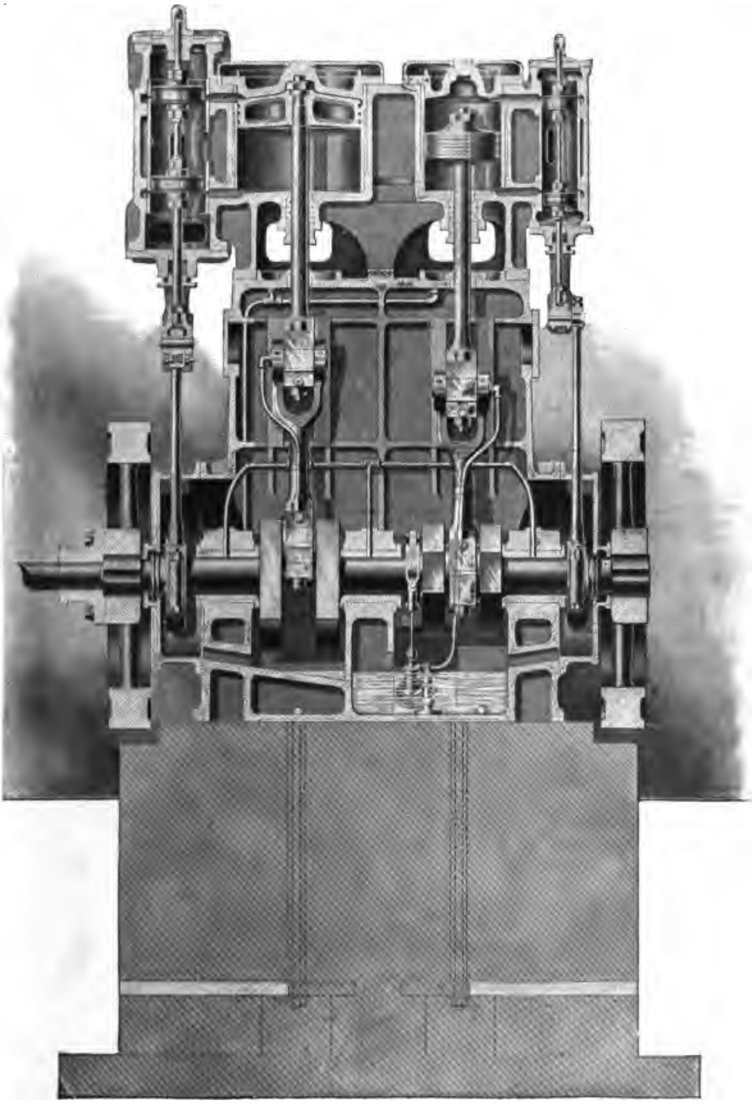


FIG. 10.—SECTIONAL VIEW OF "B.I." QUICK SPEED ENGINE.

## John Musgrave & Sons' "B.I." Engine.

For more than half a century "Musgraves" have been identified with mill engines and millwrighting. During the past few years this firm have made a number of high speed

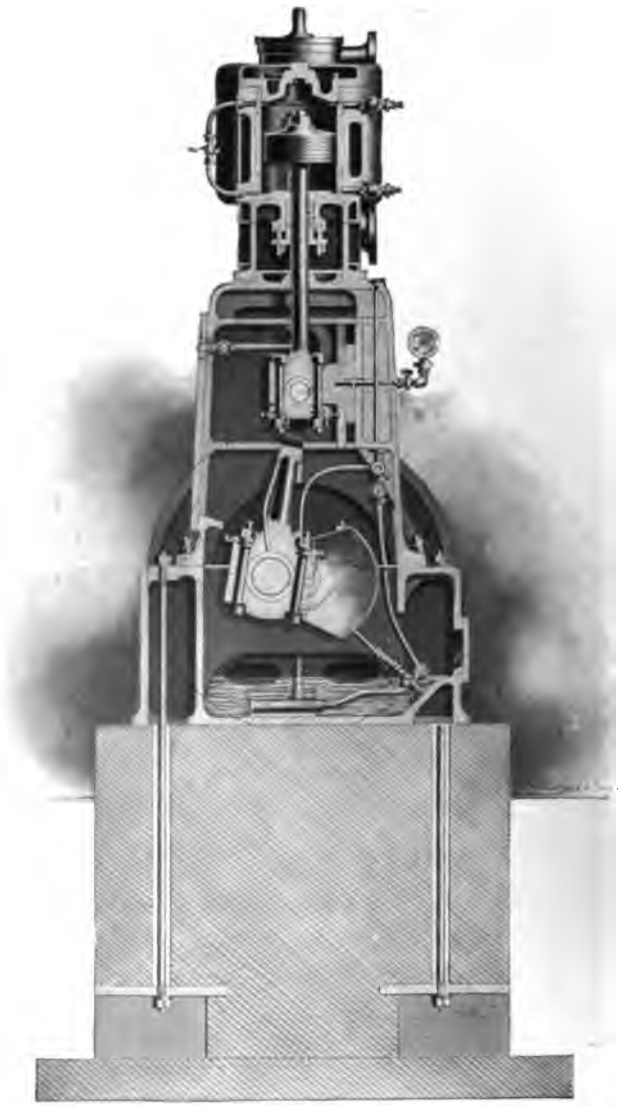


FIG II.—SECTIONAL END VIEW OF "B.I." QUICK SPEED ENGINE.

engines of the single acting type. Like many other firms, Messrs. Musgrave are now pinning their faith to double acting engines of the forced lubrication class. Figs. 10, 11, and 12 are sectional elevation, sectional end elevation and external views of " Musgraves' " " B. I." quick speed engines.

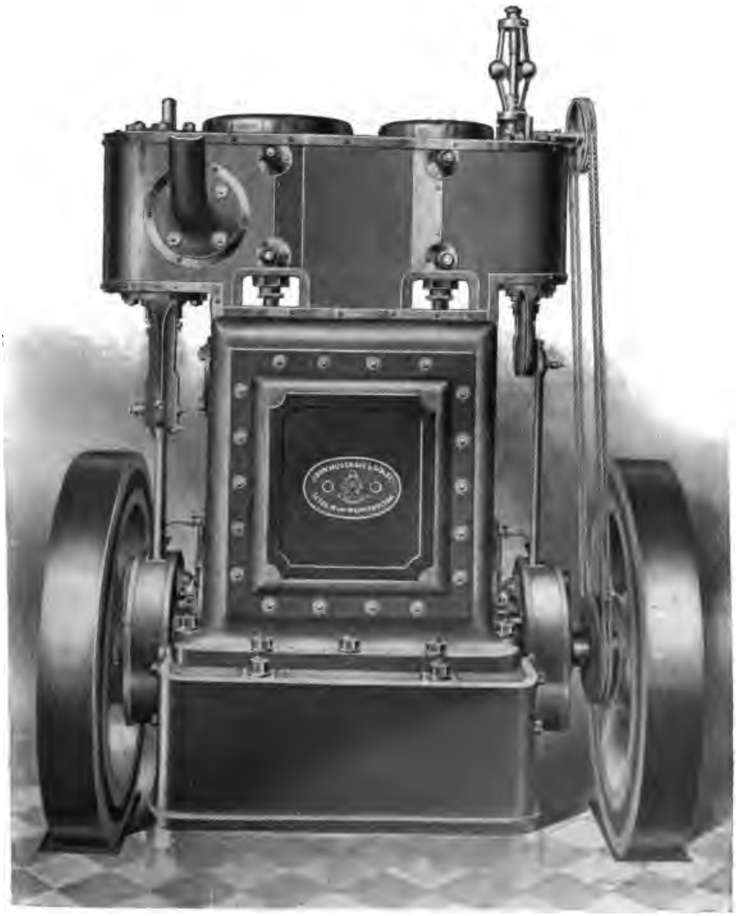


FIG. 12.—THE "B.I." QUICK SPEED ENGINE.

By referring to Fig. 10, it will be seen that this engine is arranged with external piston valves for high and low pressure cylinders. This is necessary for " timing " the valves to suit the relative position of the cranks which are set at 90 degrees. The cranks have counter-balance weights in one with the shaft. The main bearings are arranged in the base and are quite independent of the casing proper, which is open at the front and closed at the back. This enables a very substantial form of slide block being used, whilst leaving the front quite as accessible as the open "fronted" engine. As already mentioned, oil under pressure is used for lubricating the main bearing surfaces, without moving joints. The gudgeon pin receives its supply of lubricant through a cavity in the block, the oil travelling down a tube to the crank pin. Governing is effected by using either a governor of the "Pickering" type driven by ropes, acting on an equilibrium valve, or a shaft governing acting direct on the high pressure piston valve. By arranging the valve boxes on the outside the valves are easily adjusted and the main bearings have only three supports which are arranged well up to the crank webs. These engines have a piston speed of about 600 ft. per minute, and are designed for a steam pressure of 130 lb. per square inch.

## Browett, Lindley & Co.'s Engine.

Fig. 13 illustrates a well-designed High Speed Compound Engine, by Messrs. Browett & Lindley, Patricroft. It indicates 150 H.P. when running at 420 revolutions per minute with a steam pressure of 130 lb. per square inch, non-condensing.

The steam distribution is effected by means of two packed piston valves. The piston valve for the high pressure cylinder, which is arranged on the outside of the cylinder, the excentric rod, valve spindle and guide block are completely encased inside a removable cast-iron casing, so that no oil or water can escape outside of the engine.

The piston valve for the low pressure cylinder is actuated by an excentric, fitted on the crank shaft between the two cylinders.

The regulating of the steam is effected by means of a shaft governor controlling the speed of the engine by acting direct on to an equilibrium valve. Forced lubrication is used. The oil pump is of the valveless type, driven by an excentric on the engine shaft. The crank shaft is supported by two

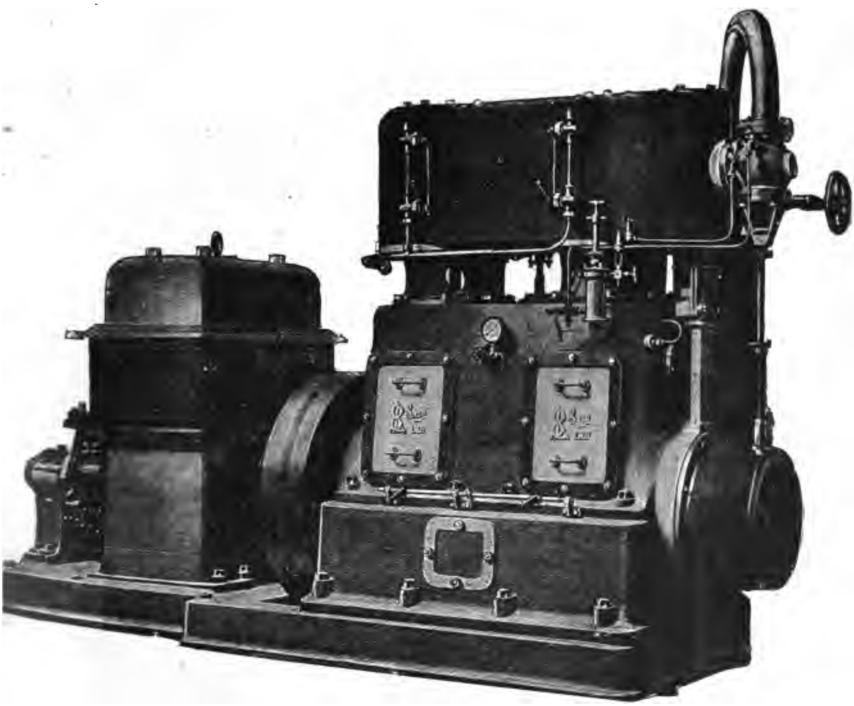


FIG. 13.—HIGH SPEED COMPOUND ENGINE AND DYNAMO BY BROWETT, LINDLEY & CO.

main outer bearings and two centre bearings, with the low pressure excentric between.

This type of engine is made in sizes from 45 I.H.P., 550 revolutions per minute up to 400 I.H.P., 350 revolutions per minute.

## The Clayton Engineering and Electrical Construction Co.'s Engine.

Fig. 14 is a part sectional elevation of a high speed compound engine, coupled direct to a dynamo made by the

Clayton Engineering and Electrical Construction Company. This engine belongs to the forced lubrication class, and develops 120 I.H.P. when running at 380 revolutions per minute, with an initial steam pressure of 90 lb. per square inch. By referring to the illustration it will be seen that the distribution of the steam is effected by means of a piston valve arranged between the high and low pressure cylinders. The length of the cylinders is somewhat long in proportion to the length of the stroke. This is a decided advantage, as

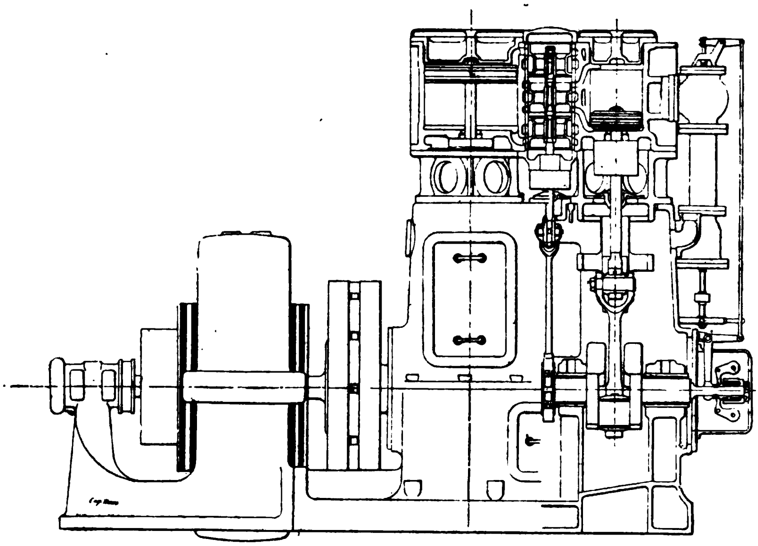


FIG. 14.—PART SECTIONAL ELEVATION OF COMPOUND "CLAYTON" ENGINE. 120 I.H.P., 380 REVS.

it admits of the top and bottom parts to each cylinder being the same length. The inside of the cylinder covers and pistons are polished so as to reduce initial condensation. This very important point is overlooked by most engineers. The cranks are set opposite to each other, and are fitted with balance weights secured by means of steel straps.

All the rubbing surfaces are lubricated with oil at a pressure of about 30 lb. per square inch. The pump is of the valveless oscillating type, worked with ram attached to main excentric clip. The governor is fixed on crank shaft controlling the speed of the engine by direct connection to the throttle valve and consists of two revolving weights and connections controlled by springs.

Fig. 15 is a part sectional elevation of a three-crank tandem compound high speed engine, designed to develop 600 I.H.P. when running at 300 revolutions per minute. The distribution of the steam is effected by means of a piston valve

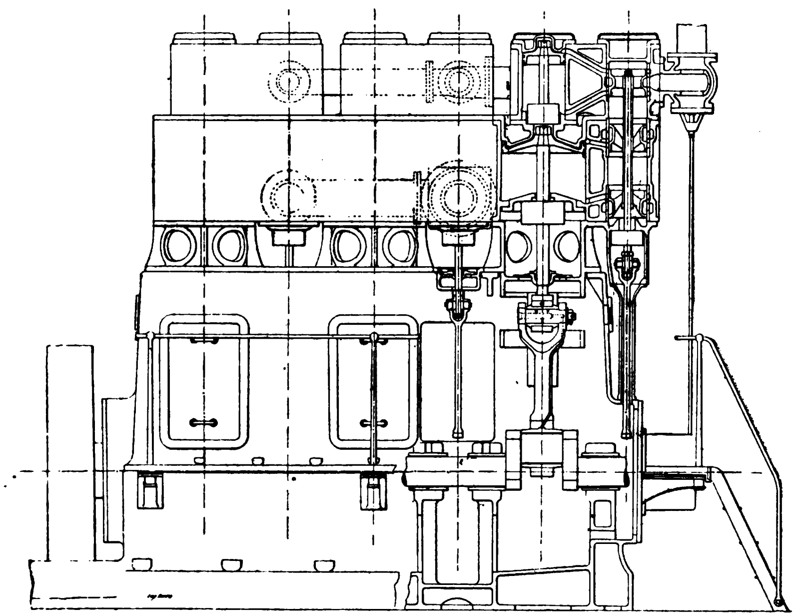


FIG. 15.—PART SECTIONAL ELEVATION OF THREE-CRANK "CLAYTON" ENGINE. 600 I.H.P., 300 REVS.

operated by an excentric having a fixed travel. The steam inlet to the high pressure cylinders is controlled by a shaft governor, which operates an equilibrium valve. The cranks are set at 120°. Forced lubrication is used on all the rubbing surfaces.

This firm also make a two-crank enclosed triple expansion vertical engine, for direct coupling to dynamo, to develop 150 B.H.P. at 300 revolutions per minute, with a steam pressure of 200 lb. per square inch. This engine consists essentially of four cylinders, one high pressure, one intermediate, and two low pressure, arranged high and intermediate side-by-side with central valve box distributing steam to both cylinders. The high and intermediate cylinders are carried above low pressure cylinders by four massive steel pillars. The low pressure cylinders are carried

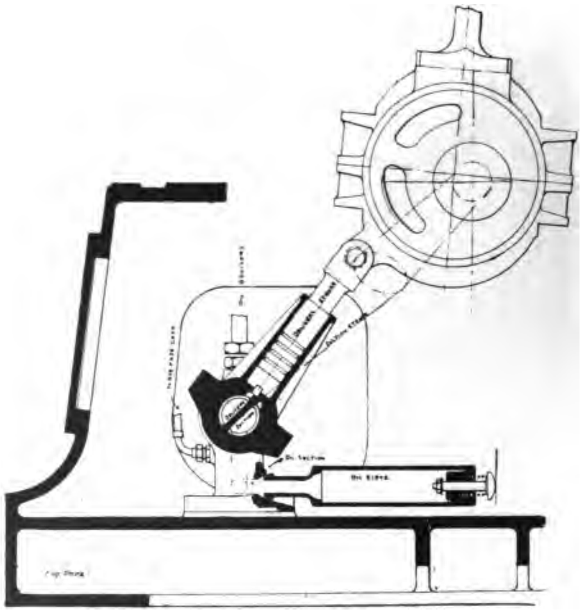


FIG. 16.—"CLAYTON" ARRANGEMENT OF VALVELESS OSCILLATING OIL PUMP.

on the crosshead guides. The valve spindle between the two sets of valves works through a long brass bush, provided with water grooves. All packings for piston and valve rods are of the United States Metallic Packing Company.

Fig. 16 shows very clearly the arrangement of valveless oscillating oil pump. It will be seen that the oil strainer can be readily detached for cleaning. Fig. 17 is a photograph of a 200 H.P. compound high speed engine, coupled to a dynamo.

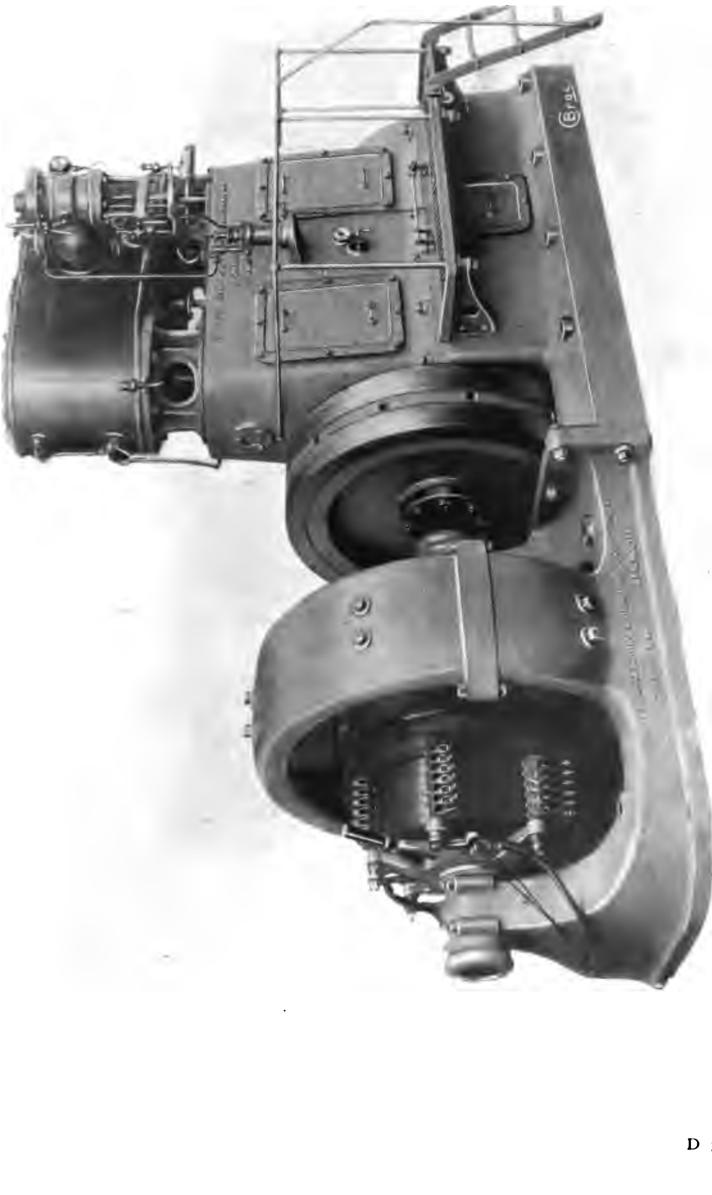


FIG. 17.—VIEW OF 200 H.P. COMPOUND "CLAYTON" ENGINE, COUPLED TO DYNAMO.

## THE "ERITH" ENGINE.

Messrs. Easton, Anderson & Goolden, Ltd., make a series of high speed engines. These engines are made from designs of Mr. Jörgen Björnstad, and possess original features, especially in the arrangement of the forced lubrication.

FIG. 18.—SINGLE CYLINDER "ERITH" ENGINE, COUPLED TO FOUR-POLE DYNAMO. 580 REVS. PER MINUTE.

Fig. 18 is from a photograph of a single cylinder high speed "Erith" engine coupled direct to a four-pole dynamo, output 20 kw. 580 revolutions per minute.

Fig. 19 is from a photograph of a three-crank compound tandem high speed "Erith" engine arranged for direct coupling to dynamo. 300 I.H.P., 400 revolutions per minute.

Fig. 20 is a sectional elevation of compound high speed engine. The smallest sizes up to 35 I.H.P. are made with

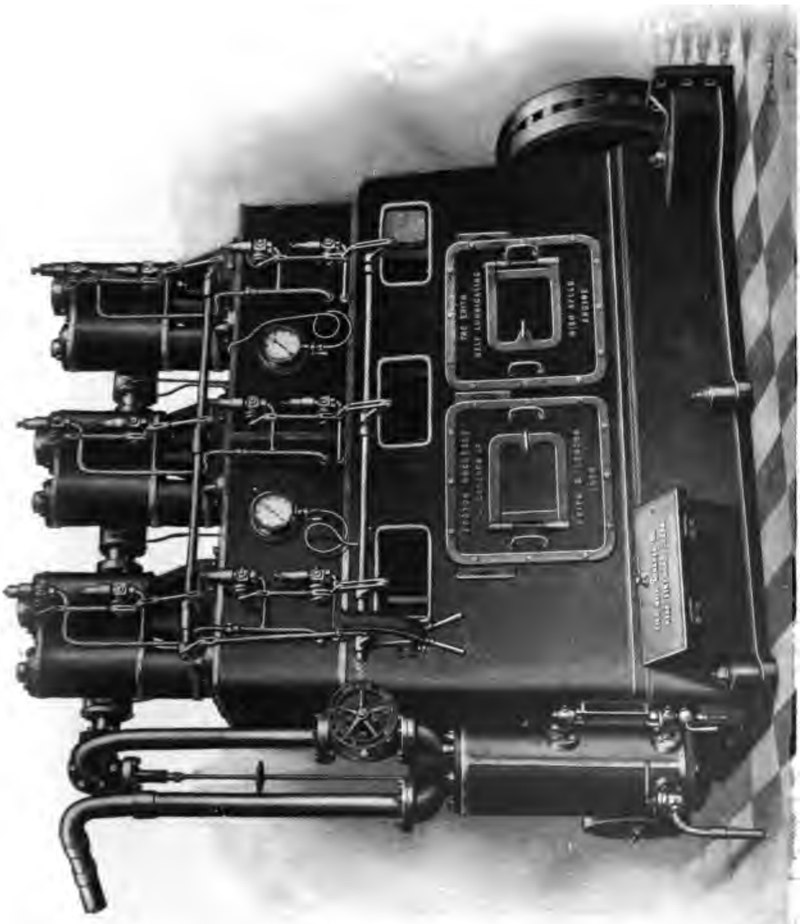


FIG. 19.—THE "ERITH" SELF-LUBRICATING ENGINE. 300 I.H.P. 400 REVS. PER MINUTE. STEAM PRESSURE, 140 LB. PER SQUARE INCH. FLOOR SPACE, 10 FT. BY 5 FT. TOTAL HEIGHT, 10 FT. 6 IN.

single cranks either with a single cylinder or with a high pressure and a low pressure cylinder arranged tandem wise. In both cases piston valves are fitted. The next sizes up to 100 I.H.P. are cross compound with cranks at 180 degrees, with one piston valve between, which serves both cylinders.

From 100 I.H.P to 300 I.H.P. two piston valves are fitted between the cylinders and are worked off an excentric, so

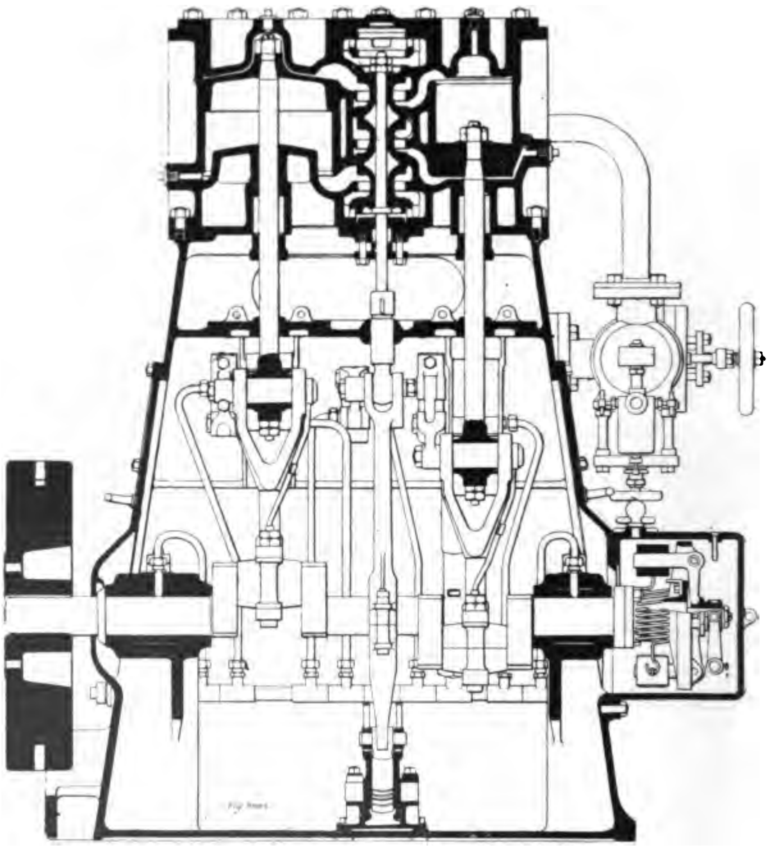


FIG. 20.—SECTIONAL ELEVATION OF "ERITH" COMPOUND ENGINE.

that their movements are identical. One valve distributes the steam to the high pressure only, while both valves are utilized for the low pressure cylinder, by which means good port areas are given with small clearances. The valve or valves are so arranged that the spindle glands are only subject to the pressure of the low pressure exhaust.

From 250 I.H.P. and upwards three-crank engines are made with one set of compound tandem cylinders over each crank. The high pressure cylinder is fitted with one piston valve, and the low pressure cylinder with two piston valves, arranged so that they can be taken out without disturbing the high pressure cylinder or its valves. The spindle of the high pressure valve passes through a passage between the two valves of the low pressure cylinder, which passage also acts as a steam pipe between the high pressure and the low pressure valve chests. The three valves are fixed to one crosshead and are driven from one excentric. The valves are arranged so that exhaust pressure only comes on the stuffing boxes for the spindles. The three-crank engines are also made as triple expansion engines by arranging the cylinders as follows:

The high pressure and one low pressure cylinder tandem over the first crank, and one intermediate pressure cylinder and one L.P. cylinder tandem over each of the two other cranks. The high pressure cylinder and the two intermediate pressure cylinders are made of the same size, so that the pistons and valves are interchangeable. The pistons are made of cast iron for the high pressure and cast steel for the low, arranged to balance each other. The lubrication is forced, and the oil is carried direct to every bearing surface by independent pipes, in accordance with Mr. Björnstad's system, so all the bearings throughout the engine are supplied with an ample quantity of oil under practically the same pressure, which is about 25 lb. per square inch. By this arrangement metallic contact between the surfaces is avoided, as there is always a film of oil under pressure between them, and the wear is thus reduced to a minimum. The mechanical efficiency is said to be 92 per cent.

The oil is pumped by a valveless pump worked from an excentric on the crank-shaft and delivered into a main placed inside the framing at the back of the engine, and led from this main through swivel pipes to the various joints. Fixed pipes lead to the crank shaft bearings and guides. An accumulator is fixed on the main pipe to allow for the pulsations in the delivery from the pump. The oil, which has pressed through the bearings, drains down into the base plate and passes through strainers in a box on the outside of the bed plate before it enters the pump again. The strainers are arranged so that one at a time may be taken out and cleaned whilst the engine is running. The governor is fixed on the end of the crank shaft and works an equilibrium throttle valve.

## Robey & Co.'s Engines.

It is questionable if any firm is more widely known than that of Robey & Co., who have been established close on half a century, and during that period have built some 20,000 engines, varying in size from 5 to 1,000 H.P.

For more than a quarter of a century Mr. John Richardson, M.I.C.E., an engineer of great energy, rare practical and theoretical knowledge, has been responsible for the designs of the numerous machines manufactured by this firm. More than twenty-five years ago Mr. Richardson made a three-cylinder compound engine to work at 500 lb. per square inch steam pressure.

About twenty-six years ago Mr. Richardson introduced the "Robey" engine, which type has been copied by a great number of engineers, both at home and abroad. It is pleasing to note that the pioneers of this very useful type of engine are still to the front.

To most readers it will be interesting to learn that some hundreds of high-speed engines have been made by Messrs. Robey & Co. having cast crankshafts of a special mixture of iron and steel. It was whilst Mr. Richardson was on a visit to the Railway Works, Brighton, that Mr. Stroudley drew his (Mr. Richardson's) attention to a large engine which had been in use many years, having a cast-iron bush upon the shaft revolving in a cast iron bearing; the idea being that cast-iron surfaces working together give better results than any other. This is confirmed by the wear of the cast-iron parts of machine tools. When they have sufficient surface the amount of wear is infinitesimal, and the wearing surfaces remain bright and smooth. It is now more than forty years since the late Mr. Robey introduced cast-iron solid slide blocks working upon cast-iron bars, and out of the many thousands that have been made in none has the wear been sufficient to need the slide bars tightening, *i.e.*, the distance between reduced. It was a knowledge of these facts that led to the introduction of cast iron of very high quality with a slight admixture of steel for use in the crankshafts of high speed steam engines. Out of several hundreds made only one case is known which resulted in an accident, and that was due to causes which would have spoiled any crankshaft. The margin of strength was very great, and the surfaces necessarily large. It was only on account of unreasonable prejudice which led to their disuse now several years ago. Siemens-Martin's steel is now used for cranks.

Such, however, has been the excellent results of their use that some of Messrs. Robey's customers who had the heavier engines insisted upon having the same material in giving repeat orders.

Fig. 21 is an external elevation of a high speed compound vertical closed type "Robey" engine, coupled with a dynamo.

It will be seen from the illustration that the whole of the working parts are enclosed within the standard surrounding the crank and effectually preventing the splashing of any oil. The working parts are lubricated from the inside, a licker fixed under the large end of the connecting-rod taking up a portion of the oil at each revolution and lubricating the crank pin. Drop lubricators in connection with slipper and piston rod are provided. This engine is made in sizes from 14 B.H.P. (500 revolutions per minute) up to 114 B.H.P. (300 revolutions per minute).

It will be seen that the simplicity of this engine is very marked. An ordinary excentric operates a common slide valve, having a fixed cut off, though this can be readily adjusted. The regulation of the steam is effected by this firm's improved centrifugal governor operating an equilibrium valve. Although this engine is styled a "closed" type, the

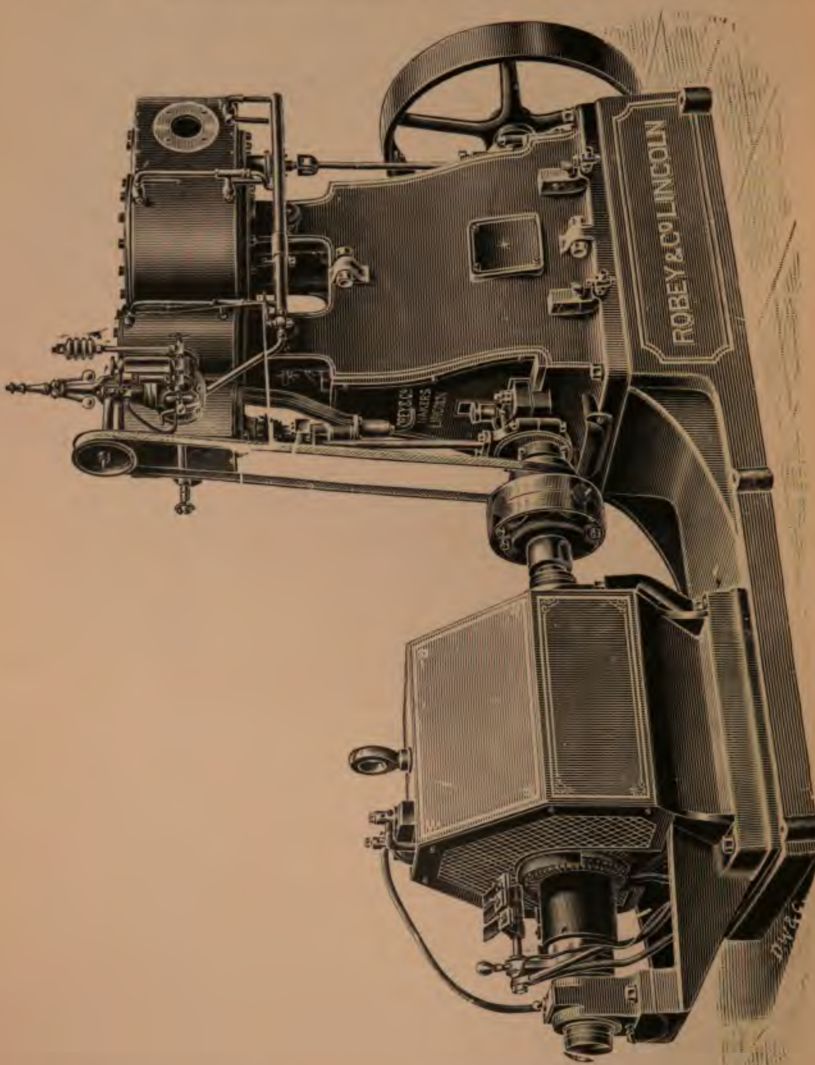



FIG. 21.—THE "ROBEY" HIGH SPEED COMPOUND ENGINE

working parts can be readily examined by simply removing the sheet steel covers.

The wearing surfaces are very much
The slide bars are of the bored type.
able if any other type can surpass
stability and right down hard work wi
attention.

Referring to the governor and equili
it will be seen that the stop valve forms

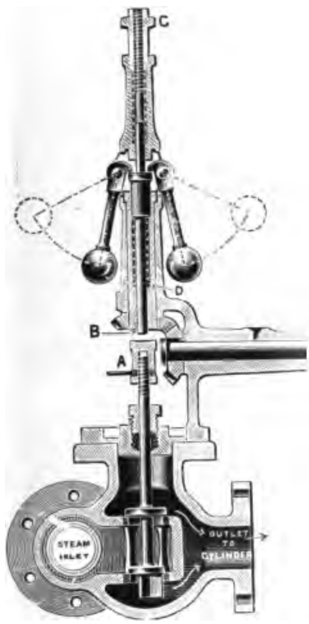



FIG. 22.—THE "ROBEY" HIGH SPEED EQUILI

body. The equilibrium valve spindl
governor spindle. When the steam i
brium valve is lifted so that the engine
amount of steam whilst the governor b
position. Since the steam valve is of
the troublesome *disturbing* action is
The main spring D is arranged in the
governor sleeve B, and the auxiliar
sleeve which is centred in the governo

position by the adjustable spool on the main spindle. By arranging the adjustable spring in an independent sleeve, the speed of the engine can be varied while running. The upper spring case can be grasped in the hand and easily held

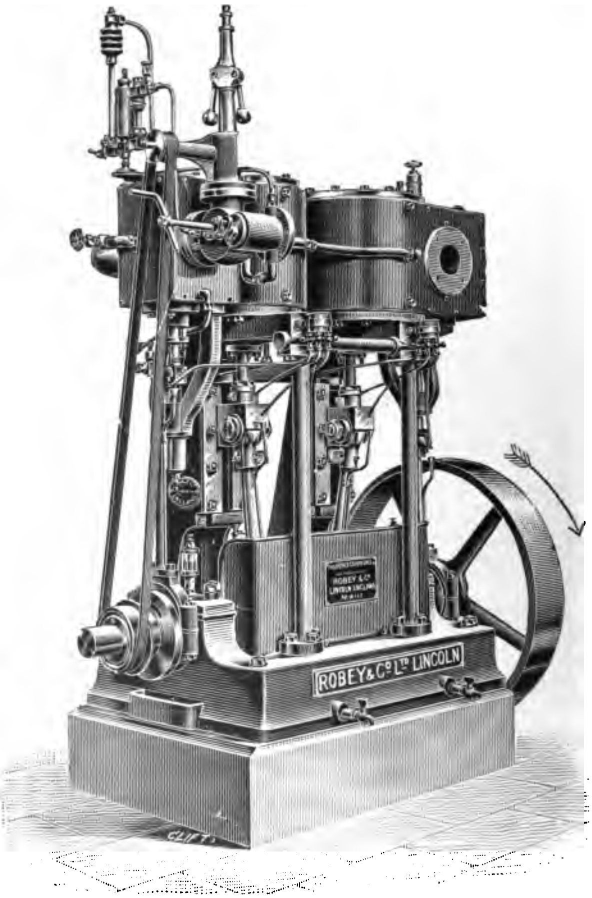



FIG. 23.—THE "ROBEY" HIGH SPEED COMPOUND VERTICAL ENGINE. OPEN TYPE.

while the governor continues to revolve without putting any additional load on the governor proper. By means of the spool C, the speed of the engine can be increased or decreased in the simplest possible manner.

Fig. 23 is an external elevation of a high speed vertical

"Robey" engine, open type. The distinguishing feature of this engine is a cross tie-rod instead of the usual entablature. This type of engine is made up to 40 B.H.P.; above this power the usual entablature is used.

Some two years ago Messrs. Robey & Co. turned their attention to high speed engines using *forced lubrication.*

Fig. 24 is from a photograph of a "Robey" high speed compound engine with dynamo. It will be seen that this

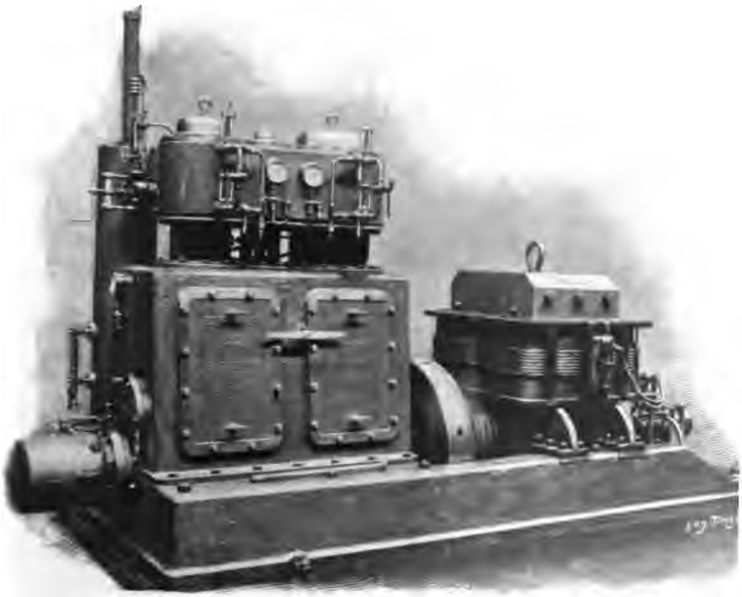


FIG. 24.—"ROBEY" COMPOUND ENGINE OF THE VALVE CLASS, SHOWN WITH DYNAMO.

engine belongs to the "Central" valve class, *i.e.*, one val common to the two cylinders. Forced lubrication is er ployed and a shaft governor operating a double-beat stea valve.

Fig. 25 is from a photograph of a "Robey" high spe compound engine with dynamo. The distinguishing featu in this engine is the use of independent valves to ea cylinder. For the low pressure cylinder the ordinary valve is used.

Some time since Messrs. Robey & Co. informed us that they were having two engines built exact duplicates and tested with the same dynamo, one with a central valve (Fig. 24), and one with a piston on the high pressure and a flat slide on the low. There is always a risk of leakage with a piston valve, and in the cases of the central piston valve the boiler pressure, say 150 lb. per square inch, on one

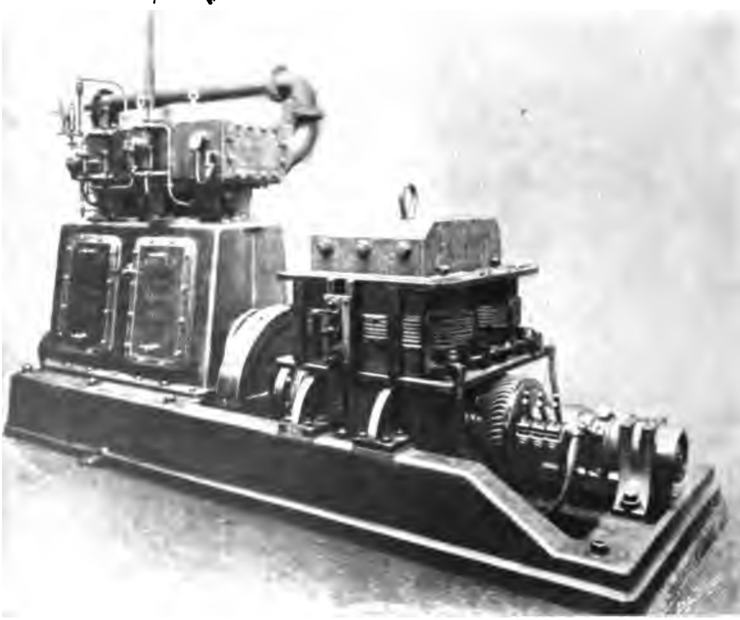
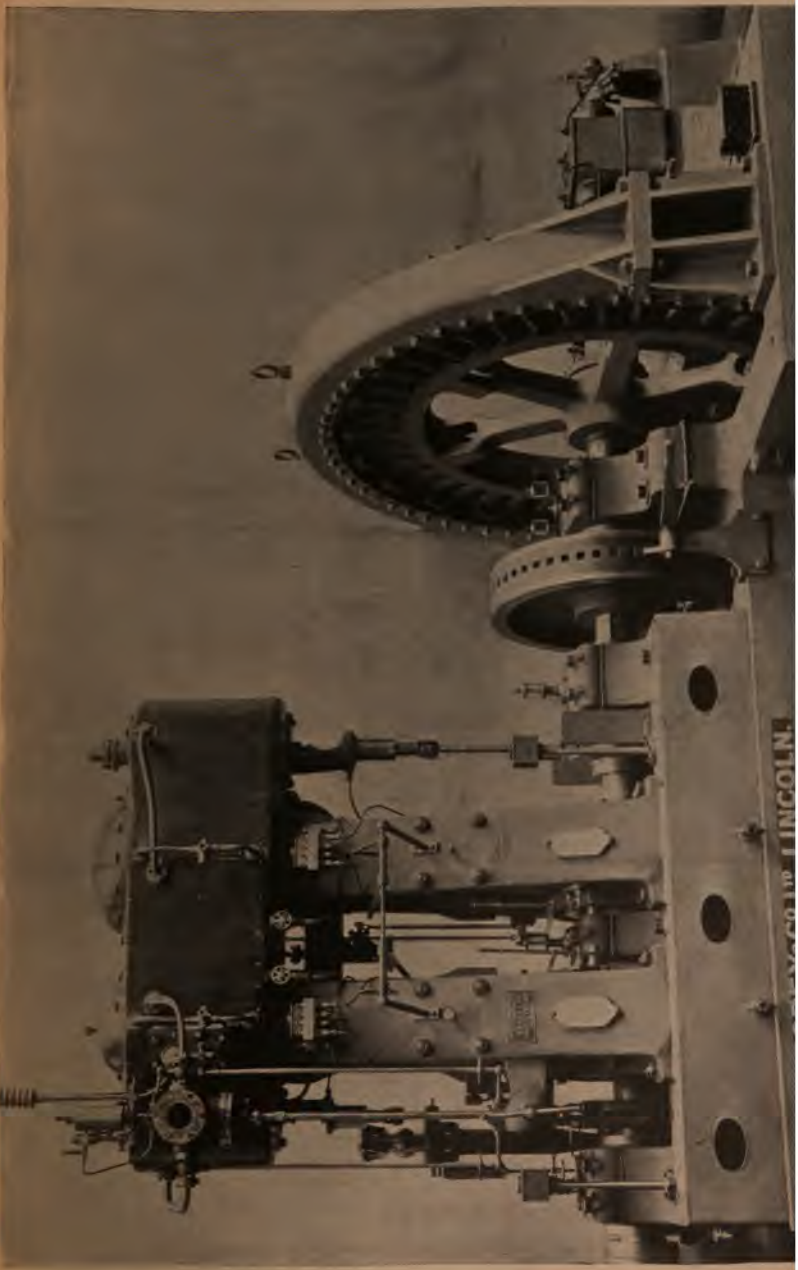


FIG. 25.—"ROBEY" COMPOUND ENGINE, DESIGNED WITH INDEPENDENT VALVES TO EACH CYLINDER, SHOWN COUPLED TO DYNAMO.

side has just a possibility of leaking past the valve, the exhaust port of which is open to the atmosphere. The leakage may be very small, especially when the engine is new and in good condition, but eventually becomes a serious item. There is the further disadvantage of the cooling action of this valve, which has the two extremes of pressure and temperature to contend with, whereas when the valves are separated the high pressure valve works always at a high temperature, and the low pressure at a low, and this


LINCOLN.

last effectually prevents leakage into the atmosphere or condenser.

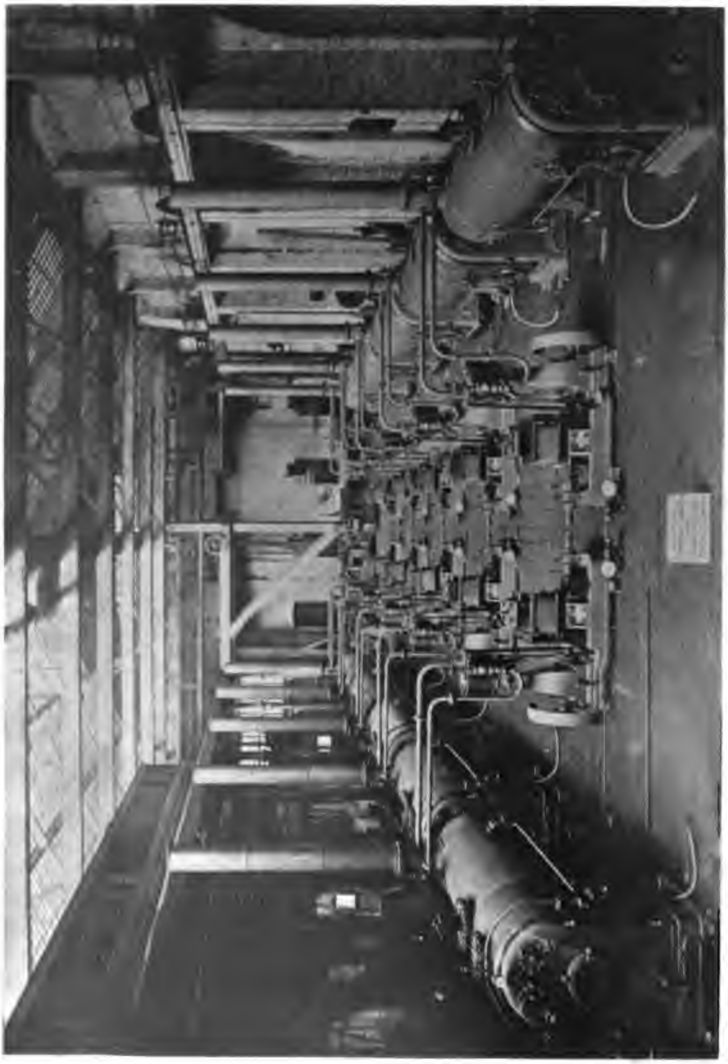


FIG. 27.—GROUP OF TEN "ROBEY" ENGINES, "TYNE" DYNAMOS AND LOCOMOTIVE BOILERS, SUPPLIED TO THE WAR OFFICE.

Messrs. Robey & Co. inform us that the tests show a very considerable advantage in steam economy in favour of the two independent valve engine.

valveless type driven from the excentric strap, the pump being placed in the bed plate of the engine and provided with a suction rose. From this pump copper pipes are taken to the four main bearings, guide bars, crossheads, crank pins, and excentric, and lubricated under an oil pressure of from 10 lb. to 15 lb. per square inch.

The engine and dynamo shown in Fig. 29 is one of three

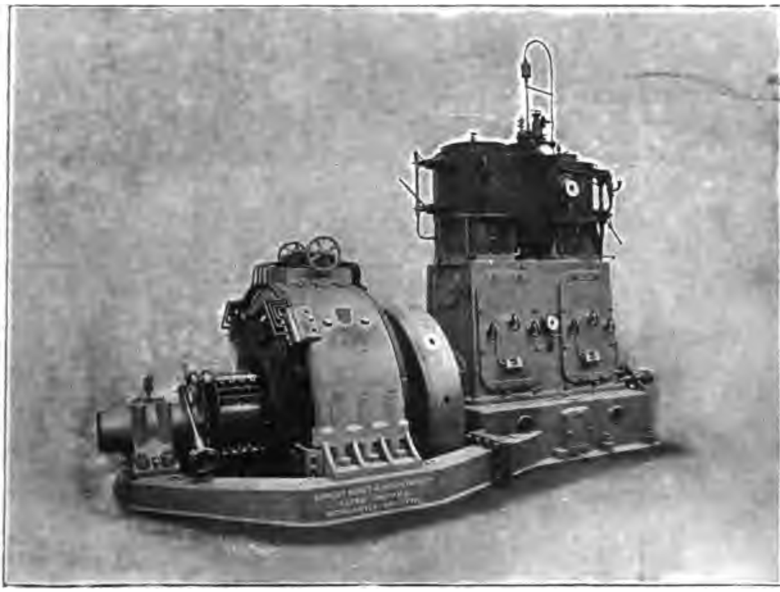


FIG. 29.—ERNEST SCOTT AND MOUNTAIN'S COMPOUND CENTRAL VALVE ENGINE, WITH DYNAMO COMBINED.

sets supplied by Messrs. Ernest Scott and Mountain to the Hill of Howth Electric Railway for the Great Northern Railway of Ireland. This combination has proved very successful. Recent installations by this firm include four sets for the Darlington Corporation for town lighting and two for the Birkenhead Corporation.

Fig. 30 is from a photograph of Scott and Mountain's single cylinder high-speed engine, "open" type.

The steam valve is of the block piston type without springs or rings. The governor is of the well-known "Pickering"

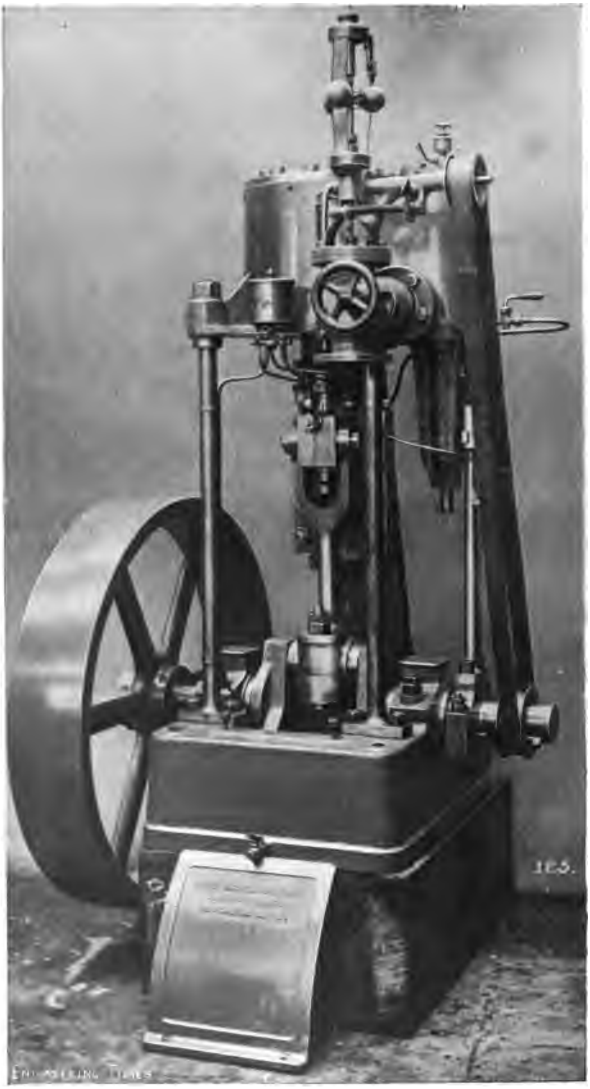


FIG. 30.—ERNEST SCOTT AND MOUNTAIN'S SINGLE CYLINDER HIGH SPEED ENGINE. "OPEN" TYPE.

type actuating an equilibrium valve. The crank is of cast steel arranged with counter's weight and ring with centrifugal lubricator for crank pin. The bearing surfaces are unusually large.

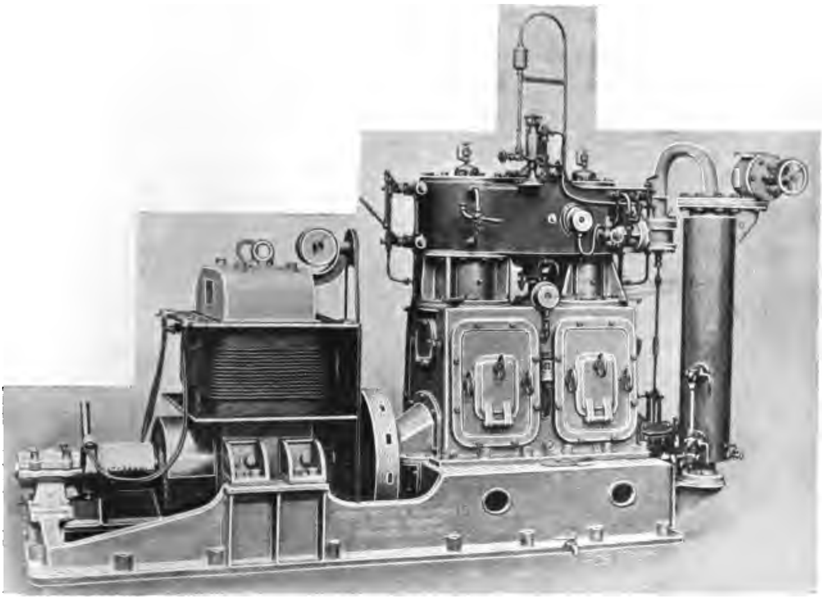


FIG. 31.—ERNEST SCOTT AND MOUNTAIN'S CENTRAL VALVE ENGINE, COUPLED TO A "TYNE" DYNAMO.

## RANSOMES, SIMS & JEFFERIES' ENGINE.

This well-known firm's practice calls for no general introduction. Fig. 32 is from a photo of a single cylinder, "open" type, high speed engine coupled direct to a dynamo. By referring to the illustration it will be seen that an automatic expansion shaft governor acts direct on the steam valve, which is of the piston type, controlling the cut-off in proportion to work done with the full advantage of the boiler pressure. The crosshead gudgeon and the crank pin are both of large diameter, and the width of each of these bearings is equivalent to twice the diameter. We are strongly of the opinion that some makers have sadly neglected the bearing surfaces in high speed engines, especially the small end of connecting rods. A connecting rod should consist of the least possible number of loose parts, and should be get-at-able. Ransomes' engine conforms to this.

Fig. 33 shows a Ransomes' high speed engine, "open" type, fitted with a crank shaft throttle valve governor. This system is not so efficient as the previously described direct method of governing, though it is free from the objectionable

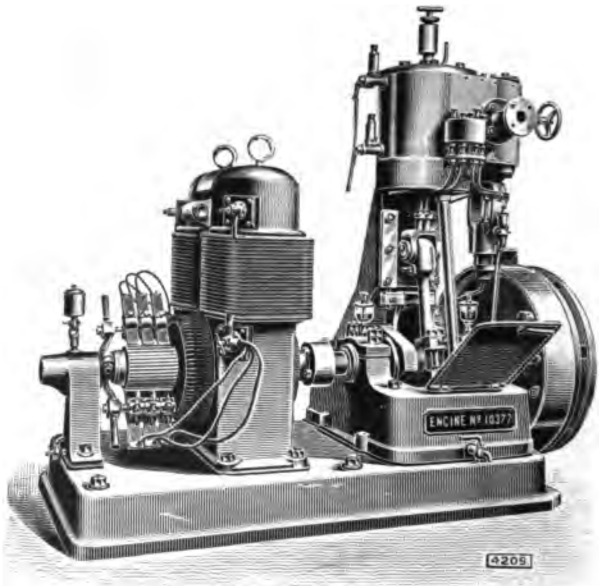



FIG. 32.—RANSOMES' SINGLE CYLINDER "OPEN" TYPE ENGINE (COUPLED DIRECT TO DYNAMO), FITTED WITH AUTOMATIC EXPANSION SHAFT GOVERNOR.

belt driven governing. These engines are built with cylinders of $5\frac{1}{2}$ × 5 stroke to $10\frac{1}{2}$ × 10 stroke, and with a piston speed of from 300 to 500 ft. per minute, suitable for a steam pressure of 100 lb. per square inch.

The misleading term I.H.P. is rightly pointed out by this firm as follows:—

If the engine is worked at 30 to 40 lb., add 65 per cent. to the B.H.P. for the I.H.P.

If the engine is worked at 50 to 60 lb., add 45 per cent. to the B.H.P. for the I.H.P.

If the engine is worked at 70 to 100 lb., add 25 per cent. to the B.H.P. for the I.H.P.

The additional B.H.P. obtained by a condenser, if the cut-off is unaltered, is the same for any given number of revolutions independently of the boiler pressure; the additional I.H.P. will be the same as the additional B.H.P.

Fig. 34 shows very clearly Ransomes' shaft governor. It will be seen that the governor consists of a circular

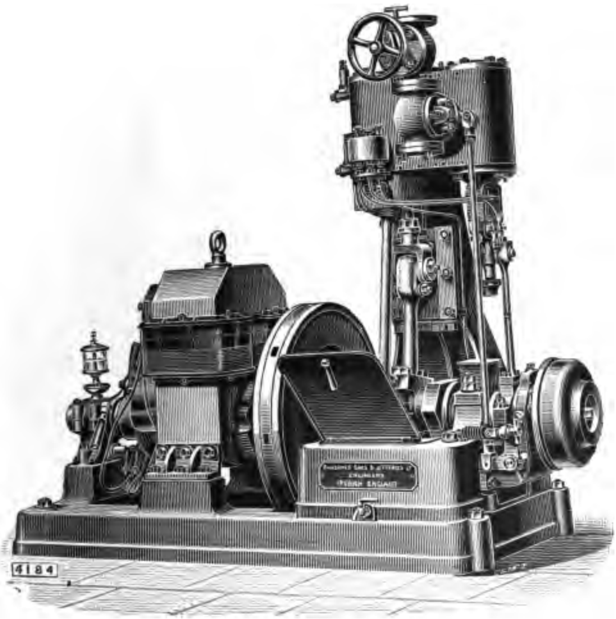


FIG. 33.—RANSOMES' ENGINE (COUPLED TO DYNAMO), FITTED WITH CRANK SHAFT THROTTLE VALVE GOVERNOR.

casing, keyed on the shaft, and carrying on one side a pair of symmetrically arranged weights, each of which is jointed to the casing at one end, while being free at the other end to move in a plane vertical to the shaft. On the other side of the circular casting are affixed a pair of straps forming a circular recess, the centre of which is at a distance from that of the shaft. A disc is fitted into the recess, and on the disc, with its centre at a distance from the centre of the disc, is the excentric which operates the slide valve. The weights are made with bosses which pass through holes in the circular casting, and are connected by links to studs on the disc. The weights, in moving outwards by the action of centrifugal force, compress spiral springs, and at the same time rotate the disc in its recess, thus changing the position of the centre of the excentric so as to vary the cut-off of the valve. The resistance of the spiral springs can be adjusted to

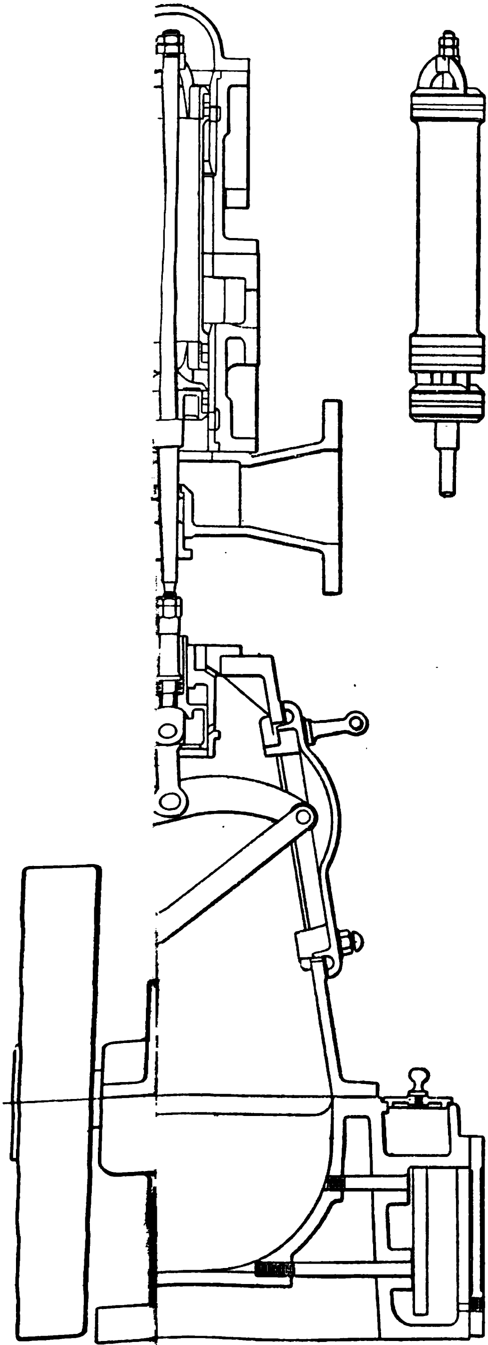
FIG. 34.—RANSOMES' AUTOMATIC SHAFT GOVERNOR.

suit the particular speed at which the engine is required to run.

*Reversing.*—When the shaft governor is applied to engines to run in either direction, the disc is provided with two studs for each of the links. To reverse the engine it is only necessary to shift the links from stud to stud.

## THE "PEACHE" ENGINE.

Fig. 35 is an external elevation, Fig. 36 is a part sectional elevation, and Fig. 37 is a sectional end elevation of "Peache" engine made by Messrs. Davey, Paxman & Co., Colchester.



LEVATION.

[*To face p.* 56.

This is a single-acting engine, the inertia of the pistons being balanced on the up-stroke by compression of steam in the space between high pressure and low pressure pistons, while the inertia of the valves on the up-stroke is balanced by compression of air in an air buffer cylinder provided for this purpose.

A peculiarity which at once attracts attention is the position of the crankshaft, which is placed in front of the axis of the cylinders by an amount equal to the throw of the

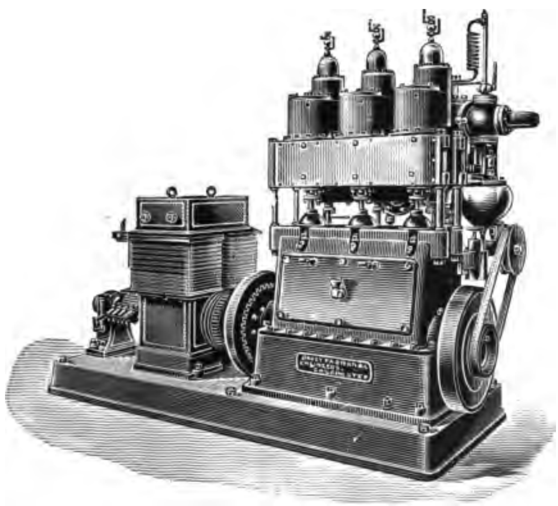


FIG. 35.—THE "PEACHE" SINGLE-ACTING ENGINE, SHOWN COUPLED DIRECT TO DYNAMO.

crank. The reason for this is that in a single-acting engine a central position of crankshaft entails a double action on the crosshead and crosshead pin, viz., the crosshead is thrown from side to side of the slides on each up and down stroke as the angularity of the connecting-rod is reversed. With the crankshaft placed out of line of the cylinders, as in the "Peache" engine, the angularity of the connecting-rod is always towards the back slide of crosshead, and the pressure on this slide is thus maintained. At the same time, the angularity of the connecting-rod is slight during the down or working stroke, while, on the up-stroke, when the angularity

**is considerable, the pressures are slight. The valve gear is also unusual. Excentrics are done away with, thus leaving room for long and well supported crankshaft bearings.**

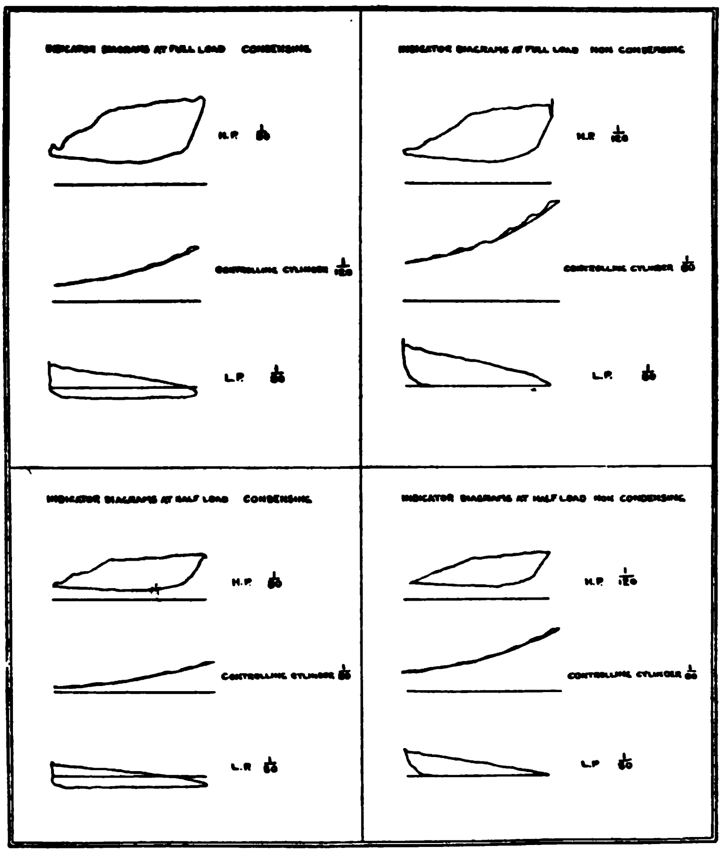


Fig. 38.

Motion for the valves is taken from a point on the connecting rod. This form of valve gearing allows of a much better steam distribution between high pressure and low pressure than could be obtained from an ordinary excentric motion.

Admission of steam is controlled by a throttle valve and centrifugal governor, and passes to a branch on the low-pressure cylinder casting, and thence outside the three high-pressure valves to high-pressure cylinder. It is then exhausted over the top of the high-pressure valve and through the centre of this valve to the low-pressure cylinder, and, finally, under the low-pressure valve to the exhaust.

Pressure is maintained in the space between the high-pressure and low-pressure pistons (called the controlling cylinder) by means of bye-pass ports, which are uncovered by the high-pressure piston near the top of its stroke. The steam then expands in this space during the down-stroke, and is compressed again during the up-stroke, the indicator-card (see Fig. 38) taken from this cylinder showing a line and line diagram. It will be noticed that the steam acts on the underside of the low-pressure piston, and at first sight it would appear that the engine must be double-acting. This power, exerted in the low-pressure cylinder, is not, however, directly transmitted to the crankshaft, but is first utilised in compressing steam in the controlling cylinder and in driving steam out of the high-pressure cylinder against the receiver pressure, and this work, so far as the controlling cylinder is concerned, is given out by expansion of the steam in that cylinder on the next down-stroke, while the work done in forcing steam out of the high-pressure cylinder against the receiver pressure is returned in work done by this steam on the low-pressure piston.

In the design of this engine care has been taken to keep everything of simple and strong design. There are no external glands or complicated parts. Every part of this engine is readily accessible. The engine is made of the three-crank tandem compound pattern in order to provide for even turning and absence of vibration.

The following are results of some one hundred and fifty high-pressure "Peache" engines now working in a central station. For this station, as in so many stations, it was specified that the engines should usually work with a condenser, but should be capable of taking the whole load non-condensing when required. The results, therefore, do not give the best figures that could be obtained, either condensing or non-condensing, but give the best compromise between the two conditions.

"PEACHE" 150 H.P. HIGH SPEED COMPOUND ENGINE.

| | Condensing. | Non-condensing. |
|---|---|---|
| | lbs. per sq. in. | lbs. per. sq. in. |
| Steam chest pressure | 94 | 119 |
| Revolutions | 438 | 438 |
| M.E.P. | 40·01 | 42·96 |
| I.H.P. | 141 | 150·5 |
| E.H.P. | 124·3 | 128·0 |
| | per cent. | per cent. |
| Efficiency | 88·3 | 85 |
| Steam per I.H.P. hour | 18·4 | 22 |
| ,, E.H.P. ,, | 20·9 | 25·8 |
| ,, K.W. ,, | 28·1 | 34·6 |
| | lbs. per sq. in. | lbs. per sq. in. |
| Steam chest pressure | 51 | 77 |
| Revolutions | 441·7 | 441 |
| M.E.P. | 23·58 | 24·1 |
| I.H.P. | 83·5 | 85·25 |
| E.H.P. | 66·6 | 65·7 |
| | per cent. | per cent. |
| Efficiency | 79·7 | 77 |
| Steam per I.H.P. hour | 20·3 | 26·9 |
| ,, E.H.P. ,, | 25·4 | 35·0 |
| ,, K.W. ,, | 34·1 | 46·8 |

## THE "SCOTT" COMPOUND ENGINE.

A novel type of high speed compound engine is made by Messrs. Reavell & Co., and known as the "Scott" Compound Engine. (See Figs. 39 and 40.) The distinguishing features are as follows :—

The second stage of expansion in a compound or two-stage expansion engine is usually obtained by transferring to a larger cylinder the steam which has just completed its first stage of expansion in the smaller, or high pressure cylinder.

The same effect, however, can be obtained by transferring only a portion of the steam which is already expanded in the first cylinder, in which case the second cylinder may be of the same size as the first cylinder, and the portion transferred will be further expanded in the second cylinder, the portion remaining in the first cylinder being utilised, as will be described later.

The first cylinder would be equivalent to the high pressure

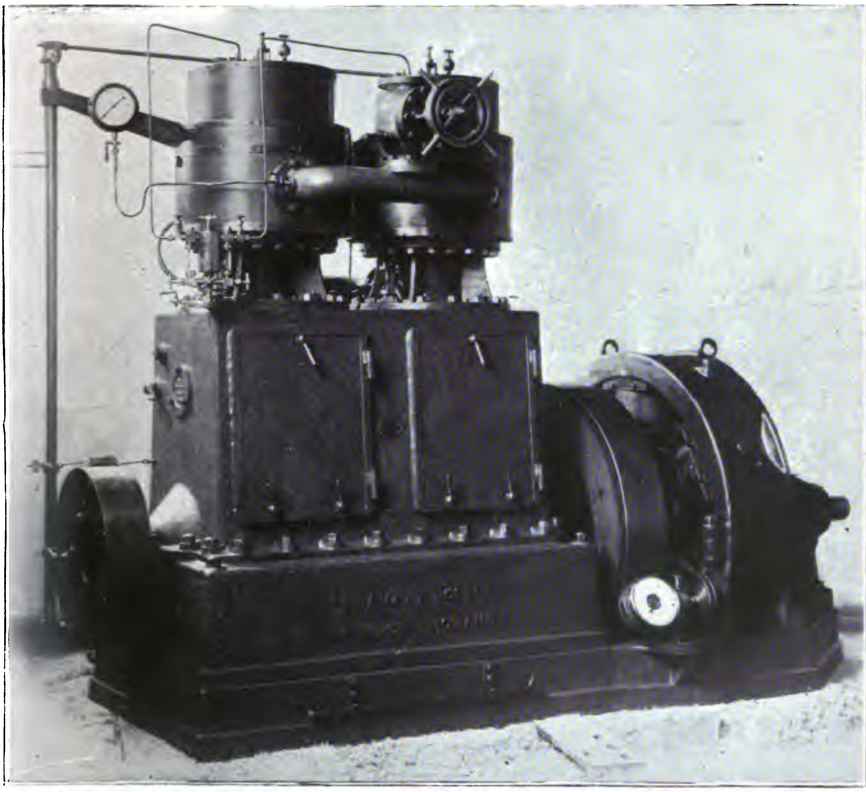


FIG. 39.—THE "SCOTT" COMPOUND ENGINE, ATTACHED TO DYNAMO.

cylinder, and the second cylinder to the low pressure cylinder in an ordinary compound engine.

This latter method is adopted in the "Scott" Compound Engine, the only difference being that, instead of employing two cylinders, the first stage of expansion takes place on the top of the piston, and the second stage on the bottom of the piston, in one cylinder.

The cycle will be made clear by reference to the theoretical diagram Fig. 41.

Steam is admitted at W, into a cylinder having a con-

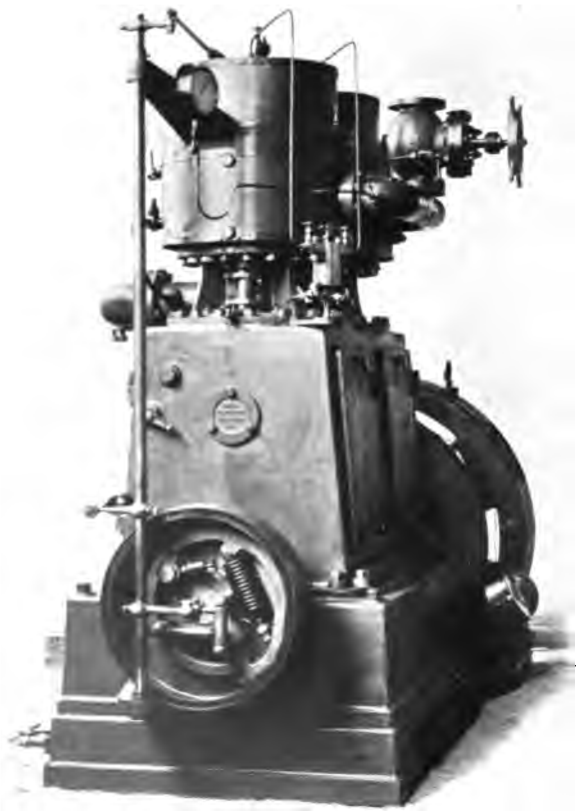


FIG. 40.—END VIEW OF "SCOTT" ENGINE, SHOWING GOVERNOR.

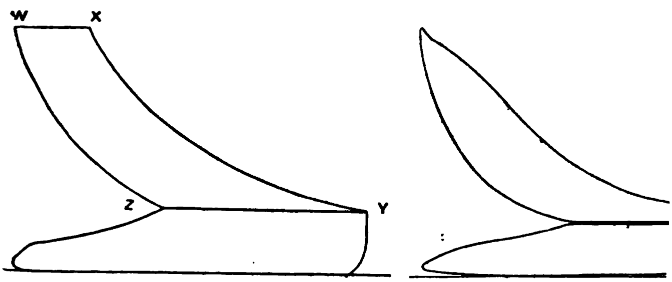
siderable clearance volume above the piston at the beginning of the stroke. This clearance volume is already filled with steam at boiler pressure, having been compressed

during the latter part of the preceding stroke, as v
explained below.

Cut off takes place at X, the actual point being vaı
the governor to suit the variations of load.

The total steam in the cylinder, which include
already in the clearance space at the beginning of the
then expands during the remainder of the down-strok

As the piston is turning the bottom centre a con
cation is opened between the top and the bottom
cylinder, which remains open till *Z*, transferring a
of the steam to the under side, where its second s
expansion takes place till the termination of the up




THEORETICAL DIAGRAM. ACTUAL DIAGRAM.

FIG. 41.—THE "SCOTT" ENGINE. DIAGRAMS.

just in the same way as it would do if transf
exhausted to a separate cylinder.

The steam which remained above the piston at t
*Z*, when the communication from the top to the
of the cylinder was closed, is compressed up t
pressure W.

Referring to the sectional views of a single cylind
(Fig. 42), it will be seen that the steam inlet flange
body of the cylinder itself, there being a steam
considerable size between the working barrel and th
of the cylinder, and between the inner and the oute

The valves of the engine reciprocate in a cen
liner secured in the bottom of the cylinder as sh
the piston reciprocates in the annular space bet

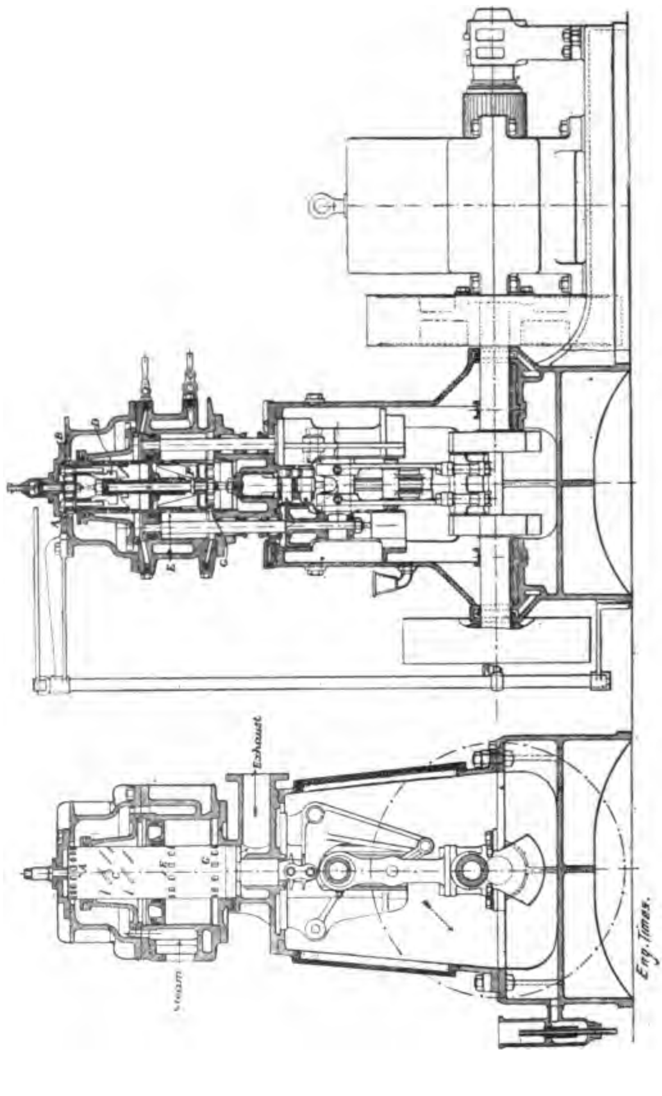



FIG. 42.—THE "SCOTT" CENTRAL VALVE ENGINE.

liner and the cylinder walls. The steam, entering through the stop valve, passes up between the inner and outer cylinder walls and covers, and is admitted into the valve liner through ports (A) near the top. The available area through these ports is regulated by a multi-ported throttle valve (B), as afterwards described.

From the inside of the liner the steam passes into the cylinder through spiral ports (C) up to the point of cut off, the clearance space shown above the piston being already filled with steam up to initial pressure, as before stated, and the cut off being effected by the valve (D), driven by the slide rod.

After an early cut off, the precise point of which is controlled directly by the governor, the steam expands during the remainder of the down-stroke, and while the crank is turning the bottom centre, the ports (E) in the centre of the liner about halfway in the stroke of the engine are opened by the valve (F), called the transfer and exhaust valve.

This valve (F), at the same time, opens the ports (G) at the bottom of the cylinder, so that while the piston is making its up-stroke a communication is made between the top and bottom of the cylinder, transferring steam at equal pressure and temperature, from the top to the bottom of the piston. This transfer continues for about half the stroke. In other words, about one-half of the steam which was above the piston is transferred to the other side.

The transfer is closed first by the piston overrunning the ports (E) in its upward stroke, and immediately afterwards by the valve (F) closing the ports (E) and (G).

The steam transferred to the under side then completes its second stage of expansion, and at the end of the upward stroke the exhaust valve opens and allows this steam to escape to the atmosphere or the condenser.

In the meantime, the steam which remained in the cylinder above the piston, when the transfer closed is compressed during the latter half of the upward stroke, and the clearance space in the cylinder is so proportioned that this steam shall be compressed to initial pressure, when the termination of the stroke is reached, and the valve (D) opens for the next admission of steam. By this means the reciprocating parts are brought to rest, and the inertia is taken up by means of the working fluid itself, while, at the same time, the parts which will be first touched by the entering steam are already heated up to initial temperature, and thus cylinder condensation is reduced.

LIST OF SIZES AND POWERS.

| Diameter of Cylinder. | Stroke. | Revolutions. | SINGLE CRANK TYPE. B.H.P. available with varying steam pressures. | | | TWO CRANK TYPE. B.H.P. available with varying steam pressures. | | |
|---|---|---|---|---|---|---|---|---|
| | | | 120 lb. | 140 lb. | 160 lb. | 120 lb. | 140 lb. | 160 lb. |
| 12″ | 6″ | 560 | 29 | 35 | 43 | — | — | — |
| 14″ | 7″ | 500 | 41 | 50 | 61 | 82 | 100 | 122 |
| 16″ | 8″ | 450 | 55 | 70 | 82 | 110 | 140 | 164 |
| 18″ | 9″ | 415 | 72 | 90 | 108 | 144 | 180 | 216 |
| 20″ | 10″ | 385 | 92 | 115 | 137 | 184 | 230 | 274 |
| 22″ | 11″ | 360 | 114 | 140 | 171 | 228 | 280 | 342 |
| 24″ | 12″ | 340 | 140 | 175 | 210 | 380 | 350 | 420 |
| 28″ | 14″ | 310 | 203 | 255 | 304 | 406 | 510 | 608 |
| 32″ | 16″ | 290 | 283 | 350 | 425 | 566 | 700 | 850 |
| 36″ | 18″ | 270 | 374 | 470 | 562 | 748 | 940 | 1124 |

The pressure on the bearings of the engine is always in a downward direction, ensuring silent running, even after the bearing surfaces become worn.

Very accurate and regular governing of the speed of the engine is obtained by a crank-shaft governor, which both varies the point of cut off of the admission valve (D), and also reduces the area through the throttle valve (B). The position and size of the openings in the throttle valve (B) are so arranged, however, that throttling does not take place except at light loads.

This throttle valve (B) has two guide studs fixed to it, which pass through holes in the admission valve (D).

The valve (D), though reciprocated by the slide rod, and having a constant stroke, is free to be rotated by the guide studs on the throttle (B), and the ports in this admission

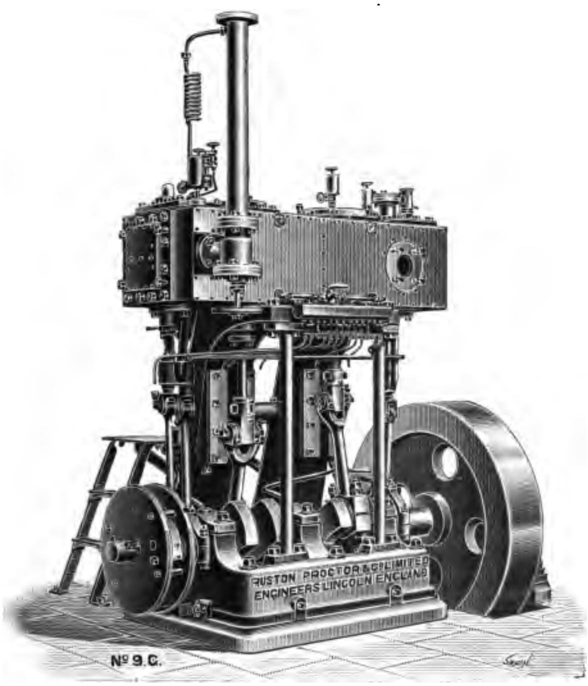



FIG. 43.—RUSTON, PROCTOR & CO.'S COMPOUND (OPEN TYPE) ENGINE.

valve (D) are so arranged in connection with the ports in the valve liner itself that a slight axial movement will cause an alteration in the point of cut off.

The valves are driven by a radial form of valve gear, operating from a point in the connecting rod, and the positions of the valve gear centres are so chosen as to enable a considerable variation in the point of cut off to be obtained, with an exceedingly slight change in the amount of lead.

An oil and water bath is formed in the bottom of the crank chamber, into which the bottom end of the connecting rod dips at every revolution, throwing a constant stream of lubrication over the working surfaces.

All the bearings have exceptionally large surfaces, so that they are subjected to low pressures per unit of area.

## Ruston, Proctor & Co.'s Engine.

Fig. 43 is from a photograph of a high speed compound engine (open type), made by Messrs. Ruston, Proctor & Co., Lincoln.

By referring to the illustration it will be seen that the main standards form distance pieces between the cylinders and basic plates, and are fitted with slide bars. These distance pieces are also supported in front by columns. The admission of steam to the high pressure cylinder is controlled by this firm's automatic crank-shaft governor acting upon a slide valve, which rides on the back of the main slide valve, the latter valve having a fixed travel. This arrangement of valves ensures a free exhaust to the low pressure cylinder under great variation of load. The whole of the

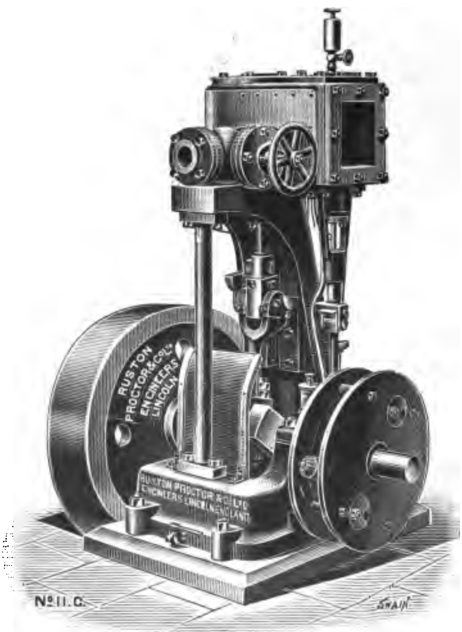


FIG. 44.—RUSTON, PROCTOR & CO.'S SINGLE CYLINDER ENGINE.

working parts are lubricated from one central oil box. The cranks are set opposite each other, and are balanced. These engines have a piston speed of about 450 ft. per minute.

Fig. 44 is from a photograph of a high speed single cylinder engine, fitted with automatic crank-shaft governor, controlling a flat slide valve.

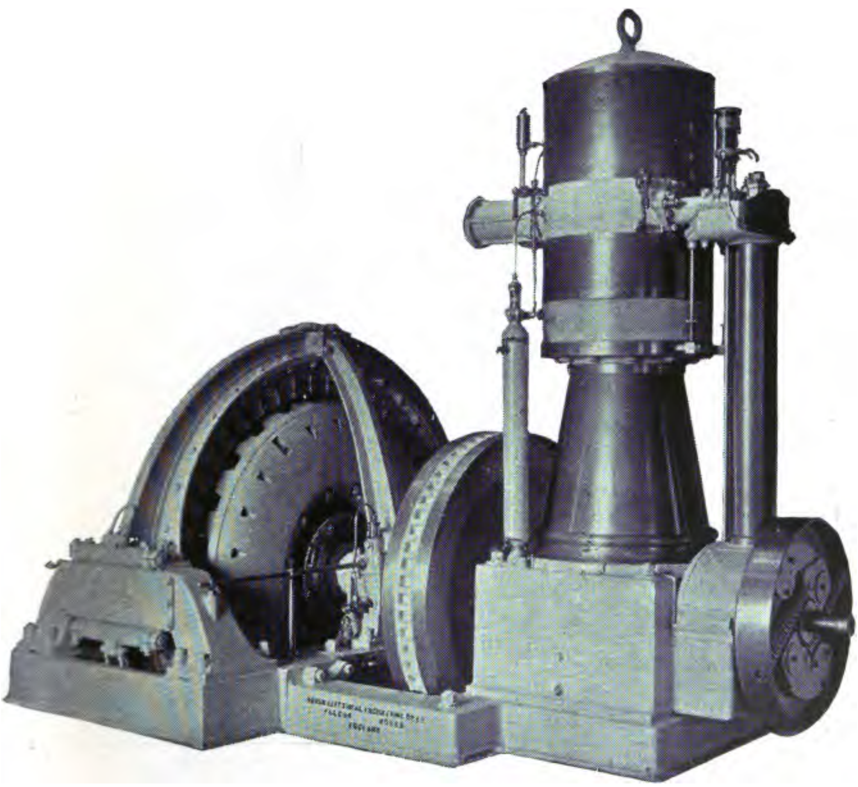
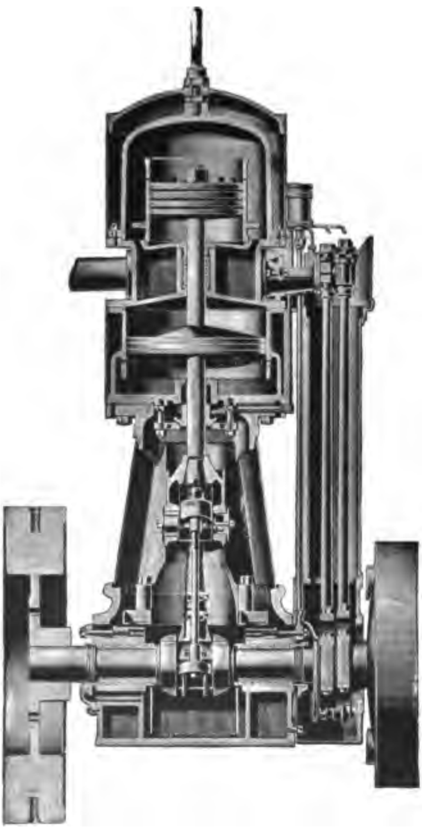


FIG. 45.—THE "UNIVERSAL" ENGINE COUPLED TO DYNAMO.

## THE "UNIVERSAL" ENGINE.

The high speed engine, which is shown in Fig. 45 coupled direct to a Mordey-Victoria Alternator, from the designs of Mr. J. S. Raworth, chief engineer and co-manager to the Brush Electrical Engineering Company, Limited, has many novel features, and is a distinct departure in high speed engine construction.

Figs. 46 and 47 show, by vertical sections in the line of the crank shaft and transversely to it, the whole of the arrangements of the parts.



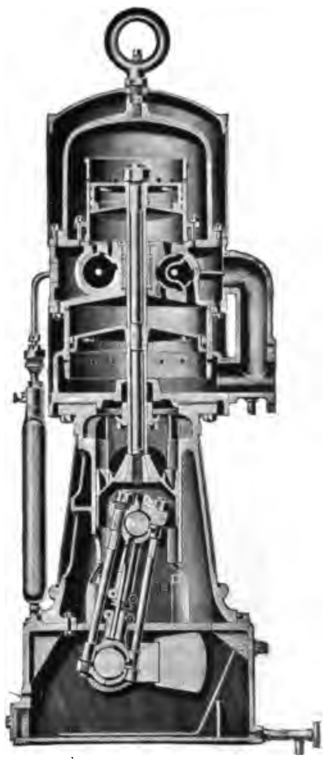


FIG. 46.—LONGITUDINAL VERTICAL SECTION. FIG. 47.—TRANSVERSE VERTICAL SECTION.
THE "UNIVERSAL" ENGINE.

In this engine "Corliss" valves are used in lieu of piston or slide valves. The object of using "Corliss" valves is to reduce the clearance; this they accomplish with highly satisfactory results. The high-pressure steam acts on the underside of the high-pressure cylinder, and, when the piston has approached the upper limit of its stroke, exhausts through a number of holes, as shown, into a surrounding receiver. The high-pressure cylinder is, it will be seen, jacketed inside and outside by steam at the pressure of the receiver. On the commencement of the down stroke of the pistons the steam in the receiver and high-pressure cylinder acts on the upper part of the low-pressure cylinder, very free exhaust being obtained by a circumferential ring of holes, as in the high-pressure cylinder, and by the opening of the exhaust valve. In the section, Fig. 47, the valves are shown as closed, both to exhaust and inlet, the piston performing the up stroke. Cushioning is effected in the ordinary way in double-acting engines, and water is easily got rid of. From the high-pressure cylinder it descends into the low, from which it passes away freely into the lower exhaust chamber through the ring of holes in the lower part of the cylinder. In the high-pressure cylinder it collects in the annular channels shown (Fig. 47), from which it freely passes away through the low-pressure valve by the large port shown and channels leading from it. From the receiver the water passes through two side ports into the cavities *a* (Fig. 48), and thence through the valve box into the low-pressure cylinder. The exhaust from the low-pressure cylinder, which does not pass away by the holes when the piston is at the bottom of its stroke, passes through the valve and thence by the valve casing into the lower exhaust chamber. The connection between the low-pressure exhaust port and the exhaust pipe is through the ends of the valve, but this cannot be shown clearly in the engravings. The method of driving the valves is such that

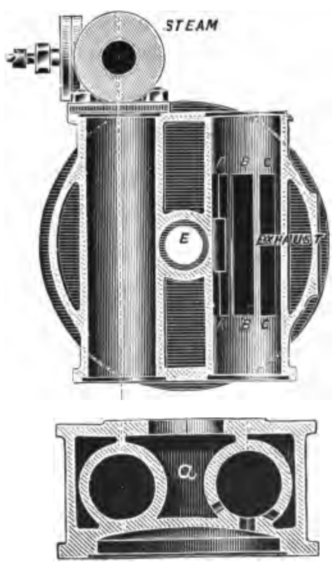



FIG. 48.—VALVE CHEST OF "UNIVERSAL" ENGINE.

each valve can automatically take up wear like an ordinary slide valve. The high-pressure valve wears upward and the low-pressure downward. The function of the upper part of the low-pressure valve is simply to isolate water which may lodge in the valve cavity from the high-pressure steam. The ports communicating through low-pressure valve between the receiver and the low-pressure cylinder are seen at *a* Fig. 48; the section Fig. 47 being on the centre line, does not show them. The valves are worked by ordinary excentrics, one of which is controlled by a shaft governor.

WATER CONSUMPTION TESTS OF "UNIVERSAL" ENGINE. *September 2nd*, 1896.

| Indicated Horse Power. | Total Weight. | Water per Indicated Horse Power. |
|---|---|---|
| 15 | 405 | 27 |
| 30 | 615 | 20·5 |
| 33·5 | 675 | 20·1 half load in E.H.P. |
| 42·3 | 840 | 19·8 |
| 43 | 852 | 19·8 |
| 44·8 | 888 | 19·8 full load. |
| 55 | 1·150 | 20·9 |

The above is an extract of an independent test made of an engine having cylinders 9$\frac{3}{16}$ in. and 14½ in., running 450 revolutions per minute, the boiler pressure being 140 lb. per square inch.

## T. COULTHARD & CO.'S ENGINE.

The compound and triple high speed engines which are shown in Figs. 49 to 55, from the designs of Mr. W. Norris, of the firm of Messrs. T. Coulthard & Co., are a distinct departure in high speed engine construction. Fig. 49 is an external view, Fig. 50 a sectional elevation, and Fig. 51 is a part sectional end view of a compound high speed engine. Here the usual central bearing is dispensed with, reducing the rocking couple to a minimum, whilst the arrangement of the cylinders effectively minimizes the lateral couple. The supply of steam, under the control of a "Pickering" governor, enters the high pressure valve chest and fills the hollow piston valves, passing to the lower end. The exhaust, which

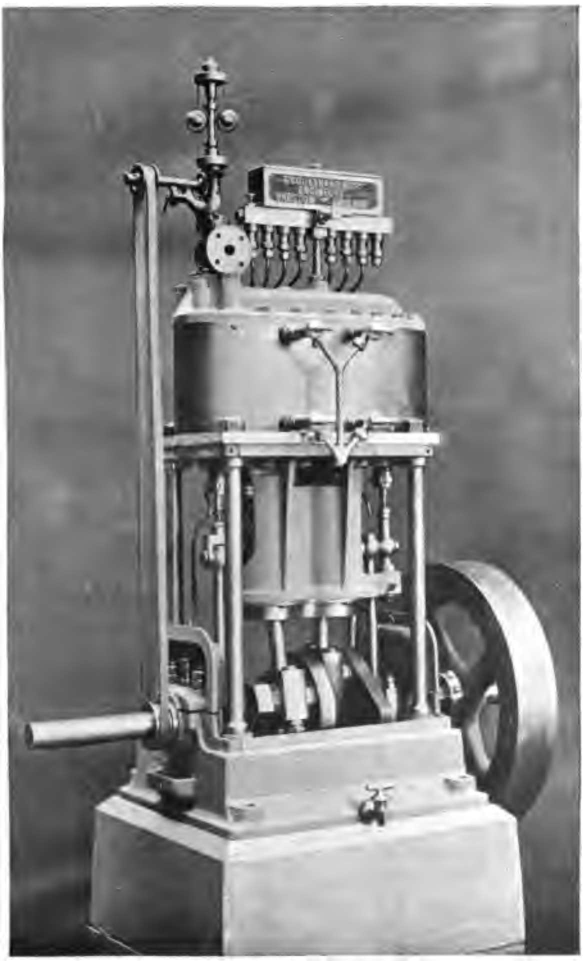


FIG. 49.—HIGH-SPEED ELECTRIC LIGHT ENGINE, BY MESSRS. COULTHARD & CO.
*Shown with steel sheet covers removed.*

passes round the outside of this comparatively thin valve and also round the steam passage in the receivers forming the top

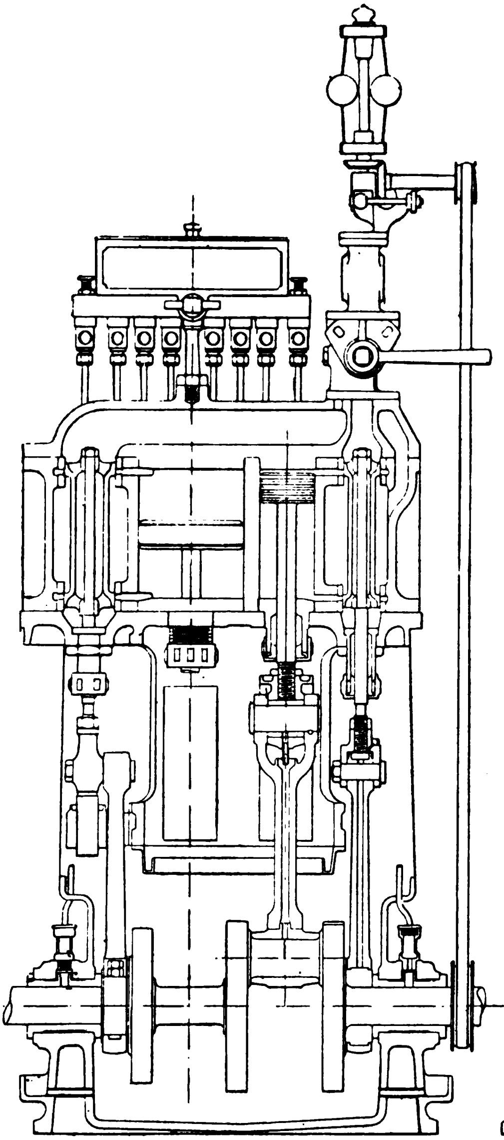


FIG. 50.—SECTIONAL ELEVATION.

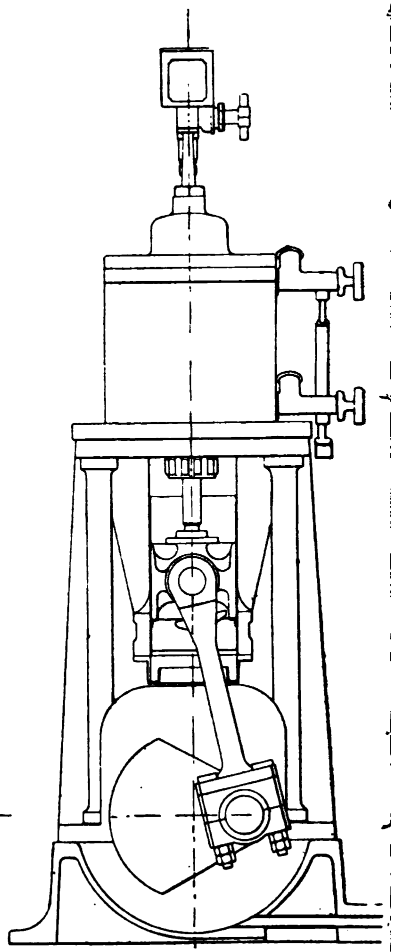


FIG. 51.—PART SECTIONAL END ELEVATION.

HIGH SPEED ELECTRIC LIGHT ENGINE, BY MESSRS. COULTHARD & CO.

cylinder cover, is in a large measure re-heated by the hot walls in contact with which it moves.

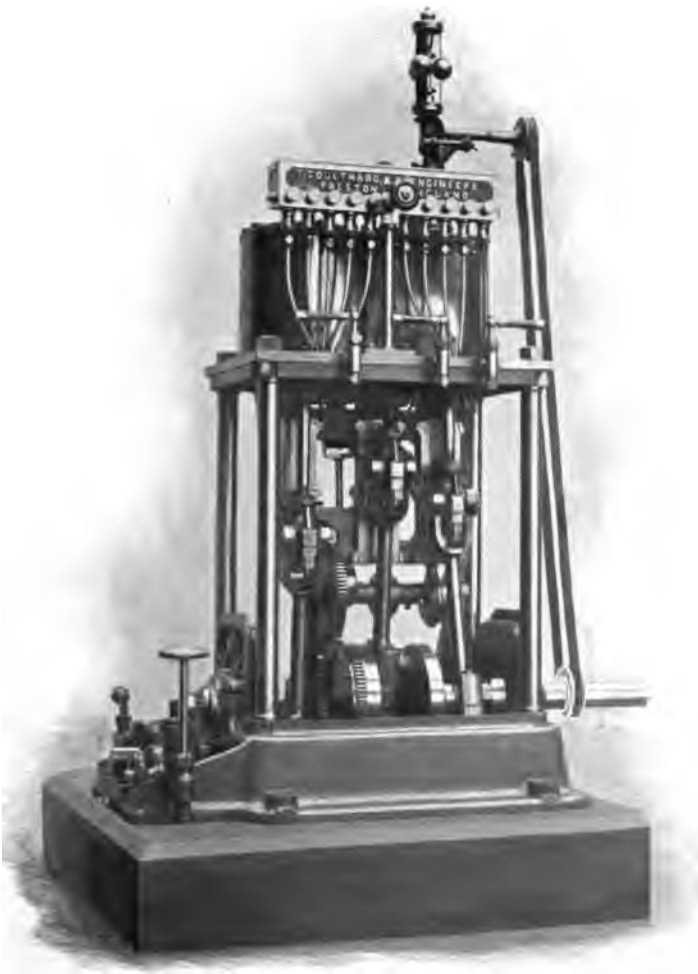


FIG. 52.—COULTHARD'S HIGH SPEED TRIPLE EXPANSION ENGINE.

The bottom cover of the high and low pressure cylinders and valve chests, together with cross head guides, are cast in one piece. Raised above the cylinder cover on a column is the oil reservoir, and from it pipes lead to the various moving parts. The method of lubricating the crank pins in particular

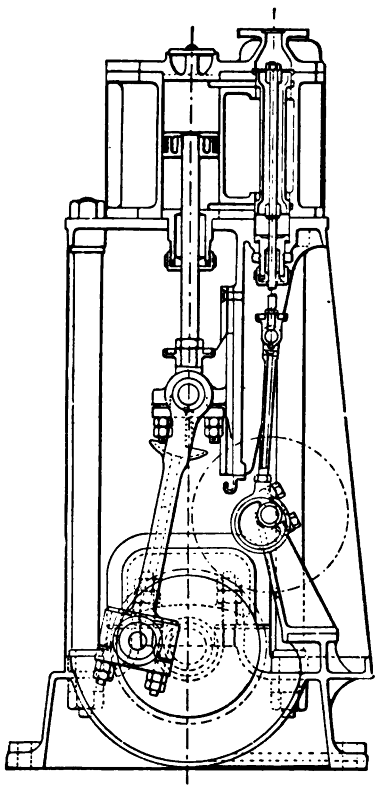


FIG 53.—SECTIONAL VIEW OF COULTHARD'S HIGH SPEED TRIPLE EXPANSION ENGINE.

will be noted from the section view. Fig. 49 shows the engine with sheet steel covers removed.

Figs. 52, 53, 54, and 55 show external and sectional views of Messrs. Coulthard's Triple Expansion High Speed Engine. Dispensing with the central bearing in a compound engine is by no means new, but a triple expansion engine with only two bearings is a bold and successful departure in high sp engine design, and, as far as we are aware, not previoı attempted by any maker. It will be seen by referring to sectional views that the cylinder casting is arranged in s

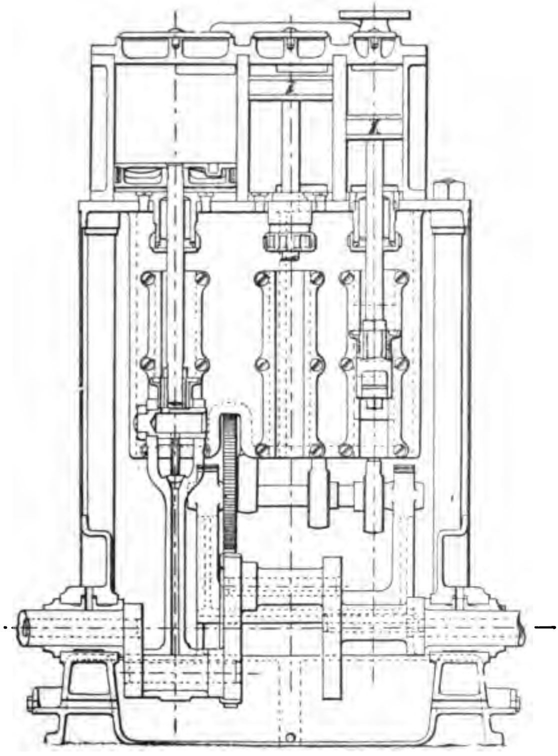


FIG 54.—SECTIONAL VIEW OF COULTHARD'S HIGH SPEED TRIPLE EXPANSION ENGINE.

a manner as to leave only a thin wall between the bore each cylinder. Piston valves are used for all the cylind and no rings or springs are employed. The steam is admil at the top to the inside of the hollow piston valves. Tl are two receivers, one between the high pressure and the in mediate, the other between the intermediate and low press

There is only one top cover for cylinder and valve chests, and the entablature serves for bottom cover and crosshead

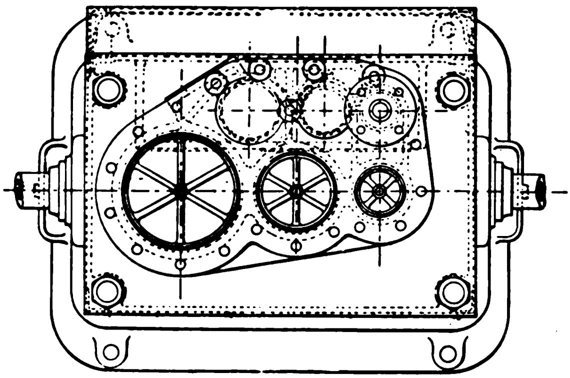


FIG. 55.—SECTIONAL VIEW OF COULTHARD'S HIGH SPEED TRIPLE EXPANSION ENGINE.

guides. The speed of these engines is 500 to 600 revolutions per minute with a 5-in. stroke.

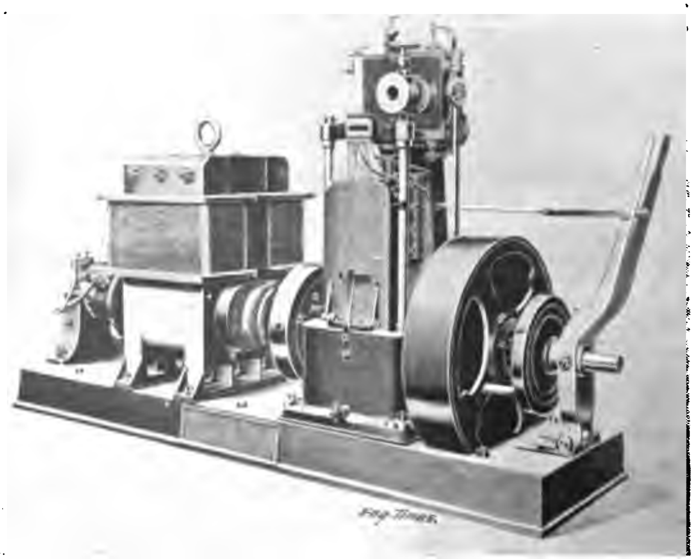


FIG. 56.—"ROBINSON AND AUDEN" SINGLE CYLINDER ENGINE, COUPLED DIRECT TO DYNAMO.

## " Robinson and Auden " Engine.

Fig. 56 shows a well-designed single cylinder high spee engine, as supplied to the M.F.B. Station, Southwark, b Robinson and Auden. It will be seen that the engine is ( the Marine type.

The diameter of the cylinder is 9½ in. and the stroke 8 in

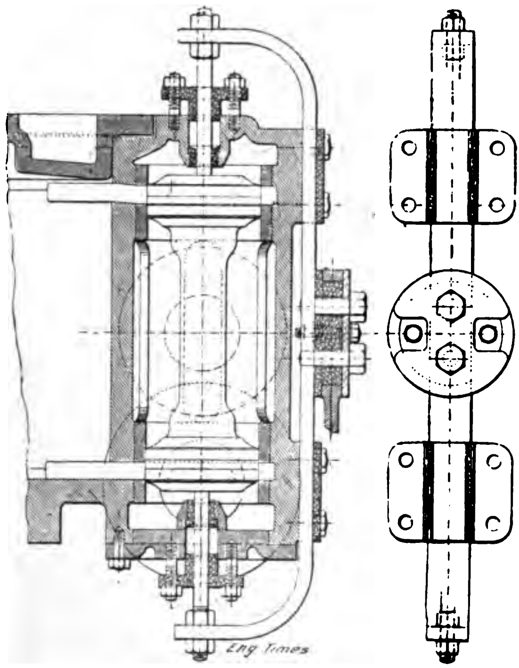



FIG. 57.—" ROBINSON AND AUDEN " ENGINE VALVE DRIVE.

normal revolutions per minute 300, with a steam pre 90 lbs. per square inch; the brake horse-power 30.

The valve (see Fig. 57) is of the piston type with this e tion, that the valve is absolutely balanced. The meth operating the piston valve enables the port clearance reduced to a minimum and provide a movement of the which is not influenced by the angularity of the excentri The steam valve is regulated by means of Robinson's fly governor.

There are three important features in the "Robinson" expansion governor (see Fig. 58).

1st.—The guiding of the frame which carries the excentric in a straight line by a jointless form of Watts parallel motion.

FIG. 58.—THE "ROBINSON" EXPANSION GOVERNOR.

2nd.—The holding of excentric frame in position by laminated steel blades, the arrangement so far being free from any working pin-joint.

3rd.—The application of power to the springs by means of four lever arms instead of weights, arranged in such a manner that the centrifugal action of the one arm governs that of the other, rendering the forces at work in the governor extremely stable and capable of meeting much slide valve resistance without being disturbed. The speed of the engine can be varied by means of a speed lever some 50 revolutions per minute. We are informed that the difference in speed between full and half-load suddenly thrown on and off is about three revolutions per minute.

## Restler's Tandem Compound Single Acting Engine.

Messrs. Clarke, Chapman & Co., Ltd., are the sole makers of a multiple expansion high speed engine of the single acting class. This new type of engine is the invention of Mr. J. W. Restler, M.I.C.E.

*The Engineer* of June 17th, 1898, gave a description of Restler's engine direct coupled to a centrifugal pump installed at Southwark and Vauxhall Water Company at Hampton. Diagrams (see Fig. 59) and tests are given herewith.

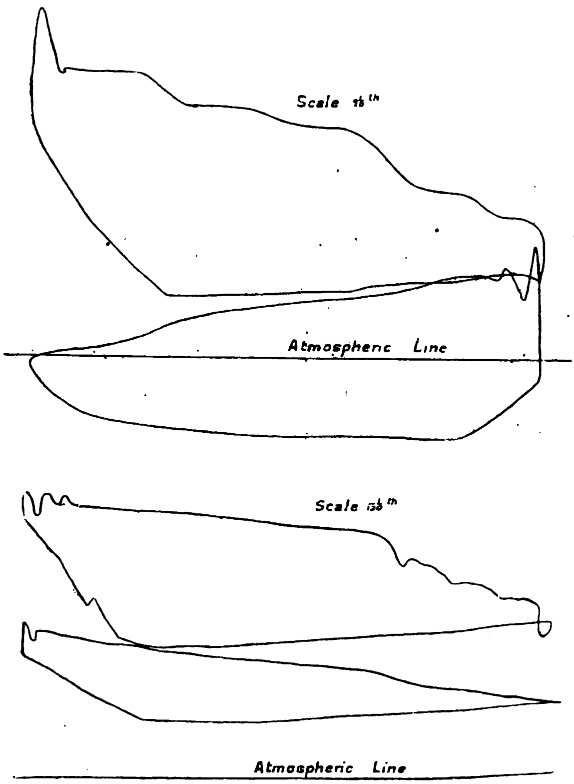



FIG. 59.

## SUMMARY OF TRIAL OF A "RESTLER" MULTIPLE-EXPANSION HIGH SPEED ENGINE AT HAMPTON, MIDDLESEX.

DECEMBER 21ST, 1896.

| | |
|---|---|
| Duration of Trial | 24 hours. |
| Cylinder Diameters, two sets, single-acting | $6\frac{5}{8}$ in., $11\frac{1}{2}$ in. & 17 in. |
| Stroke of Pistons | 9 in. |
| Effective areas of H.P. Cylinders | 34·47 sq. in. |
| ,, ,, 1st M.P. | 69·4 ,, |
| ,, ,, 2nd M.P. | 124·0 ,, |
| ,, ,, L.P. | 224 ,, |
| Mean revolutions per minute throughout trial | 252·5 revols. |
| Mean Piston Speed | 378·75 ft. per min. |

| | | |
|---|---|---|
| Mean pressure from 48 diagrams, right and left-hand Engines, | H.P. | 56·6 lb. per sq. in. |
| " " 48 " " " " | 1st M.P. | 26·1 per sq. in. |
| " " 48 " " " " | 2nd M.P. | 20·5 " |
| " " 48 " " " " | L.P. | 17·2 " |
| Indicated horse-power, H.P. Cylinders | | 22·38 I.H.P. |
| " " 1st M.P. " | | 20·79 " |
| " " 2nd M.P. " | | 29·17 " |
| " " L.P. " | | 44·21 " |
| Total indicated horse-power | | 116·55 " |
| Total amount of Steam used throughout Trial | | 45,800 lb. |
| Steam per hour | | 1908·3 lb. |
| Water per indicated horse-power per hour | | 16·375 lb. |

"The engine was arranged in two sets of tandem cylinders over two cranks, and coupled direct to an 18 in. centrifugal pump. The boiler pressure averaged 162 lb. during the first half of the trial, and was raised to 200 lb. during the last twelve hours. Indicator diagrams were taken every half hour from each set of cylinders, changing over the indicators every six hours alternately."

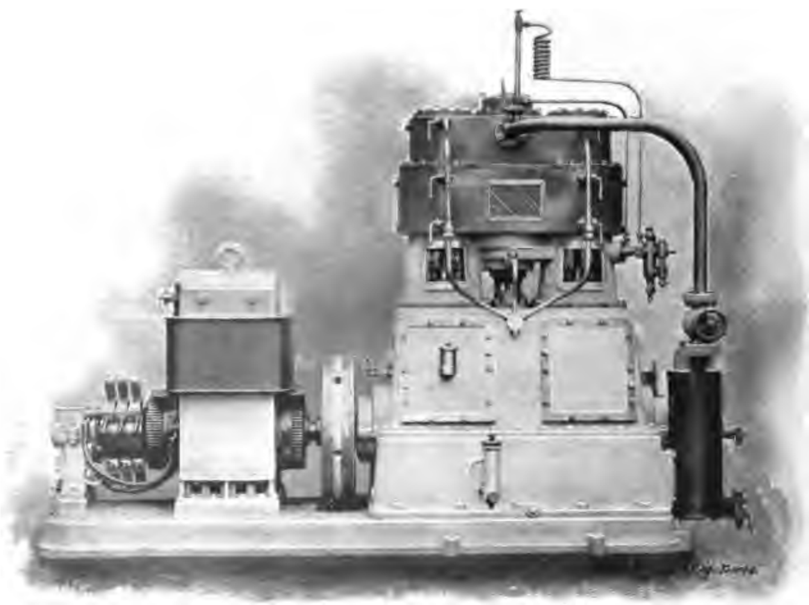


FIG. 60.—THE "RESTLER" ENGINE, COUPLED TO DYNAMO.

Fig. 60 is from a photograph of the "Restler" engine and dynamo, and Figs. 61 and 62 are sections of the engine.

It will be seen by referring to the illustration that the steam cylinders consist of two tandem sets. The piston valve, which controls the admission and exhaust of steam to both sets of cylinders, and which is formed in sections

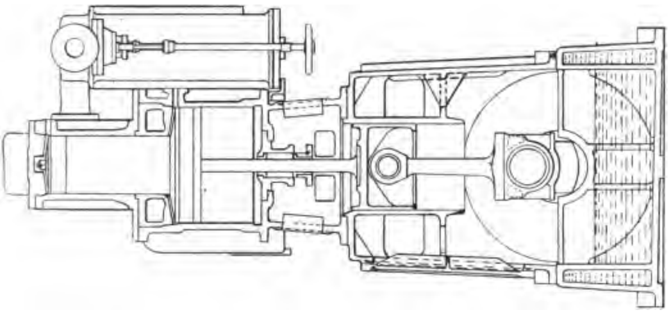


FIG. 62.—END SECTIONAL VIEW.

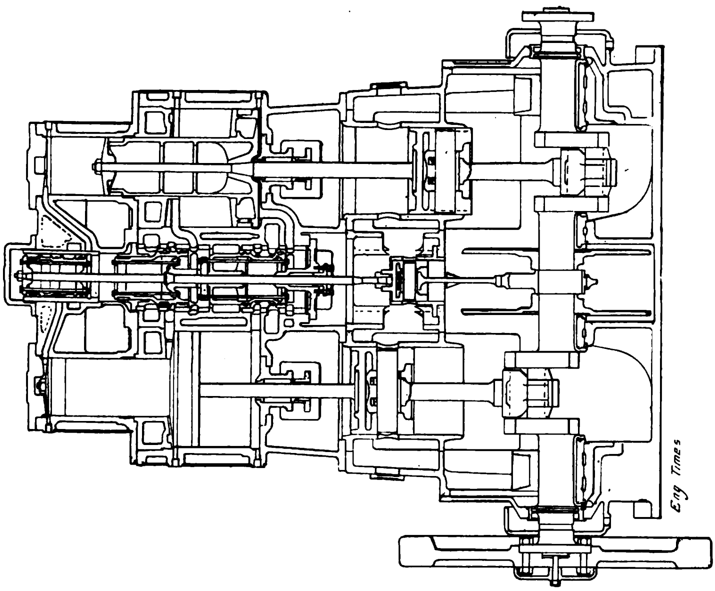



FIG. 61.—FRONT SECTIONAL ELEVATION.

THE "RESTLER" ENGINE.

threaded on the valve rod, is coupled to an automatic expansion governor.

*Steam Distribution.*—Live steam enters the upper annular chamber, and in the position shown in Fig. 61 the left hand high pressure piston is commencing the down stroke. The steam above the right hand high pressure piston, which is commencing the up stroke, is passing through the port, passage, and valve, to the upper side of the left hand low pressure piston, while the steam from underneath this piston is discharging through the passage on the outside to the valve, and through the exhaust port, to the atmosphere or condenser. The annular chamber between the low and high pressure ports is a receiver which is alternately in communication with the right hand intermediate and right hand low pressure, and the left hand intermediate and the left hand low pressure.

When the engine is supplied with an automatic expansion governor operating the steam valve direct, no air buffers are used, but in the case of engines governed by the throttle valve an air buffer is fitted on each piston rod to ensure the engine keeping in single action on "light" loads.

"Splash about" lubrication is employed.

Outside the crank casing is a water-jacket. The object of this jacket is to cool the lubricant, and is in smaller sizes, arranged in the form of coils of copper pipe through which the water is circulated.

## The "Sentinel" Engine.

A well-known type of single-acting engine is the "Sentinel," as made by Messrs. Alley and Maclellan, Glasgow. About twelve years ago Messrs. Alley and Maclellan started the manufacture of this simple type of engine, and have during that period had a very large experience. There are now some 7,000 engines of this type in operation all over the world. The simple engine is of the two-cylinder, two-crank type, having the cranks set at 180 degrees, and is made in sizes up to 150 I.H.P., and is specially adapted for running non-condensing. Fig. 63 is a longitudinal section through crank shaft. It will be seen by referring to this illustration that all the moving parts, with the exception of the fly and belt wheels, are enclosed within the frame of the engine, and on further examination it will be noticed that the internal moving parts consist of two pistons, two connecting-rods, crank shaft, a single central valve, excentric rod for same and an automatic expansion governor. Not a single gland or stuffing box is required in the whole engine. The pistons are of the trunk pattern, and of great length, which ensure a long life. It is well known that the pistons of the "Otto" type gas engines, which are of the trunk pattern,

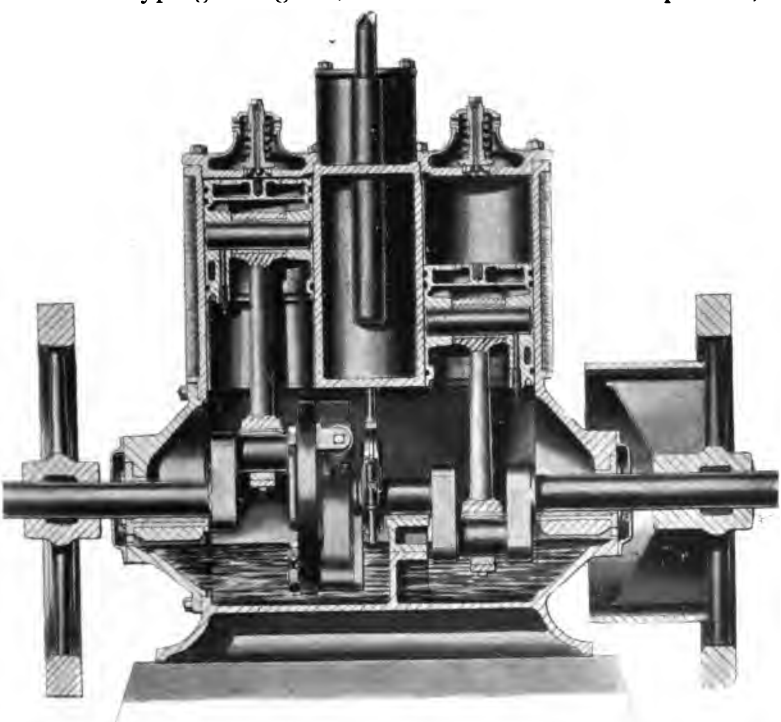


FIG. 63.—"SENTINEL" CLASS "C" SIMPLE ENGINE—LONGITUDINAL SECTION THROUGH CRANK SHAFT.

fitted with rings only at the back end, give excellent results, and though the conditions, such as varying temperature, are very severe, yet the mechanical efficiency is remarkably high. Bearing this fact in mind, then, nothing can be urged against a well-designed plunger piston for single-acting engines. The steam is distributed to the two cylinders by a single balanced piston valve, and acts only on the top of the pistons, making the engine single-acting throughout the whole revolution, the inertia of the reciprocating parts being taken up by judicious compression of the exhaust steam on the return or up stroke.

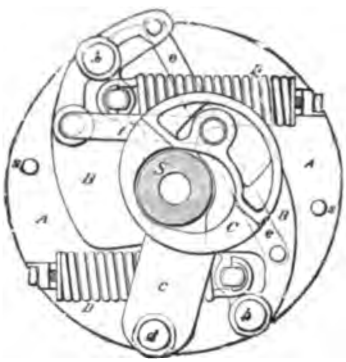


FIG. 64.—GOVERNOR OF "SENTINEL" ENGINE.

The governor is of the crank shaft variable expansion type, and acting direct on the travel of the balanced piston valve, controls the supply of steam at four points in each revolution. This governor is shown in Fig. 64, and its action in controlling the steam at varying loads is shown in Fig. 65.

Fig. 66 shows one of these simple engines of 50 B.H.P. direct driving a dynamo at 430 revolutions per minute.

The compound engine, as now made by Alley and Maclellan, is chiefly of the tandem type, and, like the simple engine, is also single acting. It is made with two cranks

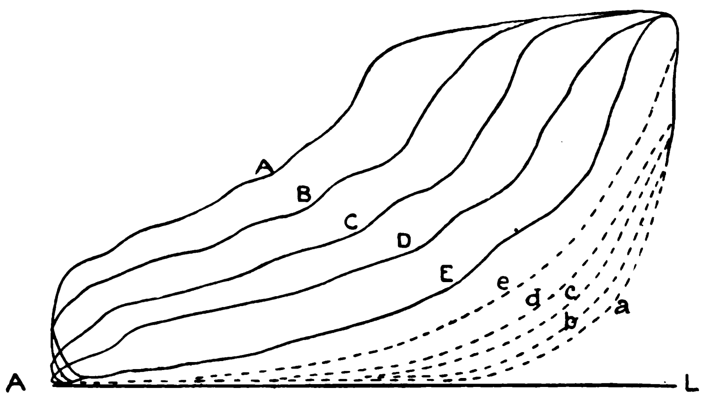



FIG. 65.—"SENTINEL" ENGINE—INDICATOR DIAGRAMS.

generally, but when exceptionally steady running is desired it is made with three cranks set at 120, the two-crank engine having its cranks at 180.

Fig. 67 shows one of these engines of 35 B.H.P. direct driving a dynamo at a speed of 475 revolutions, and Fig. 68 shows a 300 B.H.P. tandem compound "Sentinel" engine, arranged for driving dynamo at each end at a speed of 400 revolutions per minute.

The governor is built on a small extension of the crankshaft, has direct control of a balanced throttle valve, and is capable of adjustment while running, and such is

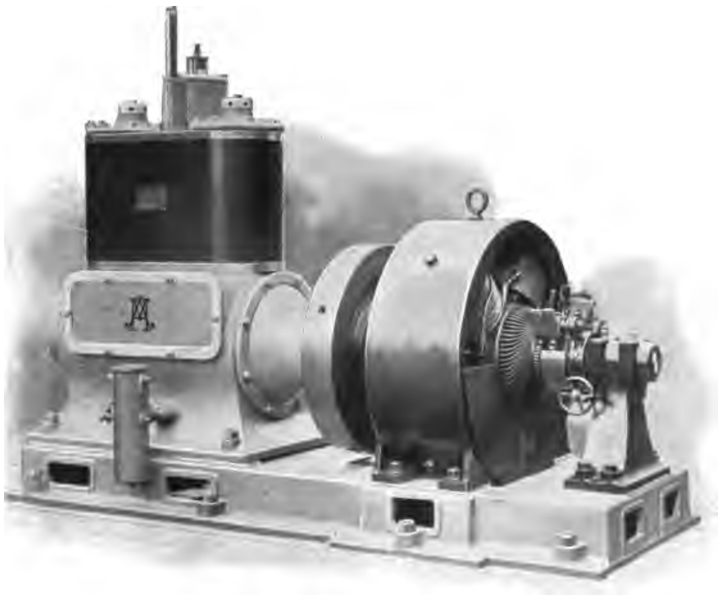


FIG. 66.—"SENTINEL" CLASS "C" SIMPLE ENGINE, COUPLED DIRECT TO DYNAMO.

the sensitiveness that these engines are made to govern within $1\frac{1}{2}$ per cent. between no load and full load without hunting.

Lubrication is effected in both simple and compound types by having the crank case filled with oil and water nearly up to the height of the crank shaft; this, when the engine is running, is in a few minutes churned into a foam, which, while it offers little or no resistance to the moving parts, thoroughly lubricates all internal bearings constantly, and, by using the same oil over and over again, economically.

Distribution of steam is effected by simple piston valves, and is on the Cornish cycle, the steam acting on the top of the high pressure piston, then exhausting to the under side of this piston, which forms a receiver into the low pressure

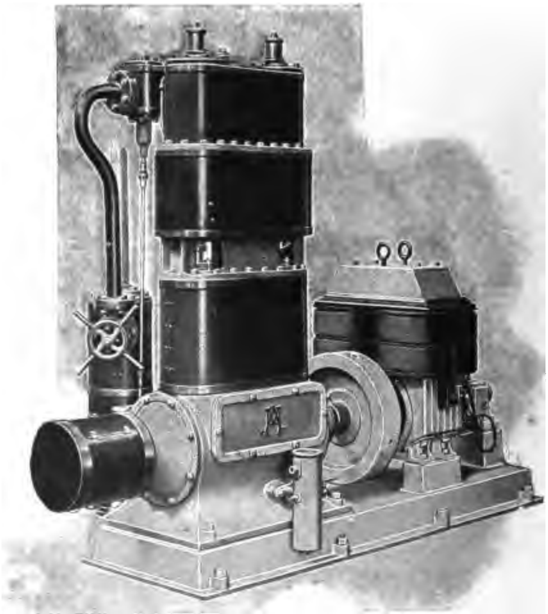
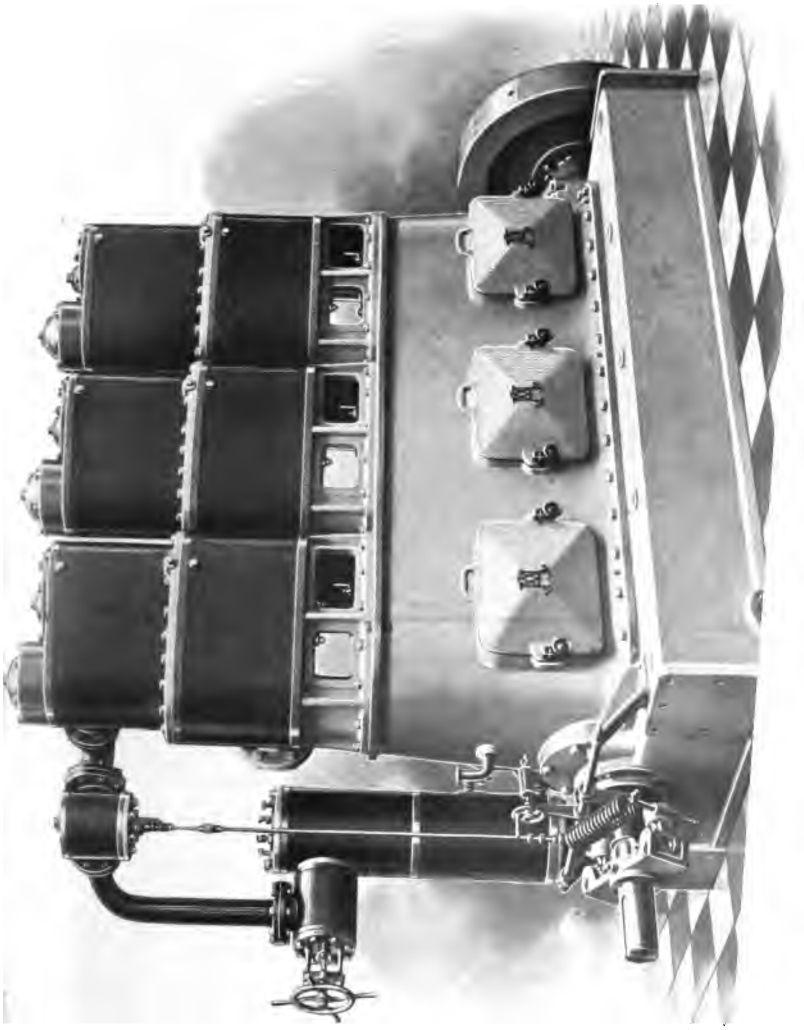


FIG. 67.—"SENTINEL" TANDEM COMPOUND ENGINE, COUPLED DIRECT TO DYNAMO.

cylinder, after which it exhausts to the atmosphere or condenser, as the case may be.

All the internal packings are of the floating metallic type. Large bearing surfaces are provided, so that the wear is reduced to a minimum, the bearings varying in length from two to three and a half times the diameter of the shaft. The main bearings are not provided with any means of adjustment. Shells lined with Babbit metal are provided, which admit of easy renewal.



## "Bumsted and Chandler" Engine.

This well-known firm have built a large number of Chandler's high speed engines. Fig. 69 is from a photograph of the "Chandler" compound engine; Fig. 70 shows the valve gear, and Fig. 71 diagram.

It will be seen by referring to Fig. 70 that the arrangement of valve motion dispenses with excentrics and a better

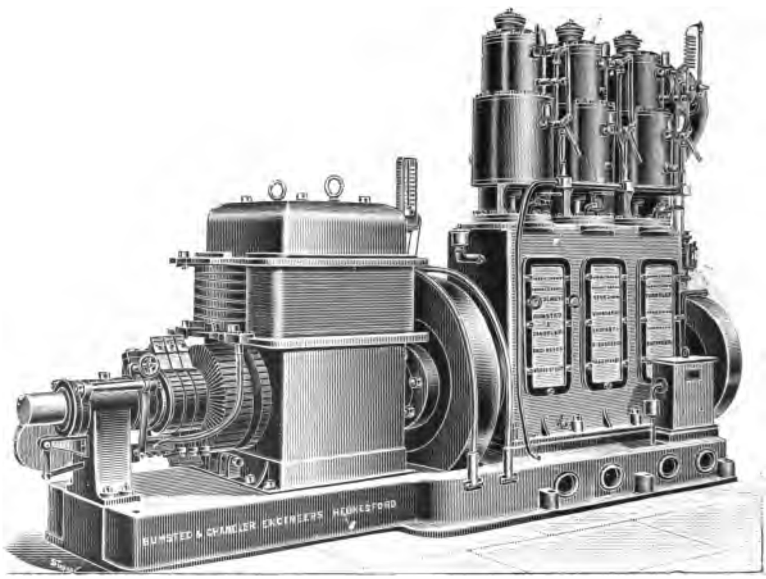



FIG. 69.—THE "CHANDLER" COMPOUND ENGINE.

steam distribution is effected. The over-all length of an engine of 180 I.H.P. is 2 ft. 0 in. shorter than can be obtained with an engine having excentrics on the crank shaft, and admits of the main shaft being supported well up to the crank webs. The saving in length is owing to the position of cylinders on the top of crank case standing at right angles to the centre line of the engine. The valves are of the piston type, with sufficient downward pressure to keep all moving parts in constant thrust.

“ Bumsted and Chandler ” Engine.

The steam cycle is the same as in a “ Willans’ ” engi

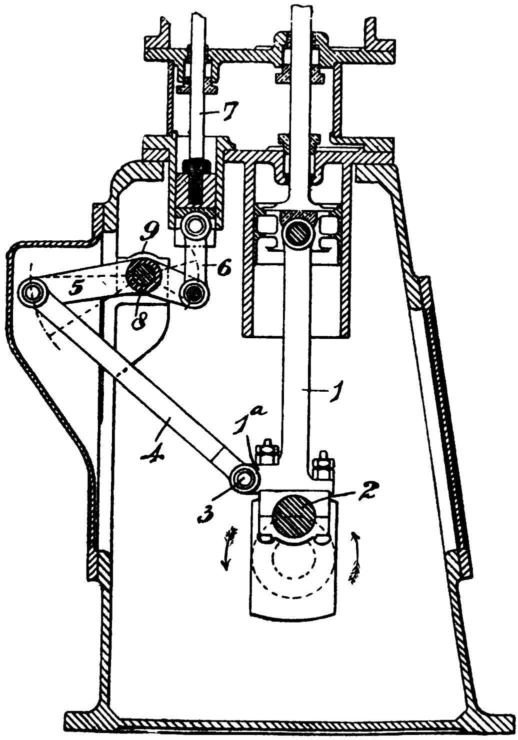



FIG. 70.—VIEW SHOWING VALVE GEAR OF THE “ CHANDLER ” ENGINE.

Steam on top of high pressure piston during down st then during up stroke the steam is transferred to under

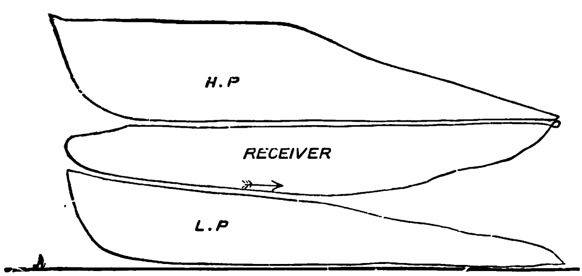
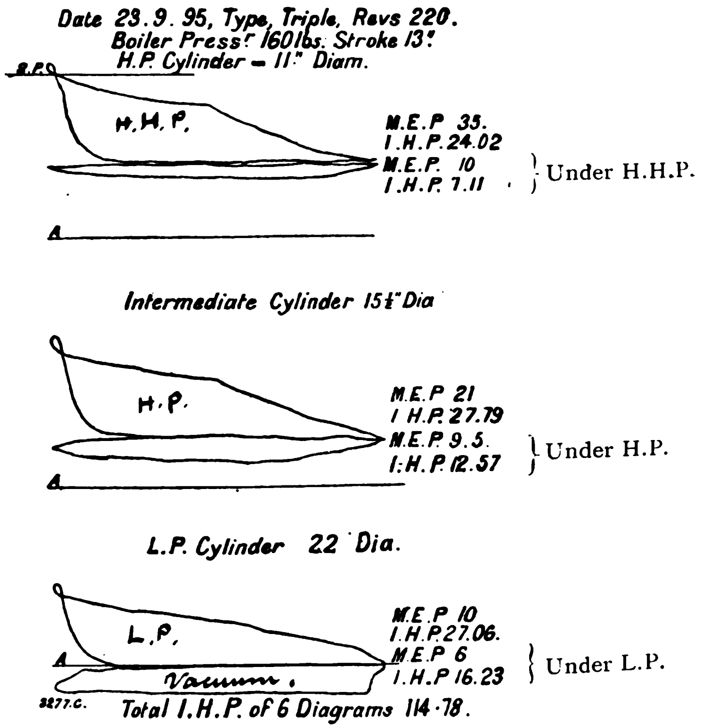



FIG. 71.—“ CHANDLER ” ENGINE, DIAGRAM.

of high pressure piston, the high pressure piston risi equilibrium ; during next down stroke steam from under high pressure passes into low pressure cylinder above the low pressure piston ; during next up stroke the low pressure piston rises in equilibrium as steam is transferred from the

*Tests of Chandler's engines.*




CHANDLER'S HIGH SPEED TRIPLE EXPANSION CONDENSING ENGINE (22 IN.).

Water consumption on four hours' test, 14 lb. per one H.P. hour. M.E.P.L.P. piston (22 in. diameter) = 42 lb. per sq. inch.

upper to the under side, and when exhausting to a vacuum a very powerful diagram is obtained under the low pressure piston during *down stroke only*, as during the down stroke the under side is in communication with the condenser.

The diagram Fig. 71 shows how very small the drop in steam pressure is in passing from one stage to another.

It will be seen that valve motion joints are small in con parison with excentrics. All the engines have "distanc pieces" between the low pressure cylinders and the crank cas This provides a ready means of packing the glands whic are subjected only to the exhaust steam, except an air buffe

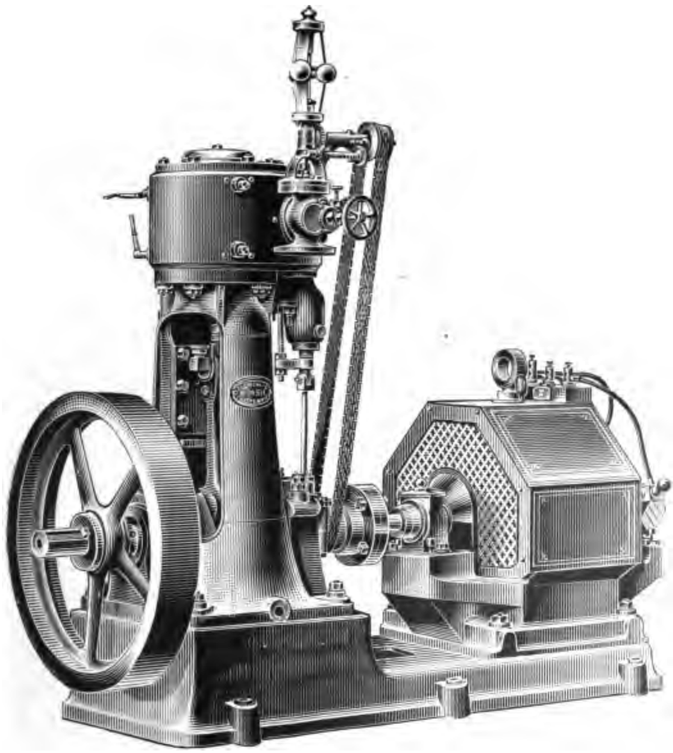


FIG. 72.—"DONKIN & CLENCH" ENGINE, COUPLED TO DYNAMO.

The whole of the bearings can be taken out without lif the crank shaft, and the two central bearings are rea adjustable. The crank shaft can be taken out of either of the engine without moving the crank case, as can alsc connecting rods and crossheads.

The larger sizes of Chandler's engines are supplied "forced" lubrication.

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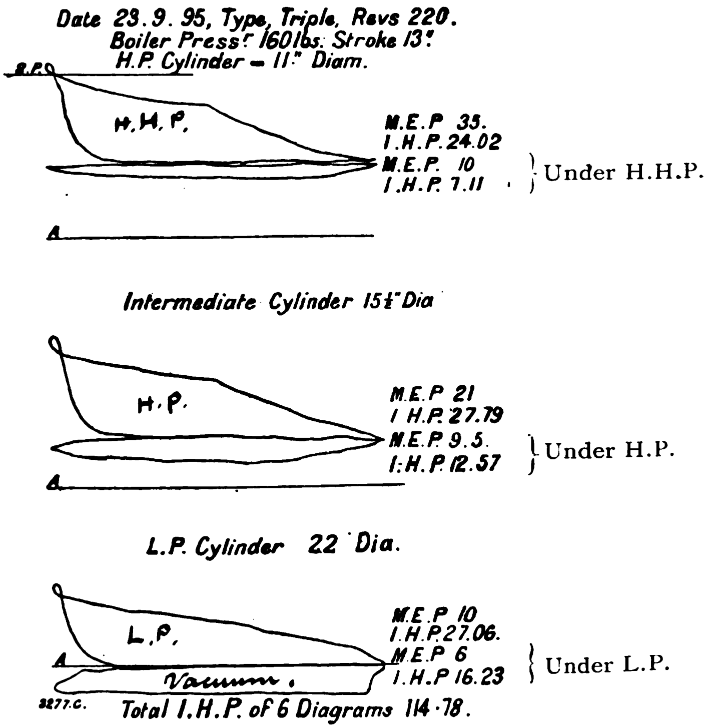
*Tests of Chandler's engines.*

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It will be seen that valve motion joints are small in comparison with excentrics. All the engines have "distance pieces" between the low pressure cylinders and the crank case. This provides a ready means of packing the glands which are subjected only to the exhaust steam, except an air buffer.

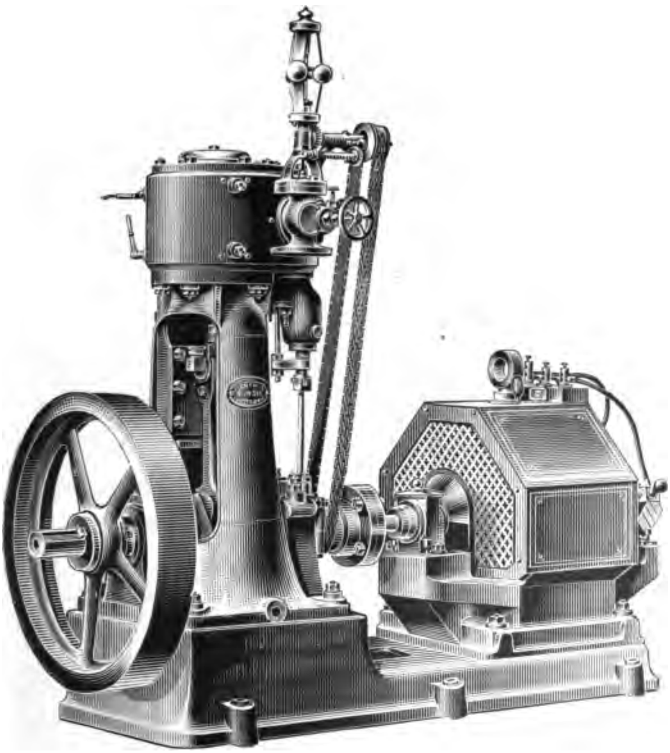


FIG. 72.—"DONKIN & CLENCH" ENGINE COUPLED TO DYNAMO.

The whole of the bearings can be taken out without lifting the crank shaft, and the two central bearings are readily adjustable. The crank shaft can be taken out of either end of the engine without moving the crank case, as can also the connecting rods and crossheads.

The larger sizes of Chandler's engines are supplied with "forced" lubrication.

## "DONKIN & CLENCH" ENGINE.

Messrs. Bryan Donkin & Clench, Ltd., make a new type of high speed engine. Three of these are in use at the

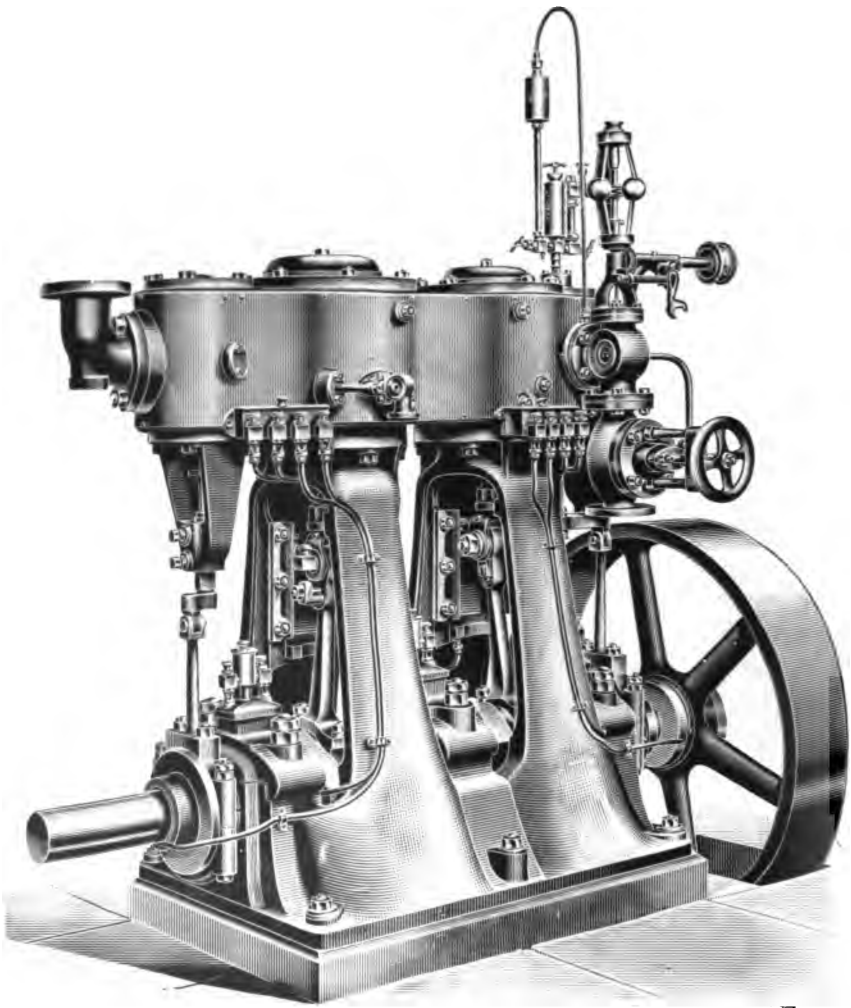


FIG. 73.—"DONKIN & CLENCH" ENGINE.

Blackwall Tunnel installation. Fig. 72 shows a single cylinder engine and dynamo. By referring to Fig. 73 it will be seen that the frame consists of two open front castings, bolted together at the base through the middle bearing. The front leg of frame is arranged to take out for examination of brasses. The cylinders and valve boxes "tie" the upper portion of the frames in a very simple manner.

The distribution of steam in the cylinders is effected by piston valves, each driven by an excentric on the crank shaft, and the steam supply is controlled by a "Pickering" governor.

The diameter of the high pressure cylinder is 11 inches, and the diameter of the low pressure cylinder 18 inches, both having a stroke of 10 inches, with a maximum number of revolutions of 300 per minute. With a steam pressure of 150 lb. per square inch, cut off ·67 stroke the B.H.P. is 120. The main bearings are 7 inches diameter and 12 inches long, and the crank pin 6 inches diameter and 6 inches long.

The working barrels or liners are surrounded by steam at boiler pressure. The cylinder covers and piston rod stuffing boxes are air-jacketed, and filled with fibrous non-conducting composition.

The smaller engines at Blackwall have high pressure cylinders 9 inches diameter, low pressure cylinder 14½ inches, and a stroke of 8 inches. Maximum number of revolutions per minute 350. With a steam pressure of 150 lb. per square inch, cut off ·65 stroke the B.H.P. is 80.

The main bearings are 6 inches diameter and 10 inches long, and the crank pins 5 inches diameter and 5 inches long.

Gravity lubrication is used throughout.

## Plenty & Son's Tri-Compound Vertical Engine.

Fig. 74 is a sectional end view, and Fig. 75 is a part sectional elevation of an unusual type of three-crank tandem compound high speed engine built by Messrs. Plenty & Son, Ltd., for the central station of the London Electric Supply Corporation at Deptford. This engine is coupled to the shaft of a 650 K.W. Ferranti alternator. By referring to Figs. 74 and 75

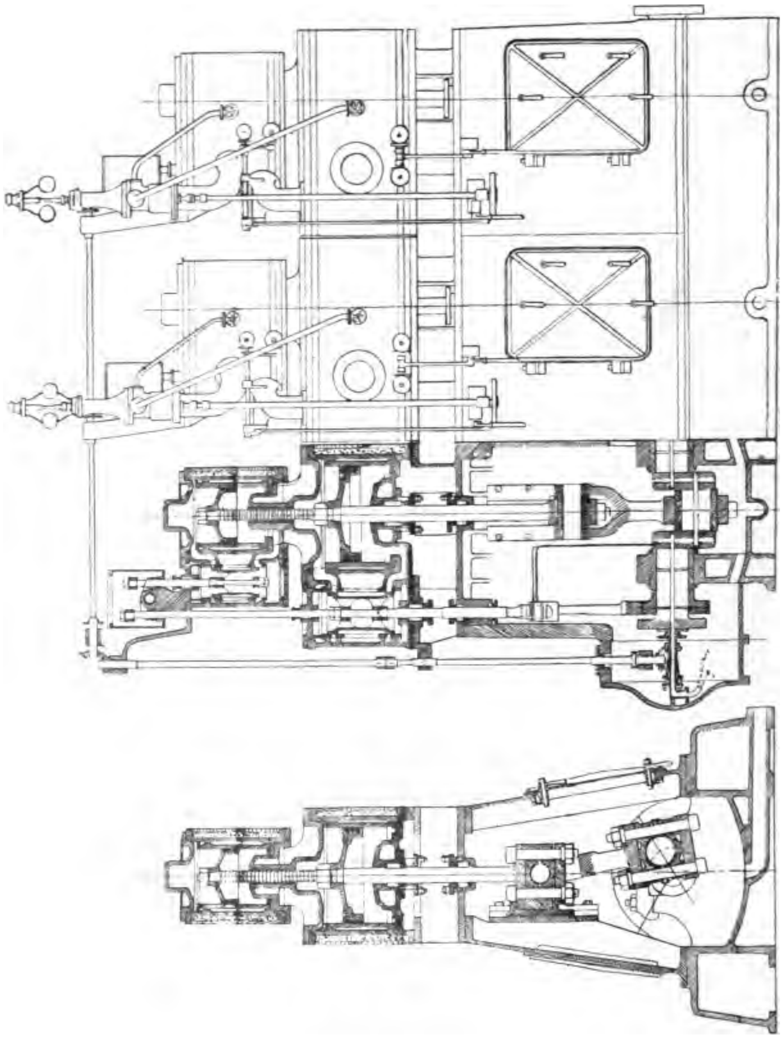


FIG. 74.—SECTIONAL END VIEW.

FIG. 75.—PART SECTIONAL FRONT ELEVATION.

PLENTY & SON'S TRI-COMPOUND VERTICAL ENGINE.

it will be seen that each high pressure cylinder is completed with its own separate stop valve, Pickering governor, starting valves, &c., and it is quite possible to run any one or two, or all three, engines on load at the same time. There are three high pressure and three low pressure cylinders, set in pairs above the crank shaft, the diameters being 16 inches and 28 inches, while the stroke is 14 inches, and the speed, of course, the same as that of the alternator—viz., 250 revolutions per minute. The total B.H.P. of this engine is 950 H.P., and it is guaranteed these engines will provide such an output, under ordinary working conditions, when provided with a vacuum of 20 inches of mercury. The working barrels or liners are steam jacketed, and are provided with steam straight from the boilers. Since the cylinder covers are not provided with a steam jacket we do not think only "partial jacketing" is worth the necessary extra complication.

The value of steam jackets has been very ably dealt with by *The Engineer*, 17th November, 1871, up to the present time, and also by Narcott and Fletcher.

The crank shaft is made in three interchangeable pieces. All the main bearing and crank pin journals are of the same dimensions, each having a length of 13 inches, and a diameter of 10 inches. Continuous forced lubrication is effected by means of oil force pumps, attached one to each engine, and such supply is still further supplemented from a separate steam-driven pump.

## Easton and Bessemer's Engine.

A neat type of high speed engine of the "open" class is made by Messrs. Easton and Bessemer, of Taunton.

By referring to Fig. 76 it will be seen that the standard is in one piece with the bed plate. The cylinder and valve box are in one casting, fitted with a lug to which the front column support is secured.

The admission of steam is controlled by a "shaft" governor which operates a balanced piston valve.

The crank is provided with counter-balance weights.

Lubrication is effected by means of sight feed "drop" lubricators, which are adjustable.

These engines are designed for a steam pressure of 120 lb. per square inch, and arranged for speeds of 500 revolutions

FIG. 76.—MESSRS. EASTON AND BESSEMER'S, LTD., HIGH SPEED SINGLE CYLINDER ENGINE, WITH EXTENDED BASE-PLATE FOR DYNAMO.

per minute in the 4 in. stroke and 225 revolutions per minute in the 14 in. shaft engine.

## Shanks & Son's Engines.

We illustrate in Fig. 77 a well-designed single cylinder engine by Messrs. Alexander Shanks & Son, Ltd., of Arbroath. The frame is of solid construction, which ensures rigidity; the bearing surfaces are very ample, and balanced cranks and automatic system of lubrication ensures cor tinuous running at high speed without heating. Th governor, as will be seen, is of the crankshaft type, contro ling throttle valve, and will maintain a uniform speed wit varying loads.

Fig. 78 shows a double-cylinder high-speed engine by th

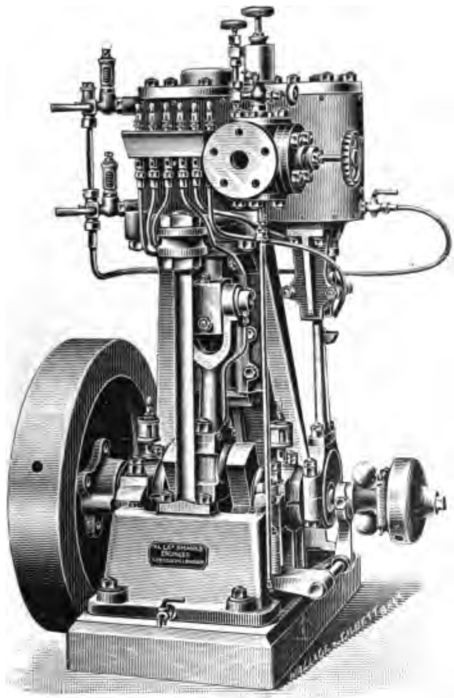


FIG. 77.—SINGLE CYLINDER HIGH SPEED ENGINE BY MESSRS. ALEX. SHANKS & SON.

same makers; it is of an open type, and very accessible all points. The governor usually fitted is of the vert high speed, driven by belt and controlling throttle va When automatic expansion gear is used a special gover is provided, as shown in our illustration, Fig. 78. A he fly-wheel for belt driving, supported by an outer bearing fitted, and for direct driving a heavy disc-coupling in p of the fly-wheel.

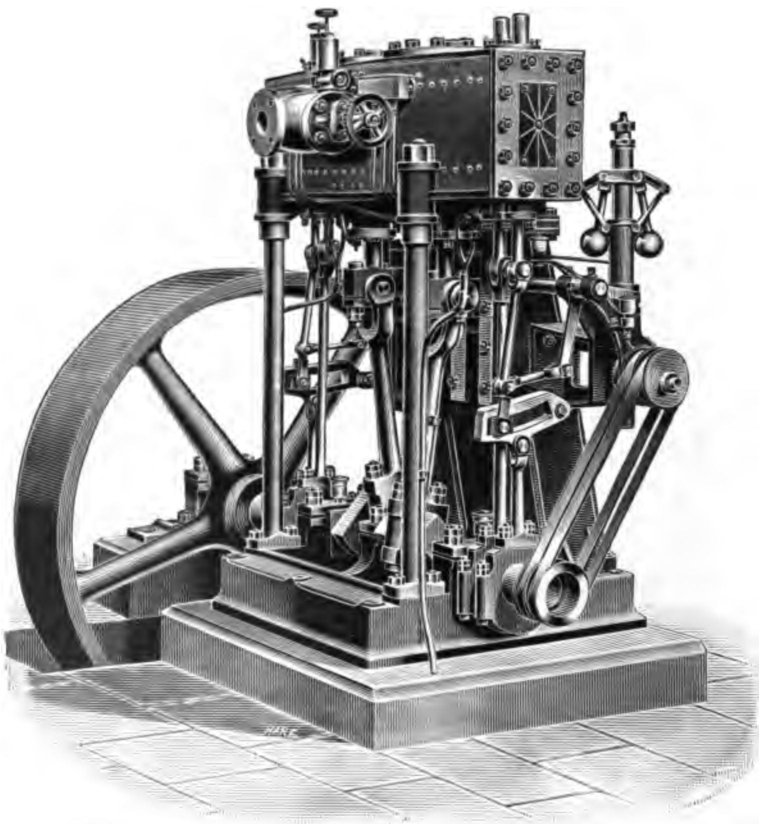


FIG. 78.—DOUBLE CYLINDER VERTICAL ENGINE BY MESSRS. ALEX. SHANKS & SON

# AMERICAN HIGH SPEED STEAM ENGINES.

## "WESTINGHOUSE" SINGLE ACTING ENGINE.

THE well-known "Westinghouse" Two Cylinder High Speed Single Acting Engine was introduced in 1881 by the Westinghouse Machine Co., Pittsburgh, Pa., U.S.A., and has proved beyond all doubt that the field of application for a simple non-condensing engine was enormous. Economy of fuel and commercial economy are not always synonymous terms. There are many situations in which for various reasons the mere steam consumption of an engine is a matter of secondary consideration, and consequently there exists, and probably always will exist, a legitimate and active demand for a non-compound, non-condensing engine.

The "Westinghouse" engine belongs to the enclosed type, and lends itself to use in locations exposed to weather, dust and grit. Fig. 79 is a longitudinal section and Fig. 80 is a cross section through cylinders of the Westinghouse "Standard" Engine. Referring to Fig. 79, it will be seen that the valve chest is arranged between the cylinders, which are fitted with pistons of the "Trunk" pattern, double walled at the upper end to prevent condensation. The length is about one and a half the diameter. We have had a long experience with pistons of this pattern on gas engines, and have no hesitation in saying that this type of piston is all that can be desired. There is no piston rod, crosshead, stuffing box, or guide, the piston serving the double function of slipper block and plunger. A shaft governor is fitted between the two cylinders working direct on the distribution valve. Between the cranks is the centre bearing, which gives what we consider a doubtful additional support to the shaft against downward pressure

FIG. 80.—CROSS SECTION THROUGH CYLINDER.

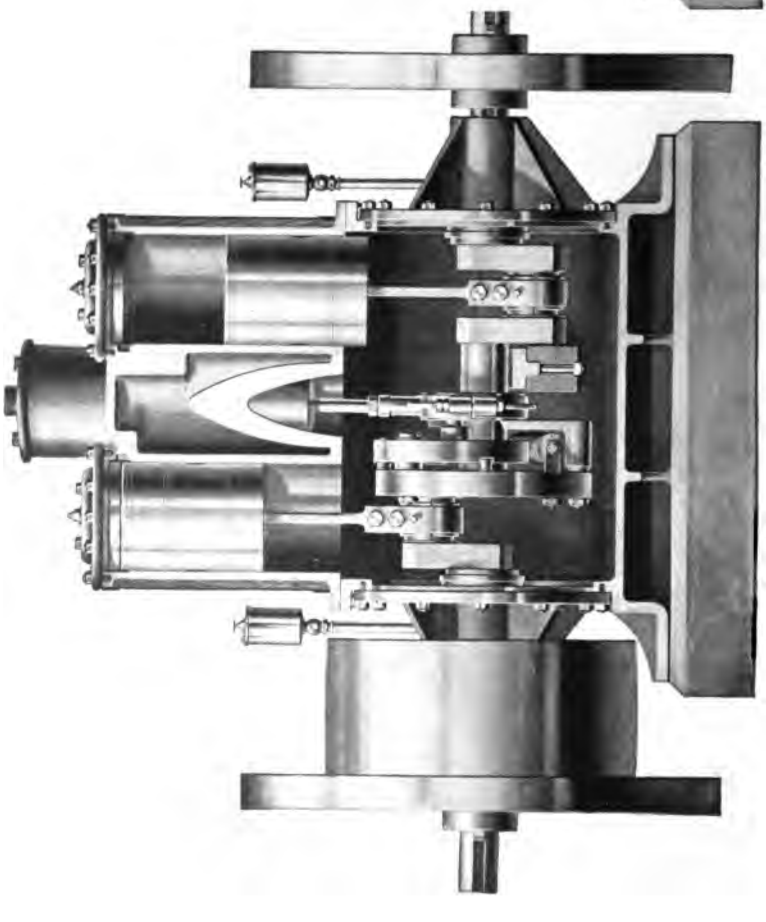


FIG. 79.—LONGITUDINAL SECTION THROUGH CYLINDERS.

"WESTINGHOUSE" TWO CYLINDER SINGLE ACTING HIGH SPEED ENGINE.

imposed by the pistons and connecting rods. The crank case is filled with water high enough to half submerge the crank pin when at the bottom of the throw, and on top of the water is floated a few gallons of lubricating oil. The motion of the cranks throw this mixture of oil and water freely over all the enclosed working parts. A wide experience with this system has proved the mixture of oil and water a more satisfactory lubricant than oil alone. The mixture is less tenacious than the pure oil, and consequently it is thrown about more freely; furthermore, the crank case is open to the atmosphere through a vent pipe, so that the slow evaporation of the water prevents the temperature ever rising above

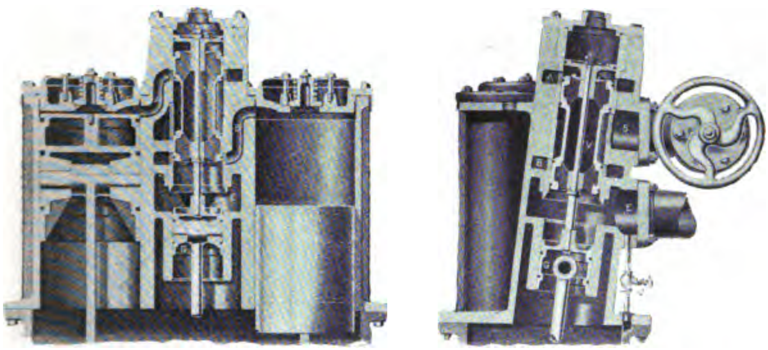


FIG. 81.—DETAIL, SHOWING CYLINDERS, PISTONS, STEAM CHEST AND VALVE.

212° Fahr. In the ordinary course of operation a little water works past the piston, sufficient in quantity to make up the small loss by evaporation. All the leakage past the piston goes into the crank case, and thence through the vent pipe into the engine room, and if excessive in amount would blow the lubricant out of the crank chamber.

The crank shaft is forged steel roughly turned, and has cast upon one of the crank webs a disc which forms a frame for the automatic governor. The cylinders and steam chest (see Fig. 81) are in a single casting. The steam chest is between and back of the cylinders, and slightly inclined from the perpendicular. This arrangement allows the cylinders being placed more closely together. A line through the centre of either cylinder would not pass through the centre of the shaft, but through a point in front of the shaft at a distance equal to one half the length of the crank. This constructure reduces the angularity of the connecting rod one half while the working or downward stroke of the piston is being made; on the up stroke the angularity of the connecting rod is of course correspondingly greater, but as the pressures on the return strokes are trifling, this increased angularity is of no consequence. The main valve V is of the piston type. Steam enters through the throttle valve at S, and passes into the annular space around the neck of the valve. In the section through both cylinders the left hand piston is shown as just starting on its downward stroke, and the right hand piston on its upward stroke. The valve has moved upward by the amount of its lap and lead, and is beginning to open communication between the steam space and the port A, admitting steam to the top of the piston, forcing it down. The extreme bottom edge of the valve has uncovered the lower port, establishing communication with the right hand cylinder and the exhaust chamber E. The crank forces the right hand piston up, the exhaust passing through the port B, under the valve into E and out through the exhaust pipe. As the revolution progresses, the valve moves upward to the limit of its stroke, and starts downward, covering the port A again at a point determined by the governor, cutting off the steam supply and allowing expansion to take place in the left hand cylinder. A little later the lower edge of the valve covers the port B so that the steam remaining in the right hand cylinder is compressed. When the stroke is nearly completed the upper edge of the valve begins to uncover the port A, when release takes place in the left hand cylinder. When the revolution is half completed the left hand piston has reached the limit of its downward stroke and the right hand piston is about to begin its downward stroke. The valve is then in the position shown in the right hand section, *i.e.*, travelling downward, beginning to uncover the port B admitting steam to the right hand cylinder, and uncovering the port A leading from the left hand cylinder. During the remainder of the revolution a cycle of operations occur similar to that just described, except that these operations take place in opposite cylinders. The exhaust steam from the left hand cylinder passes over the top edge, and down through the valve, which is hollow, into the chamber E.

The valve guide G is a small piston of about the same diameter of the valve which serves as a crosshead for the attachment of the excentric rod, and at the same time prevents the exhaust steam passing into the crank case. If the engine were exhausting against any considerable back pressure, there would be an unbalanced downward force caused by the pressure of the exhaust over the area of the valve guide G. To provide against this, the chest is extended upward, and a back pressure piston P attached to the valve stem, above the main valve high enough so that it never comes down to the port A. The upper surface of P is open to the atmosphere through a hole in the steam chest cover, while the under side is subjected to the pressure of the exhaust, which exerts a force equal in intensity and opposite in direction to that due to the pressure on G, and consequently makes the balancing of the valve practically perfect for all conditions of both steam and exhaust pressure.

## The " Westinghouse " Single Acting Compound Engine.

The "Westinghouse" Single Acting Compound Engine was introduced about twelve years ago. These engines are built in sizes from 25 to 750 H.P.; above the latter power double acting engines are built up to 5,000 H.P.

Fig. 82 is from a photograph of a 100 K.W. "Westinghouse" Compound Engine coupled to a dynamo.

Fig. 83, details of cylinder, pistons, steam chest and valves.

On referring to Fig. 83, it will be seen that the cylinders consist of two plain tubes, without ports or cored passages of any sort, cast together with flanges at top and bottom. The steam chest is also a very simple casting, the steam passages being formed by a bush. S and E are the steam and exhaust chambers around the bushing, into which connect respectively

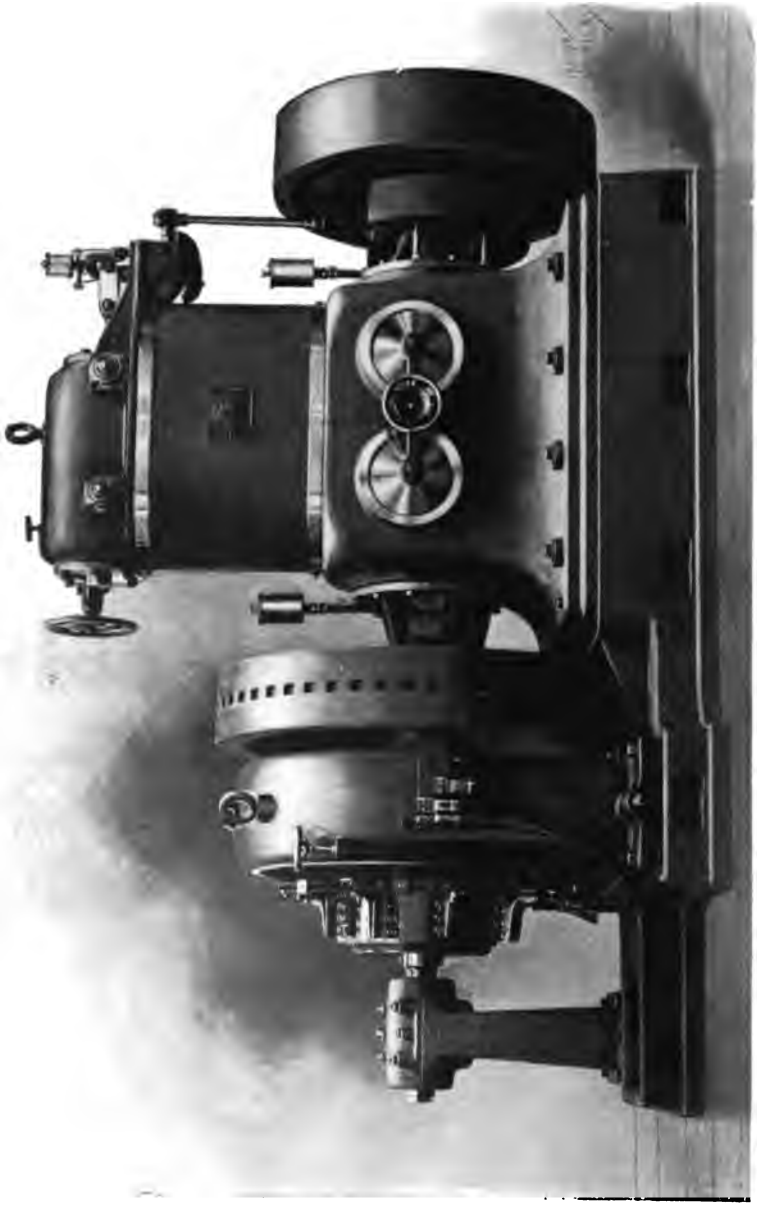


FIG. 82.—100 K.W. "WESTINGHOUSE" DIRECT CONNECTED GENERATING SET.

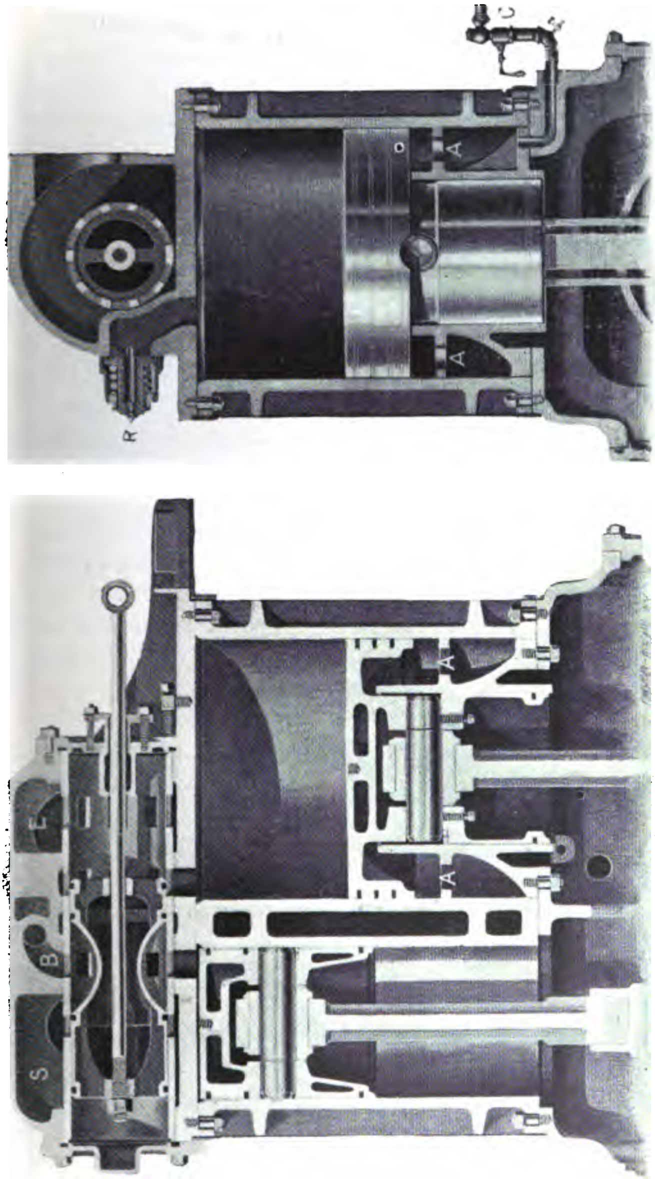



FIG. 83.—DETAIL OF CYLINDERS, PISTONS, STEAM CHEST AND VALVES.

the steam and exhaust pipes. The curved passage B connects, through the by-pass valve, controlled by a hand wheel on the back of the steam chest, with the steam space S.

The pistons are of the trunk pattern, double walled to prevent condensation. The low pressure piston differs from the high pressure in that it has two diameters. The larger diameter is that of the low pressure cylinder, while the smaller is the same as the high pressure cylinder, and works through a sleeve or internal cylinder fixed in the bottom of the low pressure cylinder. The object of this construction is two-fold:—If two pistons of unequal area were in communication with the crank case there would be at each revolution an alternate compression and suction due to the unequal displacement, which would interfere with the level of oil and water. By the construction adopted, the displacement of each cylinder is made the same, and the volume of air in the crank case remains practically constant. The annular space A underneath the larger diameter of the piston and outside of the sleeve forms a cushion chamber, in which the enclosed air is slightly compressed at the bottom of the stroke, and a partial vacuum formed at the top of the stroke. This action, involving no loss of power, assists in absorbing the momentum of the larger piston at the end of the stroke and materially relieves the crank pin and connecting rod of that duty. The cushion space is drained by a spring check valve C. By means of the handle the valve can be held off its seat to destroy the cushioning action when starting or turning the engine over by hand.

The governor, two views of which are shown (Figs. 84 and 85), is of the at present popular "single weight" or "inertia" type, used by most of the leading American manufacturers.

In general the inertia governor consists of a single weight of the typical form shown by Figs. 84 and 85, pivoted on the hub of the governor wheel to one side of the shaft, the centre of gravity of the weight being located approximately at G. A spring with an adjusting screw to regulate the tension is attached to the wheel and the weight at convenient points. Rotation being in the direction of the arrow, any increase in speed tends to make the centre of gravity of the weight seek a position further away from the centre of the shaft, and cau the weight to swing on its pivot in a direction opposite that of the wheel. The excentric is attached to the weig and this movement brings the centre of the excentric nea the centre of the shaft, and increases its annular advar thus effecting an earlier cut-off. Fig. 84 shows the positio the governor at longest travel and cut-off, and Fig. 85 shortest or zero cut-off, where the valve travel is just equa the lap. The greater part of the weight lying outside the pivot, if there be any sudden tendency of the engin ncrease its speed, the weight of its inertia tends to lag bel

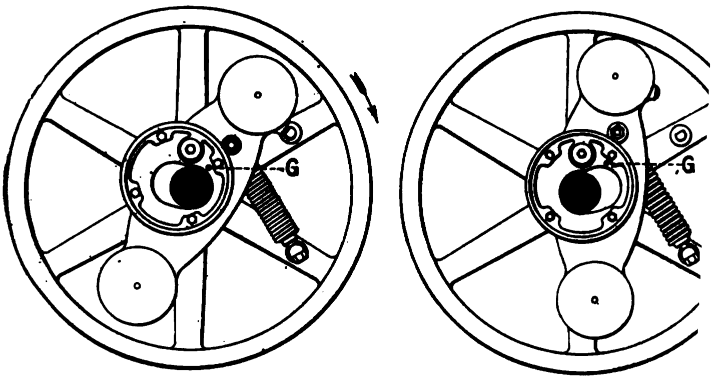



FIG. 84.—AT LONGEST CUT-OFF. FIG. 85.—AT SHORTEST CUT-OF

POSITION OF GOVERNOR PARTS AT LONGEST AND SHORTEST CUT-OFF.

the wheel, thus augmenting or almost anticipating the of centrifugal force and bringing the excentric to a sl cut-off. Conversely, if a load be suddenly thrown o engine, and there be a consequent tendency to drop in s the weight by its own inertia tends to rotate at the speed and runs a little ahead of the wheel, swingin excentric to a position of longer cut-off. It will thus b that in this type of governor, when properly designed, c fugal force, the primary regulating force, is aided b inertia of the weight, and the action of the governor is t materially hastened.

## "Westinghouse" Compound Double Acting Engine.

Fig. 86 is from a photograph of a 2,500 H.P. "Westinghouse" Compound. Three of this type have been supplied to the

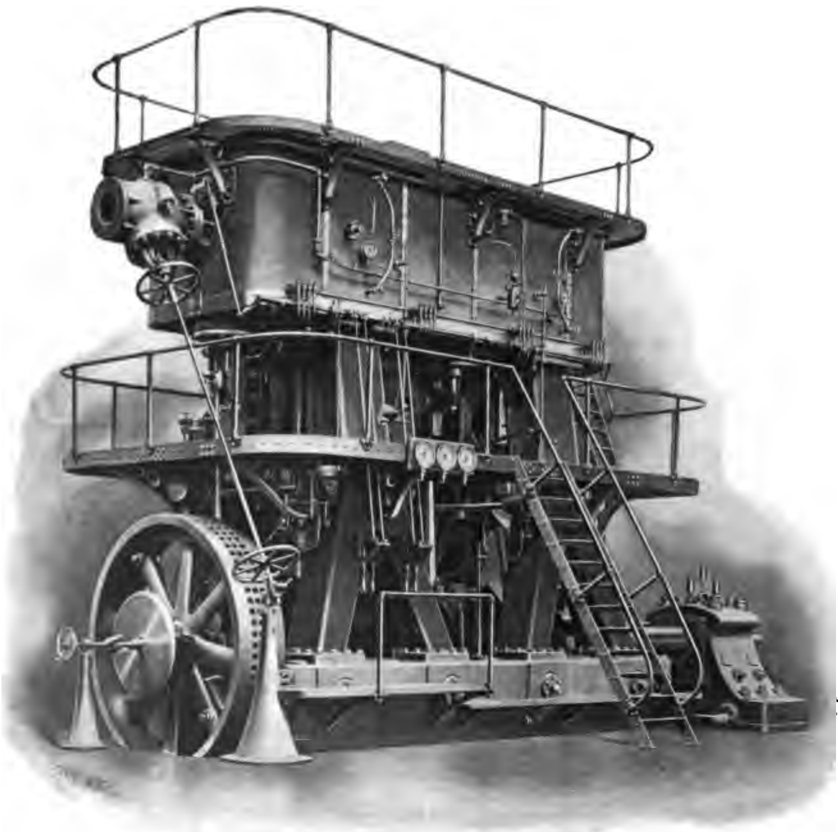


FIG. 86.—2,500 H.P. "WESTINGHOUSE" CROSS COMPOUND VERTICAL ENGINE. METROPOLITAN TYPE.

Metropolitan Electric Supply Co., Ltd. Each engine has a nominal capacity of 2,500 H.P. The extended shaft carries the armature of an alternating current generator with an output of 1,500 K.W. The armature is so designed as to diameter and weight that no flywheel is required.

TABLE OF ACTUAL STEAM CONSUMED PER INDICATED HORSE POWER. "WESTINGHOUSE" COMPOUND ENGINE, CYLINDERS 14 IN. AND 24 IN. BY 14 IN., BY TEST, UNDER VARYING LOADS AND PRESSURES.

Unjacketed and Uncorrected for Entrained Water. February, 1888.

| NON-CONDENSING. | | | | | CONDENSING. | | | |
|---|---|---|---|---|---|---|---|---|
| Boiler Pressures. | | | | HORSE POWERS. | Boiler Pressures. | | | |
| 60 lb. | 80 lb. | 100 lb. | 120 lb. | | 120 lb. | 100 lb. | 80 lb. | 60 lb. |
| | | | 22·6 | 210 | 18·4 | | | |
| | | 23·0 | 21·9 | 170 | 18·1 | 18·8 | | |
| | 24·9 | 23·6 | 22·2 | 140 | 18·2 | 18·5 | 20·0 | |
| | 25·7 | 23·9 | 22·2 | 115 | 18·2 | 18·6 | 19·6 | 20·5 |
| 26·9 | 25·2 | 24·9 | 22·4 | 100 | 18·3 | 18·6 | 19·7 | 20·3 |
| 27·7 | 25·2 | 25·1 | 24·6 | 80 | 18·3 | 18·6 | 19·9 | 20·1 |
| 30·3 | 28·7 | 29·4 | 28·8 | 50 | 20·4 | 20·8 | 20·7 | 20·4 |

## "WESTINGHOUSE" SINGLE ACTING COMPOUND.

These tests were made with 150 pounds of steam, non-condensing, and at five different loads, ranging from one-fifth up to full rated capacity of the engine

No correction for moisture in steam.

| ELECTRICAL OUTPUT. | | Indicated Horse Power. | Electrical Horse Power. | Total Efficiency Engine and Dynamo Per Cent. | Steam per Indicated Horse Power per Hour. | Steam per Electrical Horse Power per Hour. |
|---|---|---|---|---|---|---|
| Amperes. | Volts. | | | | | |
| 1000 | 125 | 202·56 | 167·56 | 82·72 | 22·82 | 27·59 |
| 810 | 125 | 162·48 | 135·72 | 83·53 | 23·23 | 27·81 |
| 610 | 125 | 124·67 | 102·21 | 82·00 | 24·31 | 29·65 |
| 400 | 125 | 81·35 | 67·02 | 82·4 | 28·06 | 34·06 |
| 200 | 125 | 46·69 | 33·57 | 71·75 | 35·21 | 49·06 |

## THE WESTINGHOUSE "JUNIOR" ENGINE.

The Westinghouse "Junior" Engine is of the simple single-valve automatic type. Fig. 87 is an outside view, Fig. 88 is a

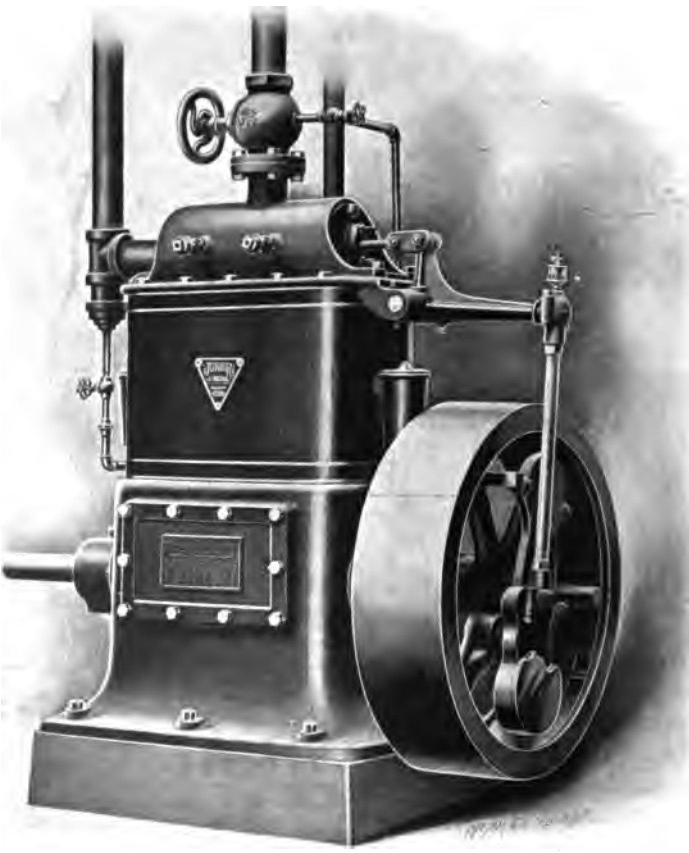


FIG. 87.—FRONT VIEW OF "JUNIOR" ENGINE.

section, and Fig. 89 is a section through steam chest, cylinders, valve and pistons.

It will be seen that this engine consists essentially of two cylinders, arranged with only a thin wall between them, which enables the central bearing to be dispensed with. We have already pointed out that there is no advantage in using a central bearing in most types of engine. We are acquainted with engines of the cross horizontal compound type developing 400 H.P. with only two main bearings. The steam chest

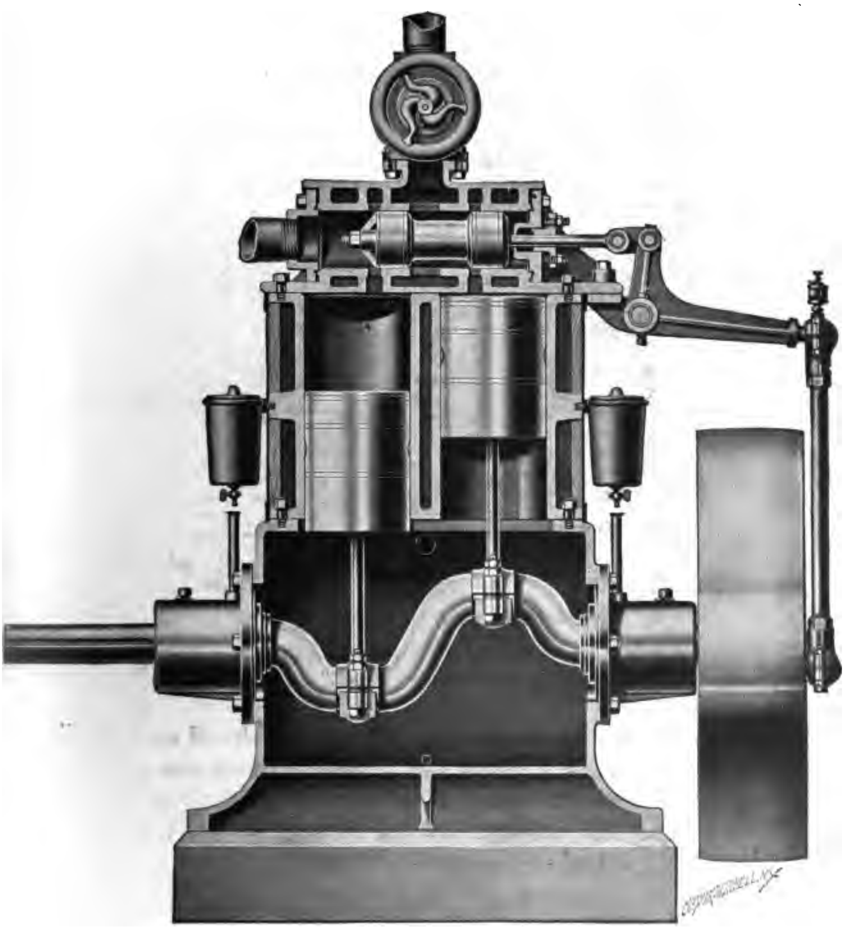


FIG. 88.—SECTIONAL VIEW OF "JUNIOR" ENGINE.

forms the cover for both cylinders. The valve is of the piston type. Horizontal reciprocating motion is imparted to it from the up and down moving excentric rod, through a bell crank rocker arm.

It will be seen that the governor is in the flywheel instead of in the crank case, as it is in the "Standard" engine. The governor is of the "single weight" or "inertia" type.

The action of the valve will be easily understood from Fig. 89. Steam entering at S fills the annular space surrounding the neck of the valve. When the parts are in the position shown, the valve is moving towards the left, establishing communication between the steam space and the left-hand cylinder through the port A, the left-hand piston just

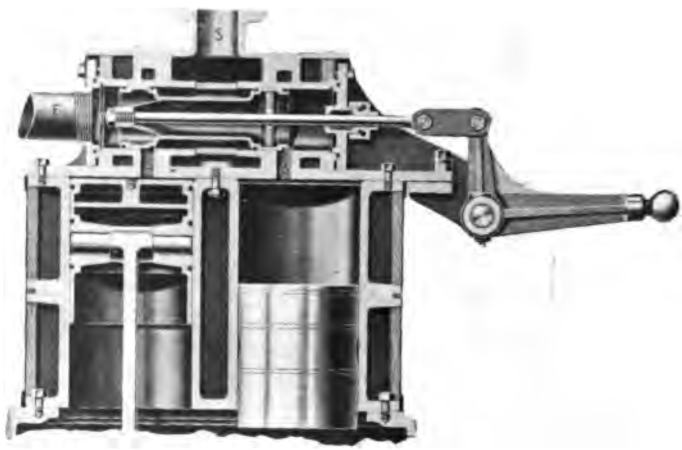


FIG. 89.—DETAIL SHOWING STEAM CHEST, CYLINDERS, VALVE AND PISTONS OF WESTINGHOUSE "JUNIOR."

starting on its downward stroke. The right-hand end of the valve has begun to uncover the port B, so that the exhaust can pass up and through the valve, which is hollow, to the exhaust pipe E. As the revolution progresses, the valve reaches the limit of its travel toward the left and starts back, covering the port A again, at a point determined through the governor by the load, allowing expansion to take place in the left-hand cylinder. Continuing its travel toward the right, the valve covers the port B, so that a portion of the exhaust steam is compressed to fill up the clearance spaces. A little later, and just before the revolution is half completed, the left-hand end of the valve uncovers the port A, so that the exhaust may have free exit when the left-hand piston begins its upward stroke. A similar cycle of operations now occurs in opposite cylinders, completing the revolution.

STEAM CONSUMPTION OF THE SEVERAL SIZES OF WESTINGHOUSE "JUNIOR" ENGINES AS DETERMINED BY ACTUAL TESTS.

Steam Pressure 100 pounds. Cylinders Unjacketed.

No Correction for Moisture in Steam.

| Size. | Indicated Horse Power. | Steam per Indicated Horse Power per Hour. Lbs. | Size. | Indicated Horse Power. | Steam per Indicated Horse Power per Hour. Lbs. |
|---|---|---|---|---|---|
| 5 × 4 | 6·75 | 42·68 | 9 × 8 | 48·62 | 32·90 |
| 6 × 5 | 16·73 | 41·21 | ,, | 25·47 | 31·42 |
| ,, | 9·42 | 42·14 | ,, | 14·11 | 34·61 |
| 7 × 6 | 22·86 | 37·53 | 10 × 9 | 61·56 | 31·00 |
| ,, | 12·12 | 36·46 | ,, | 31·28 | 32·22 |
| ,, | 7·18 | 44·84 | ,, | 20·93 | 34·54 |
| 8 × 7 | 34·47 | 33·16 | 12 × 10 | 94·25 | 30·49 |
| ,, | 18·03 | 33·94 | ,, | 47·92 | 32·21 |
| ,, | 9·47 | 44·98 | ,, | 25·74 | 34·07 |

## The "Ideal" Engine.

It is no exaggeration to say that a careful examination of the numbers of double acting engines built throughout the U.S.A. will show a majority to have included one or more of the improvements adapted after success attained by A. L. Ide & Sons upon their "Ideal" Engines. This simple self-oiling "Ideal" centre crank engine was introduced ten years ago.

Fig. 90 is a section of the "Ideal" simple engine. The main feature of this engine is the self-oiling device, which is as follows: The lowest interior portion of the engine frame is directly under the crank disc. A sufficient quantity of oil is poured into the engine frame so that the rims of the crank disc are immersed from one-half to three-quarters of an inch. So soon as the engine is started the revolving crank discs begin to throw the oil from the reservoir back on the guides and cross-head, so that when at full speed these parts, together with the wrist pin, are deluged with lubrication. The crank discs also, centrifugally, throw a continuous spray of oil forward into a trough placed across the inside of the oil guard, or hood, which at once becomes filled with the lubricant. At either end of this trough is attached a small pipe which conveys the oil to a point directly above the main bearings, leaving an open and easily visible distance from the end of the pipes to the receptacle cast in the bearing caps. In this way the constant stream of oil is visible to the attendant. This

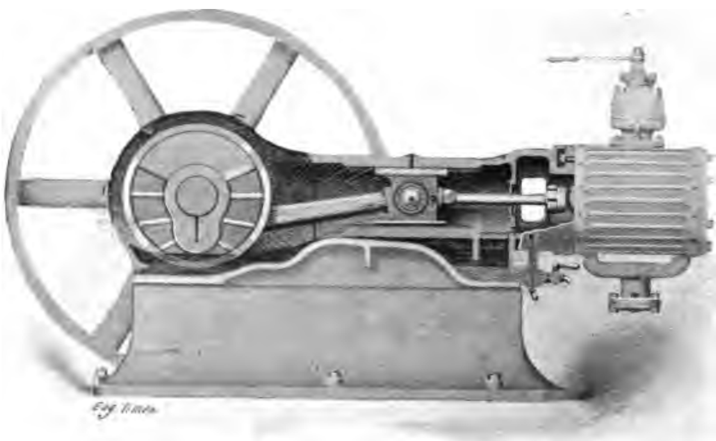


FIG. 90.—"IDEAL" SELF-OILING SYSTEM. A. L. IDE & SONS, SPRINGFIELD, ILL.

stream of oil is allowed to enter and flow along the main shaft bearings, from which it finds its passage inwardly into an annular *excentric* groove cut in the outside faces of the crank discs. From the most excentric point annular holes are drilled through to the centre of the crank pin. By these channels every drop of oil discharging into the main bearings from the oil trough within the hood is made, by centrifugal *pumpage*, to be drawn across the main bearing, and the greater part discharged by that force to the crank pin bearing. In this device, therefore, it will be seen that oiling or lubrication is actually automatic.

We had the opportunity of watching daily the behaviour for some weeks in Detroit of a tandem compound "Ideal" engine (see Fig. 91), coupled direct to a dynamo; and


FIG. 91.—TANDEM COMPOUND "IDEAL" ENGINE, COUPLED TO DYNAMO.

although the output was varied between very wide limits the governing was exceedingly "close," in fact, the general behaviour of this engine left little to be desired.

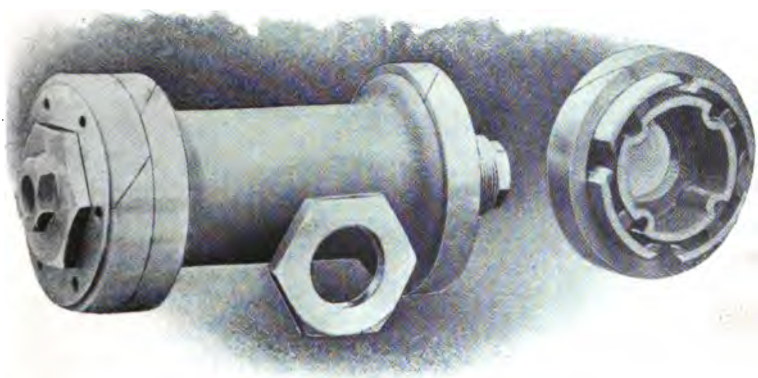


FIG. 92.—PISTON VALVE OF IDE & SONS' "IDEAL" ENGINE.

For the past fifteen years Messrs. Ide & Sons have used a plain block piston valve, and continue to use this valve on engines up to 40 H.P.; above this power they use a very simple form of adjustable piston valve. It will be seen by referring to Fig. 92, that the follower plate at either end of the valve carries a set of cams which bear against four shoes under the expansion rings. The nut behind the follower plate clamps it in position. To adjust the valve it is only necessary to slacken the lock nut, and turn the follower plate by means of a spanner, to expand the ring to the desired diameter, then lock it in the next position with the lock nut.

The crank shaft used on the "Ideal" engine is of special construction known as "Semi steel." This crank shaft is of the

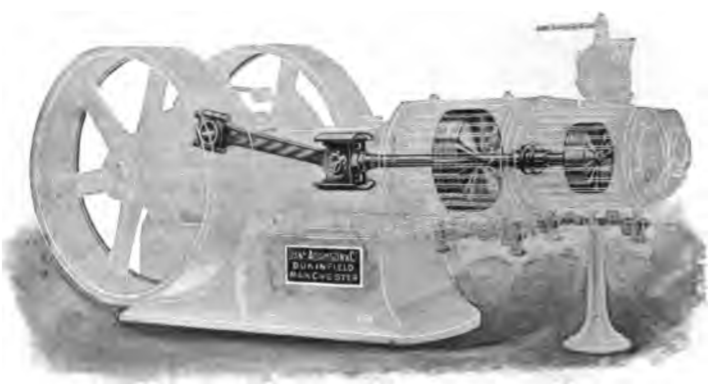


FIG. 93.—"IDEAL" ENGINE—VIEW SHOWING WATER PACKING, PISTONS, SLIPPER AND CONNECTING ROD.

built-up type with the distinguishing feature that the core is of steel, whilst the outer covering is of gun-metal. In casting, the strengthening core is supported in a mould and the metal is poured and cast so as to form the disc and shaft in one piece. The steel centre rod is heated to a degree which will enable it to become fused with the molten cast metal surrounding it. Several thousands of engines have been equipped with this form of shaft which demonstrates that the gun-metal makes a serviceable journal when used with "Babbitt" metal bearings. The built-up crank enables a "Tool" steel crank pin to be used, which is of very much stronger form than can be obtained in a forged crank.

Fig. 93 shows "Ideal" engine with water packing, piston, slipper, and connecting rod.

Rite's "Inertia" governor is used on the "Ideal" engine. This governor embodies the centrifugal and inertia principle in a single weight. It will be seen that there is only one pillar or element with its controlling spring. The inertia principle of the governor regulates all sudden changes in load, and the centrifugal principle takes care of any changes in speed which might occur from a gradual change.

Fig. 94 shows "Ideal" Simple High-Pressure Engine.


FIG. 94.—"IDEAL" SIMPLE HIGH-PRESSURE ENGINE.

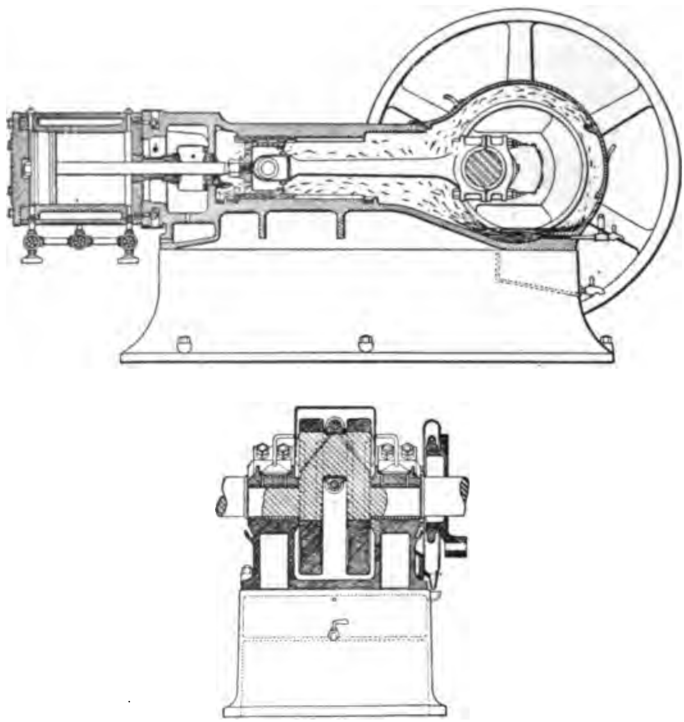
These engines are now made in England by Messrs. D. Adamson & Co., Dukinfield.

## THE "HARRISBURG" ENGINE.

The Harrisburg Co. manufacture self-lubricating engines on the Ide system.

Figs. 95 and 96 are sections of the Harrisburg "Ideal" engine, built under Messrs. Ide's patents.

Fig. 97 shows the "Ideal" engine running on three steel points. The Harrisburg Co. finally test all their engines on steel points, sufficient in number to prevent rocking. As soon as the steam indications are found to be correct, the engine is subjected to a system of counter-balance, which gradually reduces the thrust or vibration until such tendencies are reduced to a degree which, even with the engine thus delicately supported upon steel points, and the fastening



FIGS. 95 AND 96.—SECTIONAL VIEWS OF THE HARRISBURG "IDEAL" SIMPLE ENGINE.

clamps gradually but entirely removed, will show the engine to be operating without thrust sufficient to disturb by vibration by its own weight. Some thrust, due to the motion of reciprocating parts, doubtless remains, but this is thrown at an angle of 45° from horizontal, and is obviously very slight.

Another type of self-oiling engine is made by this firm, belonging to the side crank class. That is, the shaft is

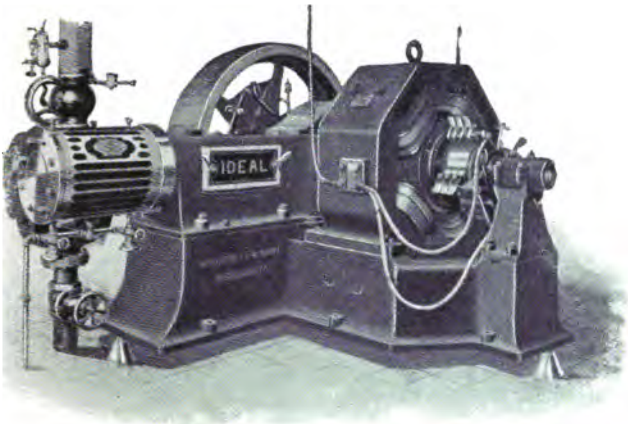



FIG. 97.—VIEW OF A HARRISBURG "IDEAL" ENGINE RUNNING ON THREE STEEL POINTS, SHOWING BALANCE

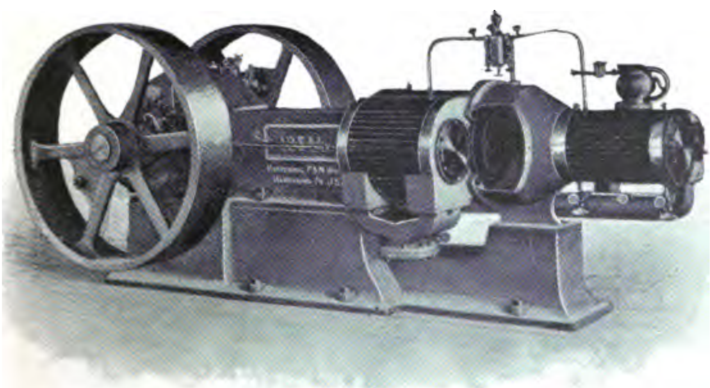


FIG. 98.—HARRISBURG "IDEAL" TANDEM COMPOUND ENGINE—BELTED STYLE

supported by one bearing on the side of the frame, one a "piilow block." The oiling device is the same as used on the "Ideal" engine.

It is well known that there is a difficulty in keeping in line more than two bearings. In the two-bearing engine, when the outer bearing is not "self-contained," there is the possibility of an unequal settling to contend with. It will be seen that all parts are accessible. This type of engine is also made with "Corliss" valves fitted with "live" steam for accelerating cut-off.

## The "Chandler and Taylor" Engine.

This Chandler and Taylor Co. was established in 1857, and claim to be the originators of the self-contained side crank engine. The firm is represented in this country by Messrs. Robert Blackwell & Co., Ltd., of 59, City Road, London, E.C. Fig. 99 is an external view of a self-contained high speed engine. The engine bed with overhanging cylinder is well known in this country as the "Tangye." The main bearings for the shaft are of the reservoir type, and are oiled by means of ring or chain oilers from an oil reservoir below. This method is positive, and permits of the oil returning to the reservoir, where any sediment that has accumulated may settle. These bearings are fitted with removable Babbitt linings which admit of easy renewal. It will be seen that the reciprocating parts are not closed, but are open at all times for inspection. The cylinder is made with double walls, there being an air space between the inner and outer shell of the cylinder proper. This non-conducting air space in a large measure arrests radiation and consequent condensation. This arrangement has been used for a considerable period by many well-known English firms, notably Robey & Co., on small and larger size engines.

The valve is of the balanced box type. A heavy pressure plate covers this valve, and is arranged so that the valve and the pressure plate can lift to give relief in the event of any accumulation of water. All surfaces of this valve are flat and parallel, and are free to expand or contract. The governor used on the "Chandler and Taylor" engines is made under Mr. F. M. Rite's patents, a type of governor which is largely used in America.

## The "Russell" Engine.

A type of engine which has been highly successful is that known as the "Russell" engine, built by Russell & Co., Massillon, Ohio.

Fig. 100 is a front view of the simple type of "Russell"

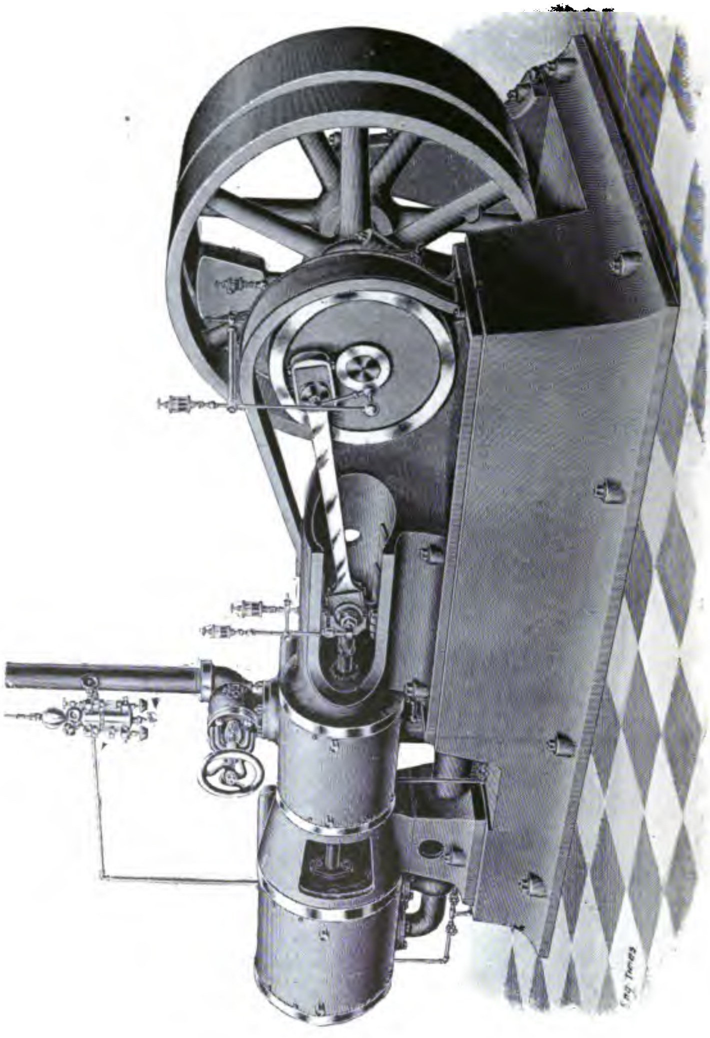


FIG. 99.—THE "CHANDLER AND TAYLOR" HIGH SPEED STEAM-ENGINE.

engine. The bed is of the "box" type, or a combination of the well-known "Tangye" and "semi-girder" patterns,

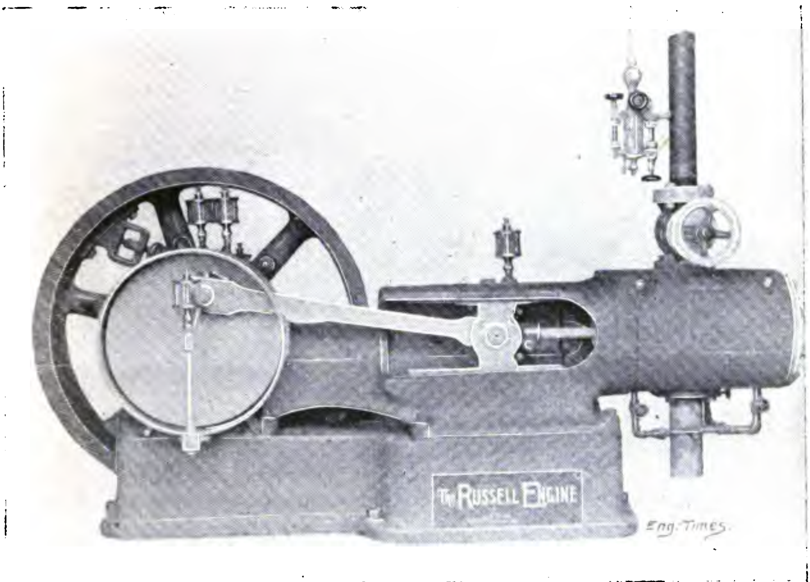



FIG. 100.—FRONT VIEW OF "RUSSELL" ENGINE.

with projecting cylinder, free to expand whilst working. The guides are bored, and permit a certain amount of self-adjustment in the crosshead.

Fig. 101 is a part sectional plan through the cylinder and steam chest. It will be seen by reference to Fig. 100 that the admission valve is double ported and balanced through needle ports leading into steam and exhaust ports. The steam chest cover is surrounded with a light casing, which not only gives a neat appearance

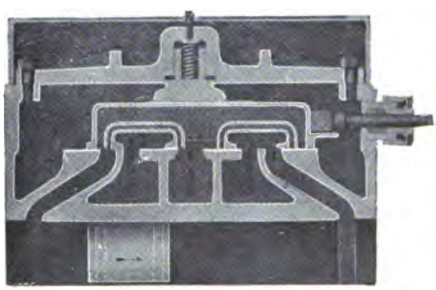
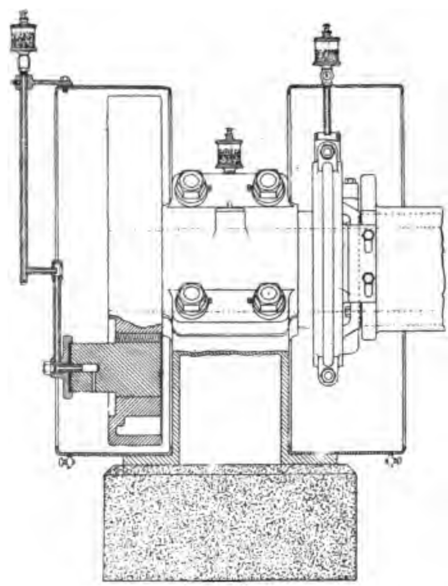


FIG. 101.—"RUSSELL" ENGINE—PART SECTIONAL PLAN THROUGH CYLINDER AND STEAM CHEST.

to the steam chest, but admits of ready removal in case of overhaul.

The proportions of the main shaft and crank pin are somewhat different to English practice. The main bearing is half the crank pin, quarter the diameter of the cylinder. The arrangement of oil guards will be clearly seen by reference to Fig. 102.

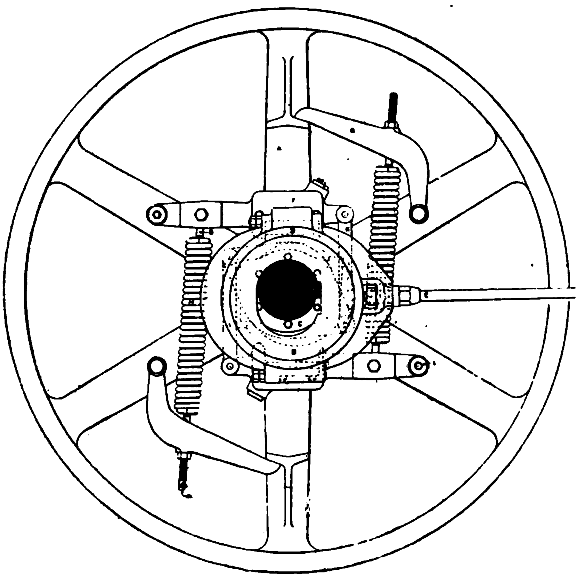
The governor (see Fig. 103) controls the speed of the engine through the inner excentric R, which fits loosely on the hub of the governor wheel A, and is connected with the weight arms F, through the links K, in such a manner that the inner excentric is moved round the hub of the governor, forward or backward, as the weights change their position. This forward or backward movement is communicated through the inner excentric strap Q to the main excentric strap B, causing this to slide on the hub plate C, in a *straight line across the shaft*, thus maintaining a constant "lead" for all points of cut-off. This movement across the shaft is always in the direction of reducing the excentricity of the main excentric, consequently reducing the travel of the valve.



OIL GUARDS.

FIG. 102.—"RUSSELL" ENGINE—SHOWING ARRANGEMENT OF OIL GUARDS.

When the weights are at the inner position, the throw of the excentric is at its *maximum*, and steam is admitted three-quarters of the engine's stroke. When the weights are at their extreme outer position the throw of the excentric is at its minimum, and the steam is cut off at the beginning of the stroke. Between these two extremes any number of positions of the weights and corresponding angular positions of the eccentric may be had, and as the steam is thus adapted to the load in each position, it follows that a slight increase or decrease in speed must make a change in the cut-off, and to bring the engine again to standard speed. The free movements of the



Governor

FIG 103—"RUSSELL" ENGINE—GOVERNOR.

weights F is opposed by the springs H. By tightening the tension screw N the force of the springs is increased, and by adding weights to the weight arms F the centrifugal force for any given speed is also increased. Now it is clear that there is a point where these two forces exactly balance each other, and but for the unsteadiness produced by the equilibrium of these two forces, this would be the proper adjustment for the best regulation. It is Messrs. Russell's practice to give a small preponderance to the weights F, by reducing the tension of the springs just enough to overcome the unsteadiness, and after the spring tension has been thus adjusted, it should not be tampered with to make any desired change in speed, as speed should always be adjusted at the weights and not at the springs.

Fig. 104 shows very clearly Rite's governor is fitted to the "Russell" engine.

The single cylinder engines are made in sizes from 18 H.P., cylinder 6 in. bore × 10 in. stroke, making 325 revolutions per


FIG. 104.—"RUSSELL" ENGINE—RITE'S GOVERNOR.

minute, up to 175 H.P., with cylinder 16 in. bore × 20 in. stroke, making 175 revolutions per minute. Steam pressure 125 lb. per square inch.

A very neat type of tandem compound engine is made by Messrs. Russell & Co., which is largely used for driving dynamos direct. See Fig. 105.

It is well known that the greatest economy attached to the use of the compound engine is obtained when running it condensing, as the larger area of the low-pressure piston exposed to the action of a more or less perfect vacuum adds considerably to the efficiency of the engine. The ratio between the cylinders should be greater for condensing than for non-condensing engines to obtain the best results, but engines fitted with a condenser often are compelled to be run non-condensing for a longer or shorter period of time, owing to lack of sufficient water supply or other causes, and as engines originally intended to be run non-condensing are later supplied with a condenser, Messrs. Russell proportion the cylinders of their engines so as best to meet both these extremes, so that whilst recommending the use of a condenser

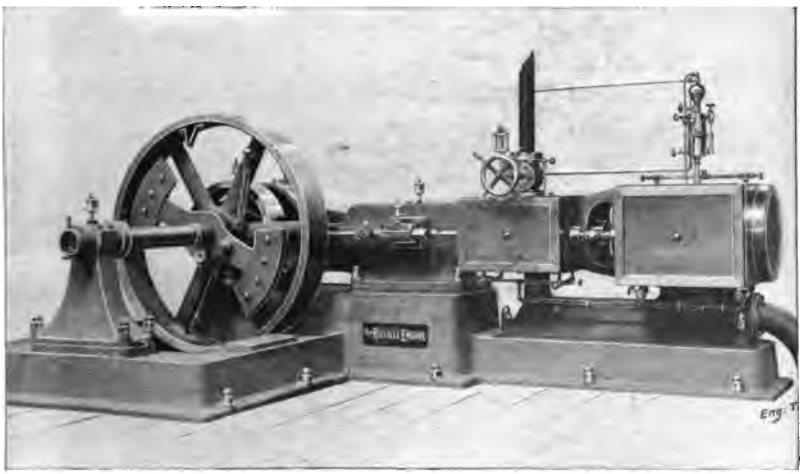


FIG. 105.—THE "RUSSELL" HIGH SPEED TANDEM COMPOUND ENGINE.

in connection with their compound engines, they claim that with a high steam pressure of, say 125 lb. per square inch, almost as economical results can be obtained non-condensing as condensing. We agree with Messrs. Russell on this point, having for some considerable time failed to see how a condensing plant for a small installation of, say 100 H.P., would warrant the outlay, to say nothing of the up-keep.

Referring to Fig. 105, this type of high-speed tandem compound engine possesses several very good features, and is admirably suited for driving dynamos direct. It will be seen that the engine and dynamo are arranged on one base.

The receiver between the high and low pressure cylinders forms a substantial support for both cylinders, and is well arranged for sliding the cylinders. Every part of the engine is get-at-able, and is altogether a first-class job. The tandem engines are made in sizes from a 9 in. × 14 in. × 14 in. stroke, making 260 revolutions per minute, up to 13 in. × 20½ in. × 20 in. stroke, making 210 revolutions per minute. The cut-off, non-condensing, =·30, and condensing, ·20 of the engine stroke.

## The "Robb Armstrong" Engine.

The "Robb Armstrong" Engines were introduced in 1891 by the firm of that name of Amherst, N.S. This firm built

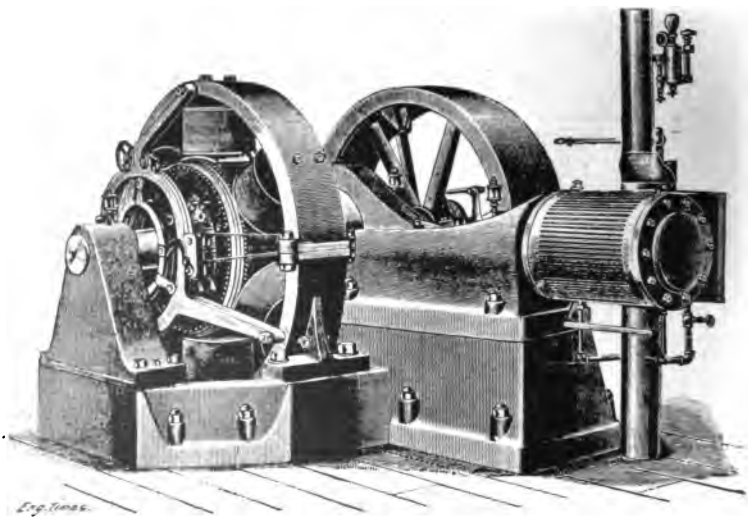


FIG. 106.—THE "ROBB ARMSTRONG" DIRECT CONNECTED ENGINE AND DYNAMO.

engines of the centre crank, side crank, and side crank tandem compound. Fig. 106 is from a photograph of a single cylinder high speed engine direct coupled to a dynamo. The governor used on these engines is a modification of Professor Sweet's straight line governor.

The valve is a flat plate, arranged to give a double opening both for admission and exhaust. This valve is provided with a back pressure plate.

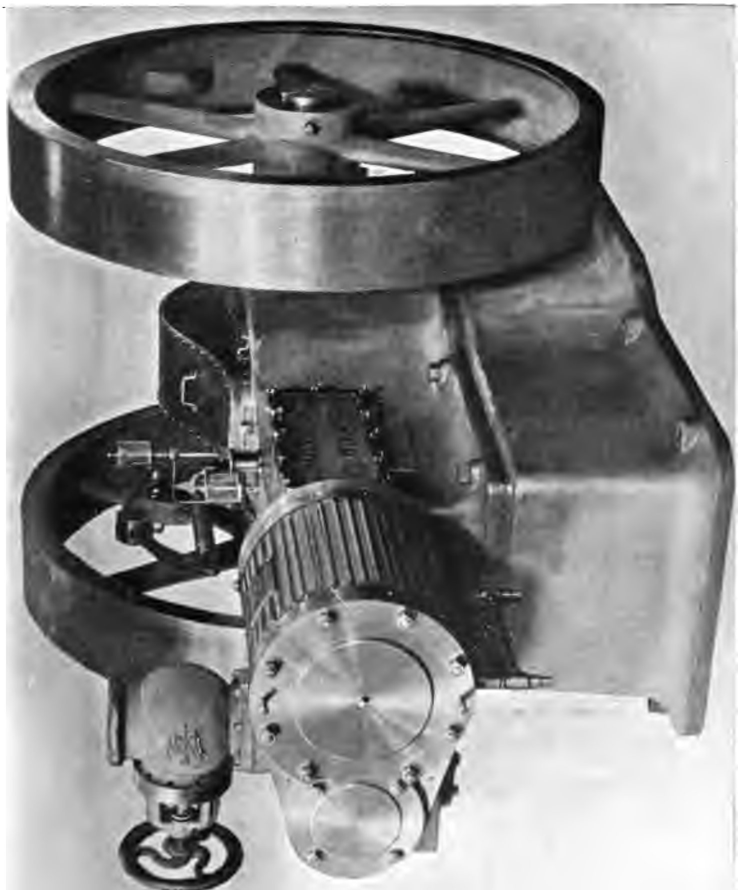


FIG. 107.—THE BUFFALO FORGE CO.'S ENGINE.

The main bearings are lubricated by means of the well-known ring system.

BUFFALO FORGE CO.'S ENGINE.

Another self-lubricating engine is that made by the Buffalo Forge Co., shown in Fig. 107, and known as the Buffalo Automatic Cut-off Engine.

The self-lubricating system, as regards the main bearings, differs from the "Harrisburg" in dispensing with the trough fixed in the hood, the lubricant being guided to a recess in the main bearing cup arranged inside the crank hood.

The distribution of the steam is effected by means of a piston valve fitted with snap rings. This valve is coupled direct to a flywheel governor.

The cylinder differs somewhat from other self-lubricating types, inasmuch as the cylinder and inside cover with stuffing boxes are separate. The division plate is dispensed with. We consider the division plate a necessity, inasmuch as the stuffing boxes can be inspected without stopping the engine, and the oil is kept on the hot cylinder end.

## The "Ball and Wood" Engine.

Fig. 108 is from a photo of a 600 H.P. Vertical Compound Condensing Engine, with 200 K.W. direct connected railway generators, made by the Ball and Wood Co. This engine does not belong to the high rotative speed class, though the piston speed is 960 feet per minute; the revolutions per minute being 190.

The chief features of this engine are its small clearances and "close" regulation.

The Ball and Wood engine valves are of the "Corliss" type, and are fitted to the extremities of the cylinders so that the clearance is under 2 per cent. The valve is made to lift in the event of water entering the cylinder, thus allowing the water to be returned to the valve chest. Relief valves by this arrangement are dispensed with.

Another feature of this engine is the re-heating coil in receiver, which reduces the drop in the initial between the high pressure exhaust and low pressure admission. The makers state that their experience has proved that this re-heater gives greater economy than jacketing. It will be noticed in the illustration, Fig. 108, that the engine bed is built up; but the usual practice is to build it to two longitudinal girders with separate bed for high pressure and low, bolted and held in place by tongued and grooved joints with machined faces, and to fit four intercostals made of brickwork. This gives a very rigid bed-plate, enabling the parts to be easily handled under the most awkward conditions,

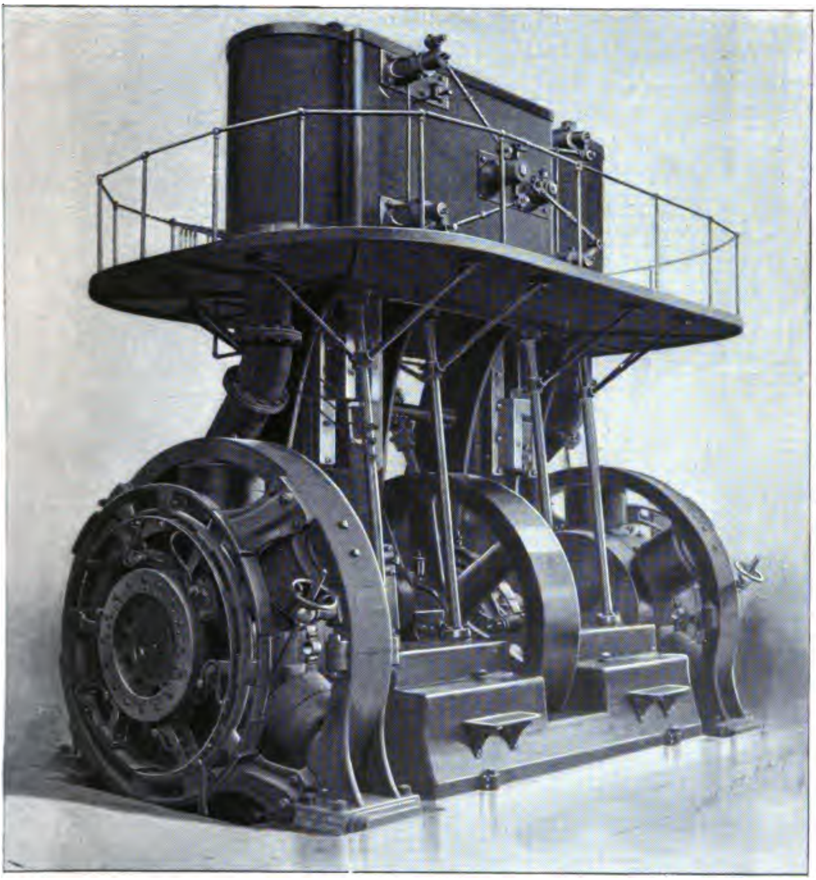


FIG. 108.—THE "BALL AND WOOD" ENGINE.

and also insures a bed of much greater rigidness than it is possible to obtain where the high and low pressure beds are cast separately and bolted together. Another feature consists in the arrangement of the front columns; the back columns are made sufficiently massive to enable the front columns to be removed should it be so desired to replace the crank shaft.

The Ball and Wood Co. give some interesting figures of the Edison Electric Illuminating Co., Paterson, N.J., who have 6,000 H.P. of their engines made up of 10 units.

The actual output per pound of coal, costing four shillings per ton delivered at their works, is 300 watts. There is no doubt that this high economy is largely due to the excellent arrangement and system. Unlike many central stations in England, the buildings have been designed to suit the machinery. It is well known that the cause of failure in many instances is due to the machinery having been arranged to suit the buildings.

## CRANKLESS ENGINES.

### PARSONS' STEAM TURBINE.

THE search for the ideal in connection with the steam engines has always been directed towards one which should have but a single revolving part and a constant circular movement. To convert a reciprocating into a circular motion has been left severely alone by most engineers who have pinned their faith to the sweet simplicity of the crank and connecting rod as the easiest possible means to make a marketable engine.

We have carefully followed Parsons' Steam Turbine, and have no hesitation in stating that Parsons' system is no mean rival to the highest grade of single or double acting steam engines.

Fig. 109 shows a section of the compound steam turbine, as applied to driving dynamos.

The turbine motor consists of a cylindrical case with rings of inwardly projecting blades, within which revolves a concentric shaft with rings of outwardly projecting blades. The rings or blades on the case nearly touch the shaft, and the rings or blades on the shaft lie between those on the case, and nearly touch the case.

Fig. 110 shows a form of blades which is used. Steam entering at J (Fig. 109) passes first through a ring of fixed guide blades, and is projected in a rotational direction upon the succeeding ring of moving blades, imparting to them a rotational force. It is then thrown back upon a succeeding ring or guide, and the reaction increases the rotational force. The same process takes place at each of the successive rings of guide and moving blades.

The energy to give the steam its high rotational velocity at each successive ring is supplied by the drop in pressure, and the steam expands gradually by small increments.

At the left side of the spindle are grooved pistons or dummies, which fit into corresponding grooves in the cylinder.

The object of the dummies is to prevent end thrust, and there is, therefore, a passage into the cylinder between each diameter of the spindle and the dummy of the same size.

The dummies also act as a practically steam-tight joint, since the clearance between the grooves can be adjusted longitudinally by a thrust block in the end oil keep.

The bearings are of the tubular pattern, and, owing to the

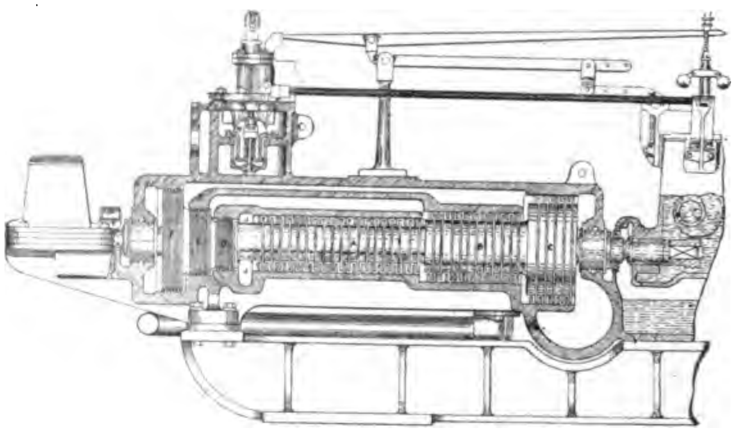


FIG. 109.—SECTIONAL VIEW OF PARSONS' STEAM TURBINE.

light weight of the revolving spindle, the wear is so small that the bearings often run for several years without being touched.

The armature is directly coupled to the motor spindle by means of a steel sleeve. The sleeve carries a thread which works a worm-wheel, and the worm-wheel actuates the oil pump and the steam admission governor by means of an excentric.

The governing of the machine is accomplished as follows:—Steam is admitted to the turbine by a series of gusts by the periodic opening and closing of a double-beat valve. This valve is operated by means of a steam relay in mechanical connection with the turbine shaft.

The duration of each gust is controlled by an electric solenoid, which is connected as a shunt to the field magnets.

The core of the solenoid is hung from the end of the long lever.

The fulcrum of this lever is periodically moved up and down by means of a link connecting it with the excentric, which receives its motion from the worm on the sleeve coupling, the excentric also serving to work the oil pump.

The short end of the lever controls the valve of the steam relay.

Each periodical movement causes a gust of steam to be

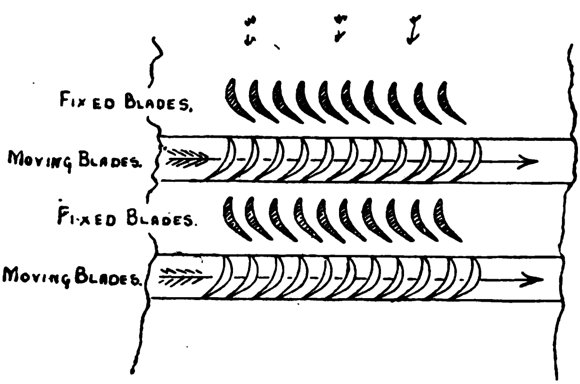



FIG. 110.—BLADES OF PARSONS' STEAM TURBINE.

admitted to the turbine, the duration of the gust depending on the height of the distant end of the long lever.

The bearings are all under a head of oil, and as the oil is continually circulated by means of a pump there is very little used.

One of the advantages that the Parsons' steam turbine has over other engines is, that no lubricant is used in the cylinder, and the exhaust steam is, therefore, entirely free from oil and other impurities.

With alternating machines a series of solenoid is also placed above the shunt solenoid, being connected to the top side of the long lever; thus, as the load on the dynamo increases, the lever rises and increases the duration of the gusts of steam.

In 1892, Professor Ewing tested a 140 K.W. turbo alternator, condensing type, and reports as follows :—

"A consumption of 27 or 28 lb. of steam per electrical unit at full load, and 30 or 32 lb. at half load, is a result that does not need to have its significance emphasized. The efficiency under comparatively small fractions of the full load is probably greater than in any steam-engine, and is a feature of special interest in relation to the use of the turbine in electric lighting from central stations. A consumption of steam at the rate of 28 lb. per electrical unit is equivalent to 15·7 of feed-water per 'indicated' horse-power hour. Similarly, the steam consumption of half-load is equivalent to about 17 lb. per 'indicated' horse-power hour."

Since then considerable improvements have been made, as is shown by the following test by Mr. Hunter, the Engineer of the Newcastle and District Electric Lighting Company, Limited, on a 150 K.W. condensing type alternator, complete with exciter, which was supplied to him in November 1896.

It will be noted that the pressure at the steam-chest of the motor was only 70 lb. per square inch, and the vacuum only 26⅛ inches and 26¾ inches, so that neither pressure nor vacuum were exceptionally favourable to economy. The object of the test made, however, was to ascertain the economy under ordinary working conditions.

The consumption of steam was measured by carefully calibrated tanks, from which the feed was drawn, and the electrical output was taken by a "Kelvin wattmeter" cross-checked by independent amperemeter and voltmeter; no steam separator was used, nor was the steam superheated. The power was absorbed by a water resistance.

Reference to the diagram shows the total water used per hour, for about full, half, and quarter load, to be respectively 3,484, 1,950, and 1,150 lb., or expressed as pounds per electrical horse-power per hour, the figures become 17·28, 20, and 22·01 respectively.

It is further to be noted that the quantity of water used when the generator was running at full voltage, but without doing work, was exceedingly small, and since the diagram shows that from this point the consumption of water increases with the load at approximately constant ratio, the importance of being able to keep the "no load" consumption down is at once apparent.

| Units. | Vacuum at Cylinder. | Total Water per hour, lb. | Water per unit, lb. per hour. | Water per E.H.P. lb. per hour. | Revolutions per minute. | Remarks. |
|---|---|---|---|---|---|---|
| 150·33 | 26⅛ | 3,384 | 23·17 | 17·28 | 2,700 | Barometer 29·3. Pressure of steam at Generator 70 lb. per sq. in. |
| 72·84 | 26⅛ | 1,950 | 26·77 | 20·0 | 4,700 | |
| 38·97 | 26¾ | 1,150 | 29·51 | 22·01 | 4,700 | |
| ·175 | 26¾ | 437 | — | — | 4,600 | |

TESTS SUPPLIED BY MESSRS. C. A. PARSONS & CO. OF 500 K.W. PARSONS' TURBO ELECTRIC GENERATOR.

27TH OCTOBER, 1899.

| | | | | |
|---|---|---|---|---|
| Boiler pressure | 137 | 139 | 145 | 140 |
| Vacuum | 24⅞ | 24½ | 26⅝ | 27⅝ |
| Barometer | 29·6 | 29·6 | 29·6 | 29·6 |
| Duration of Test | 9 min. | 9½ min. | 17-10 | 11½ min. |
| Total Water used | 2,011 | 2,011 | 2,011 | 800 |
| Nett Water per hour | 13,400 | 12,675 | 7,029 | 4180 |
| Average Kilowatts | 598 | 526·4 | 256·1 | 124 |
| Average Volts | 2,120 | 2,015 | 2,115 | 2,015 |
| Average Speed | 2,775 | 2,750 | 2,750 | 2,700 |
| Lb. per K.W. hour | 22·5 | 24 1 | 27·5 | 33·7 |

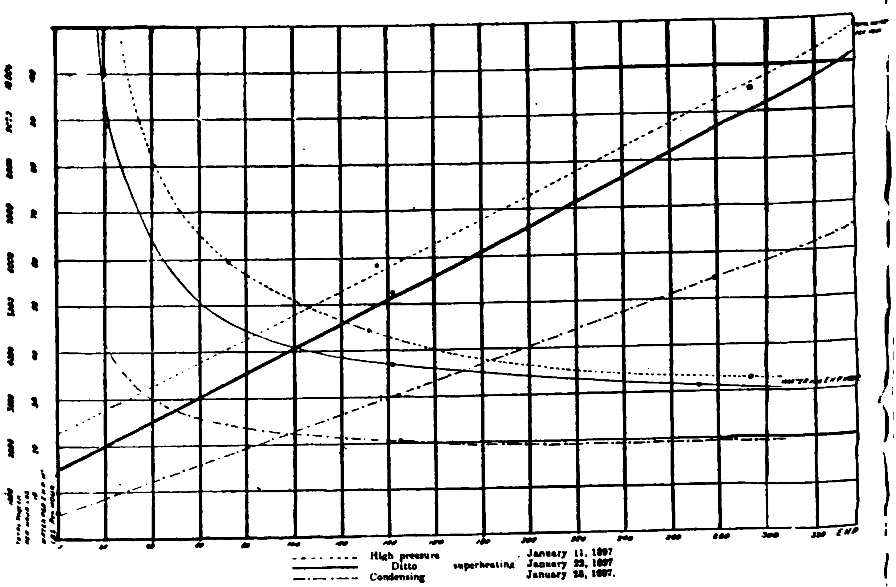
We are indebted to Mr. R. C. Quin, M.I.E.E., M.I.Mech.E., consulting electrical and tramway engineer, who not only kindly allowed us to watch the behaviour of the Blackpool installation, but furnished us with the following reliable data :—

"As you know, we have now four turbines here, and are having another four. They vary in horse-power from

100 to 1,000 each. The steam consumption is less under the specified conditions than with reciprocating engines placed side by side with them. In order to secure the best

TESTS OF 200-UNIT TURBO DYNAMO.

| Kilowatts. | Total water per hour. Lbs. | Water per Kilowatt. Lbs. per hour. | Water per E.H.P. Lbs. per hour. | |
|---|---|---|---|---|
| 219·2 | 9,466 | 43·20 | 32·22 | Non-condensing. |
| 98·7 | 5,848 | 59·23 | 44·18 | |
| 54·5 | 4,330 | 79·50 | 59·30 | |
| 0 | 2,092 | — | — | |
| 203·0 | 8,429 | 41·52 | 30·97 | Non-condensing and superheating 30° Fahr. |
| 106·1 | 5,287 | 49·83 | 37·17 | |
| 0 | 1,402 | — | — | |
| 208·0 | 5,443 | 26·16 | 19·51 | Condensing but no superheating. Vacuum at full load 25 in. |
| 108·4 | 3,037 | 28·02 | 20·90 | |
| 0 | 531 | — | — | |




economy it is essential that the turbines should be provided with dry steam, preferably super-heated, and a good vacuum. Our turbines, as you know, are direct coupled to dynamos,

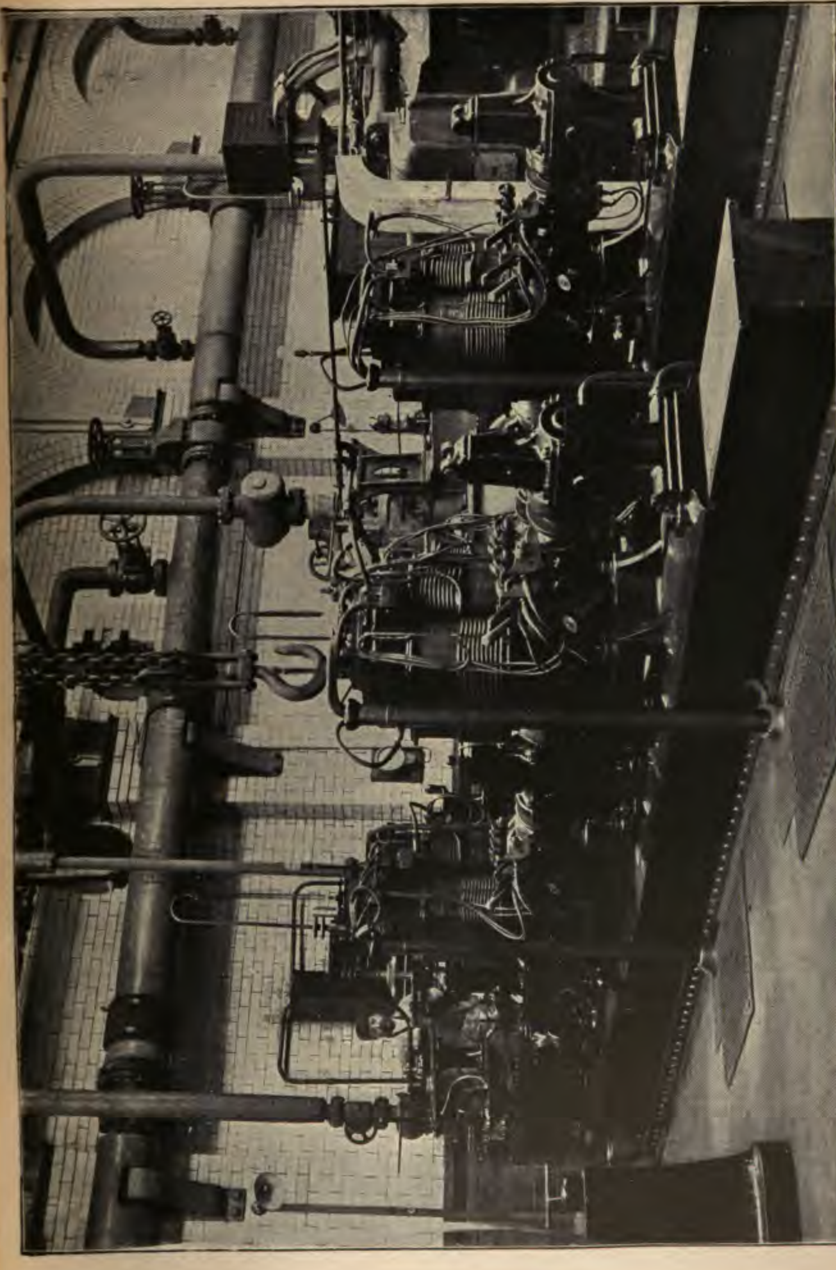


FIG. 111.—BLACKPOOL CORPORATION TRACTION TURBO PLANTS.

and the steam consumption when working at full load was, with the larger sets, 22 lb. of steam per kilowatt hour, and with the smaller sets 24 lb. In the maintenance of the turbines several points have specially to be observed, the balancing and maintenance of steam joint in the dummy piston chambers. Both of these are readily adjusted for wear. The bearings have given us no trouble whatever, although the question of suitable oil for the high speed and high temperature is a difficult one for oil blenders. We have only been able to obtain one oil after considerable trouble which is satisfactory. The governing of the machines is almost perfect."

Fig. 111 is from a photograph of the Blackpool Corporation Traction Turbo Plants.

## THE "DE LAVAL" STEAM TURBINE.

In an ordinary steam-engine the expansion of the steam in the cylinder gives out useful work, but in the "de Laval" steam turbine the steam is allowed to expand before doing useful work. This expansion takes place in conical nozzles, and the increased volume at exhaust pressure imparts a very high velocity to the steam jet issuing from the nozzles. In this way, by the expansion of the steam, the static or potential energy of the steam is converted into kinetic energy, and if the nozzles are made suitable for the expansion all the static energy of the steam will be stored up as kinetic energy in the steam jet when leaving the nozzles. This kinetic energy will, for a given quantity of steam, be absolutely identical to the work given out in a cylinder by the expansion of the same quantity of steam down to the pressure of the exhaust.

The steam issuing from the nozzle at very high velocity strikes the buckets of the turbine wheel, the impulse imparting motion to the wheel on a similar principle to the impulse water wheel. As the turbine rotates the steam passes through the buckets, and to get a high efficiency the peripheral speed of the wheel must be great to correspond with the high velocity of the steam. The following table gives

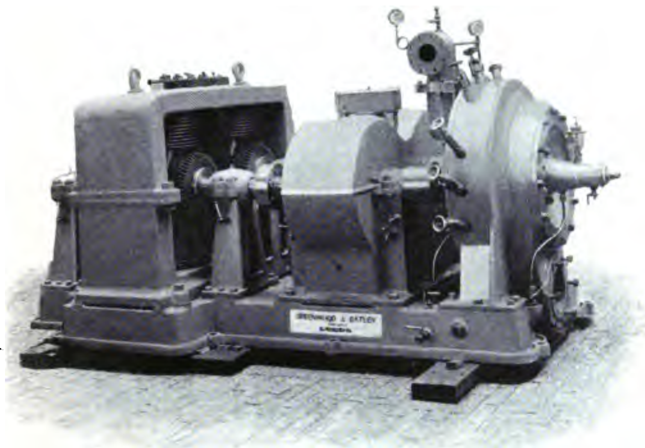


FIG. 112.—100 B.H.P. "DE LAVAL" STEAM TURBINE AND DYNAMO.

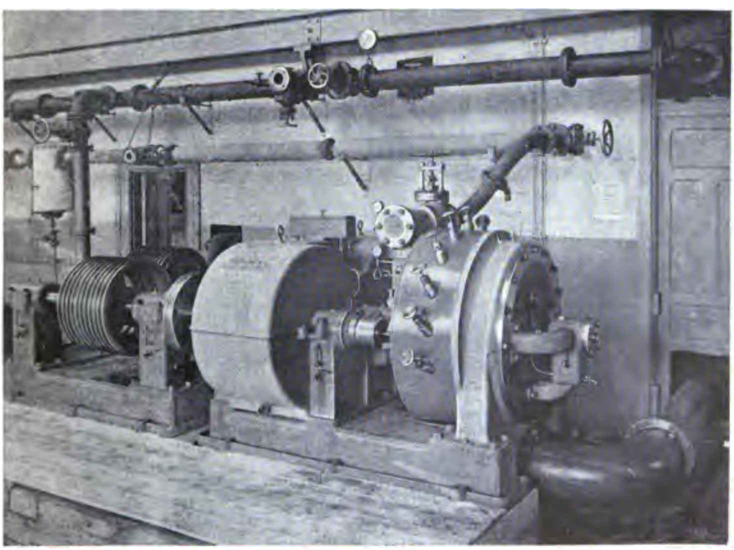
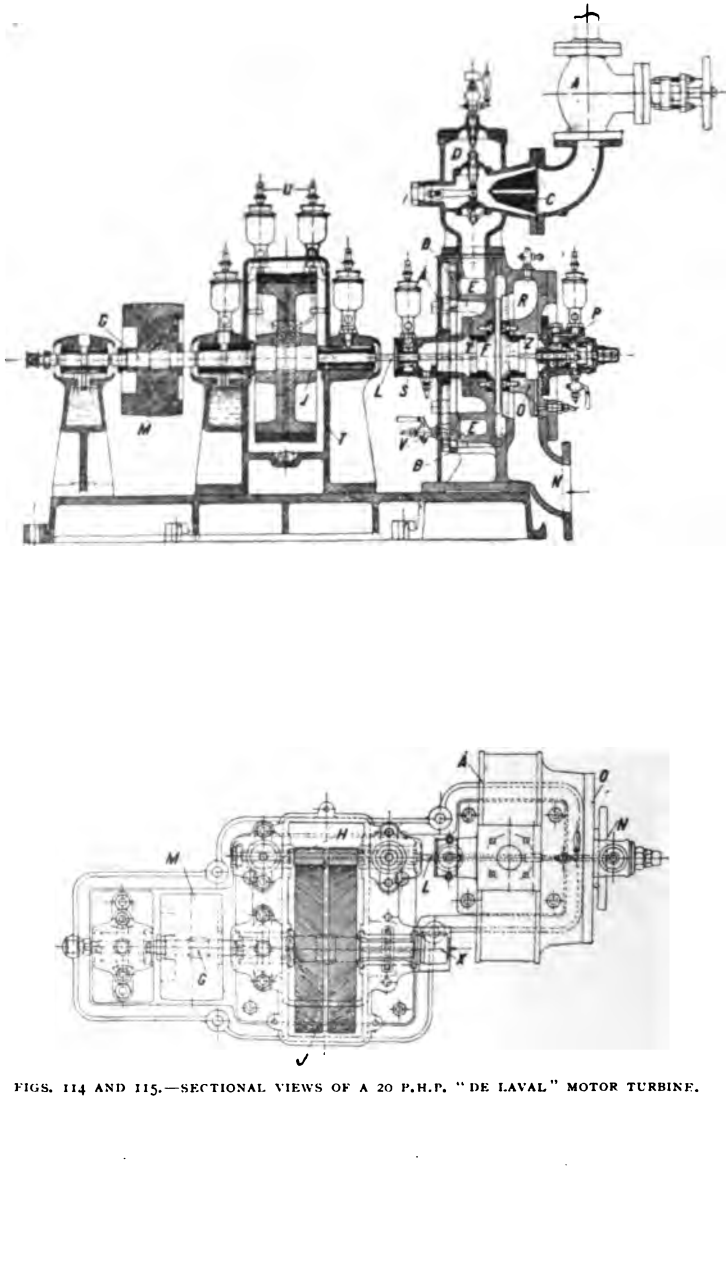


FIG. 113.—300 B.H.P. "DE LAVAL" STEAM TURBINE MOTOR.




FIGS. 114 AND 115.—SECTIONAL VIEWS OF A 20 P.H.P. "DE LAVAL" MOTOR TURBINE.

an idea of the velocity of overflow of dry saturated steam blown out through suitable nozzles against different pressures:

| Initial Steam Pressure. Lbs. per square inch. | Velocity of Outflow. | 145 Feet per Second. | |
|---|---|---|---|
| | Counter pressure = 1 atmosphere. | Counter pressure = 2·4 lbs. corresponding to 25″ Vacuum. | Counter pressure = 0·93 lbs. corresponding to 28″ Vacuum. |
| 100 | 2717 | 3520 | 3871 |
| 150 | 2953 | 3690 | 4023 |
| 200 | 3115 | 3810 | 4127 |

In these motors the peripheral speed varies with the size of the wheel. The 5 H.P. turbine wheel running at 30,000 revolutions per minute, has a rim speed of 515 feet per second; the 300 H.P. wheel running at 10,600 revolutions per minute, has a rim speed of 1,378 feet per second.

Direct driving, due to these excessive speeds, is impossible. A second shaft driven by reduced gearing of special form is provided. The shaft also serves to carry the centrifugal governor by which the speed of the turbine is regulated by means of a balanced valve, which throttles the steam admission. The variation of speed between "no" load and "full" load on the larger sizes has been found by actual tests not to exceed 1 per cent.

Fig. 112 shows a 100 B.H.P. "De Laval" Turbine and Dynamo, and Fig. 113 a 300 B.H.P. Turbine Motor. Figs. 114 and 115 are sectional views of a 20 B.H.P. turbine made for driving machinery by means of belt. This is called a turbine motor. The steam entering the ring formed channel E, and passing governor valve D, issues from the nozzles and impinges on the vanes or brackets of turbine wheel E, exhausting at N. The power is transmitted from the turbine wheel shaft L through the gearing H J to shaft G, power being taken from the pulley M.

The following table gives the results of a test made in December, 1899, with a 300 B.H.P. "De Laval" Steam Turbine Motor:—

| Pressure of Admission Steam. Lbs. per square inch. | Vacuum Inches of Mercury. | No. of Nozzles open. | Loads in Brake. H.P. | Lbs. of Steam per Brake. H.P. per hour. | REMARKS. |
|---|---|---|---|---|---|
| 192·7 | 27·3 | 7 | 303·6 | 14·1 | Work for Condensing is not included. |
| 196·3 | 27·6 | 6 | 255·5 | 14·7 | |
| 196·3 | 27·6 | 5 | 216·9 | 14·4 | |
| 196.3 | 27·6 | 4 | 172·6 | 14·5 | |
| 190·6 | 27·8 | 3 | 121·6 | 14·9 | |
| 196·3 | 28·1 | 2 | 74·2 | 17·2 | |
| 213·3 | 28·5 | 1 | 31·5 | 21·6 | |

# HIGH SPEED STEAM ENGINES AT THE PARIS EXHIBITION, 1900.

## WILLANS AND ROBINSON'S EXHIBIT.

A Willans' Central Valve Triple-Expansion Engine, capable of developing 3,000 H.P., was exhibited. This engine was the only example of the high speed type in the Exhibition of such gigantic size, and so far as we are aware, it is the largest high speed engine of the reciprocating type ever made.

Fig. 116 is a photograph of the engine, taken at the makers' works. The bed-plate is divided into two parts longitudinally down the centre line of the crank shaft, and is bolted together to form the usual oil bath. Each piece weighs about 15 tons. The crank chamber upper part is also divided; the lower portion into four pieces, so as to enable the crank shaft, connecting rods, and crossheads to be got at and withdrawn if necessary without dismantling the engine. The exhaust chamber is in one piece. The crank shaft, in spite of its size, is in one piece. The diameter of the journal is 14·5 in., and the total weight of the shaft about 12 tons. The necessary fly-wheel is obtained in the armature of the Siemens dynamo, to which it is shown coupled, and a coupling disc only is supplied upon the engine, which serves also for the purpose of barring. The engine is triple-expansion, with three lines of cylinders arranged tandem in the usual Willans manner, the diameters being $18\frac{7}{8}$ in., $30\frac{5}{16}$ in., 48 in., as near as possible, the original figures being given in the metric system, which is used by Messrs. Willans and Robinson. We are pleased to learn that several well-known firms are adopting the metric system, and though the change necessarily means some expense in the first instance, makers will soon have a return which will more than pay for the trouble and expense. The stroke of each trunk is $23\frac{5}{8}$ in. The maximum power for continuous running is 2,400 H.P., with boiler pressure at 190 lbs. per square inch, but the engine is capable of

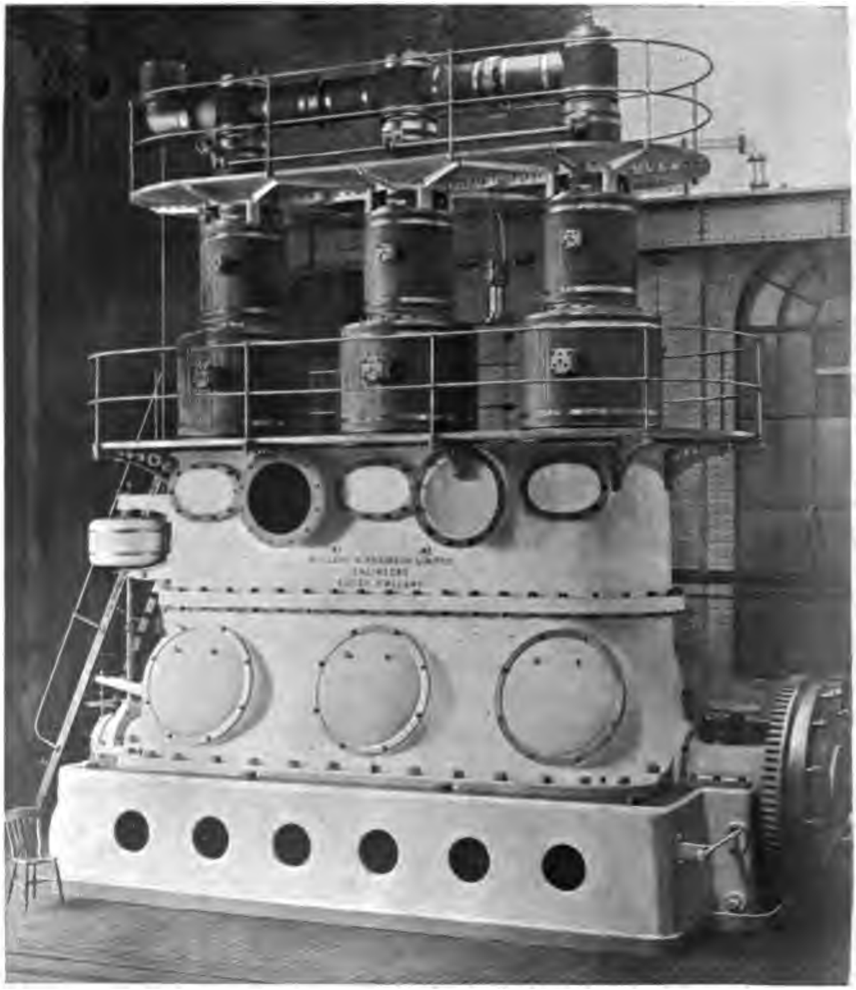


FIG. 116.—WILLANS' CENTRAL-VALVE TRIPLE-EXPANSION ENGINE, CAPABLE OF DEVELOPING 3,000 H.P.

developing 3,000 for shorter periods. The speed is 200 revolutions per minute. The total weight of the engine is about 120 tons. The floor space occupied is only 31 ft. by 11 ft. 1 in.

The exhaust is conveyed into a jet condenser supplied by the Worthington Pumping Engine Company. We have given a full description (see page 12) of the "Willans" engine, and it is therefore unnecessary to go fully into the details here. The smoothness with which this engine ran in the Exhibition is what we have long been accustomed to from the Rugby firm, and must have added to their already high reputation.

## Galloway's Engine.

This engine is shown in Fig. 117 coupled to Messrs. Mather and Platt's Multipolar Dynamo. It is of the compound condensing type, and capable of developing 680 I.H.P. when running at 105 revolutions per minute, with steam at 140 lbs. per square inch. The high pressure cylinder is 18 in. diameter, and the low pressure 34 in. diameter, both being arranged with a stroke of 3 ft.

The cylinders are fitted with "Corliss" valves, having separate chests for steam and exhaust, both sets of valves deriving their motion from excentrics fitted on crank shafts driven from the end of the main shaft.

The governor, which is of the "Porter" type, is driven by means of gearing, and controls the admission of steam to the high pressure cylinder. Provision is also made for the adjustment of speed by hand while the engine is running. We have pointed out (see page 5) that "in a well-designed governor the disturbing action may be neglected, since the object of the governor should be to signal to a separate part of the engine to perform the work, such performances being carried out without interfering with the governing proper." To overcome the disturbing action dashpots and counterweights are used, but fail to give that necessary quick response to call for variation of steam admission.

Forced lubrication is adopted, and the steam is superheated between high and low pressure cylinders. The condenser, which is of the ejector type, is fitted with an independently driven water pump.

The bed-plates have been arranged to meet the whole of the straining action within the structure of engine and

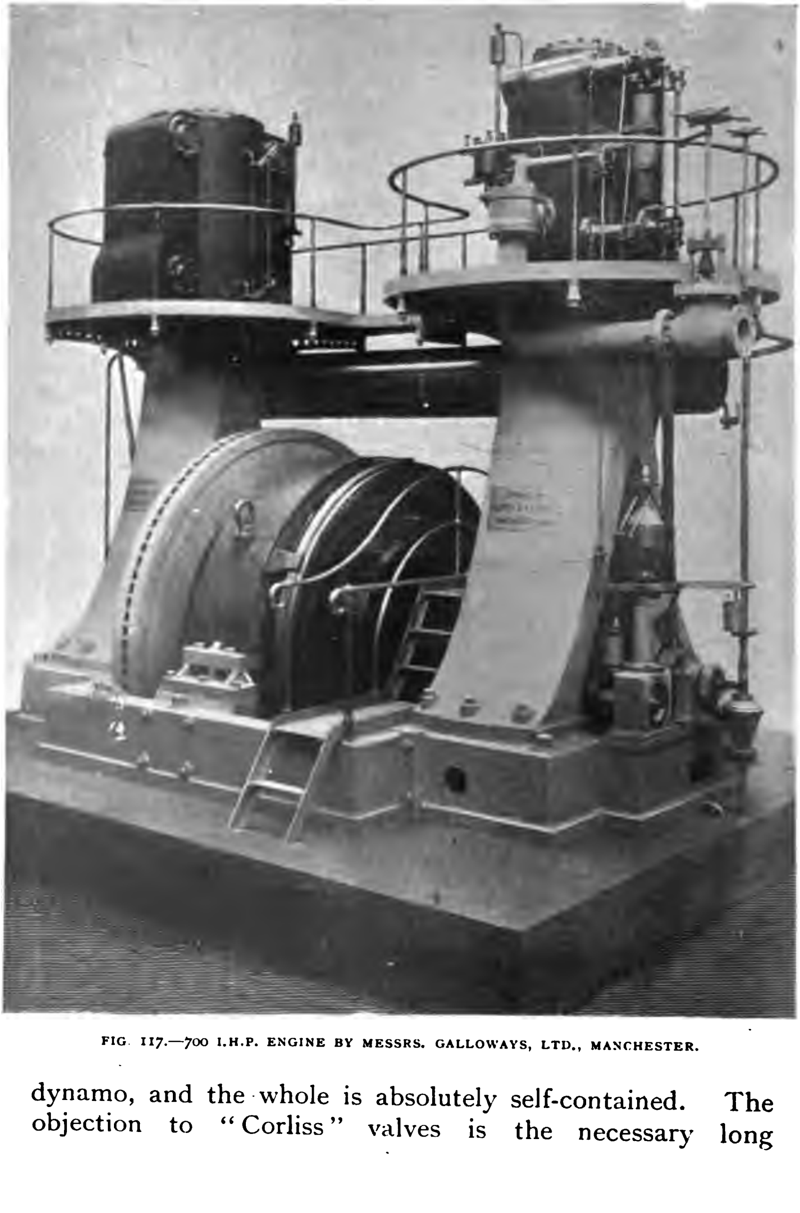


FIG. 117.—700 I.H.P. ENGINE BY MESSRS. GALLOWAYS, LTD., MANCHESTER.

dynamo, and the whole is absolutely self-contained. The objection to "Corliss" valves is the necessary long "wait" between opening and closing, which means cyclical variation, though 105 revolutions is much above the ordinary practice.

## Mertz's Triple-Expansion Engine.

The distinguishing feature of this "enclosed" engine is the quadruple action. By referring to Figs. 118 and 119, it will be seen that the high, intermediate, and low pressure cylinders are placed in position upon a stout framework, completely enclosed, which forms an excellent foundation base. In each of these cylinders of quadruple action, two pistons, whose rods are fitted one in the other, are transposed in an opposite way, the steam acting in succession on their internal and external faces. The cranks operated by these two piston arrangements of each cylinder are connected to the driving shaft at 180 degrees in such a manner that the pressures put upon the pedestals are done away reciprocally, and in consequence of this absolutely balanced working the necessity of a heavy fly-wheel is dispensed with. There are four piston valves, two for the low pressure cylinder, arranged between the cylinders and actuated directly by means of excentrics. The piston valves for the intermediate and low pressure cylinders have a fixed travel.

The distribution of the steam to high pressure cylinder is regulated by a shaft governor.

The diagrams shown (Fig. 120) were taken on 18th July, 1900, at the Paris Exhibition :—

| | |
|---|---|
| Pressure of steam at high pressure cylinder .. .. | 95 kilos. |
| Vacuum .. .. .. .. .. .. .. | 59 c.m. |
| Cut-off in high pressure cylinder .. .. .. | 0·48 |
| Average pressure in high pressure cylinder .. .. | 1·7 k.sq. c.m. |
| ,, ,, intermediate ,, .. .. | 2·02 k.sq. c.m. |
| ,, ,, low pressure ,, .. .. | 0·52 k.sq. c.m. |
| I.H.P. .. .. .. .. .. .. .. | 344 |
| Revolutions per minute .. .. .. .. .. | 280 |

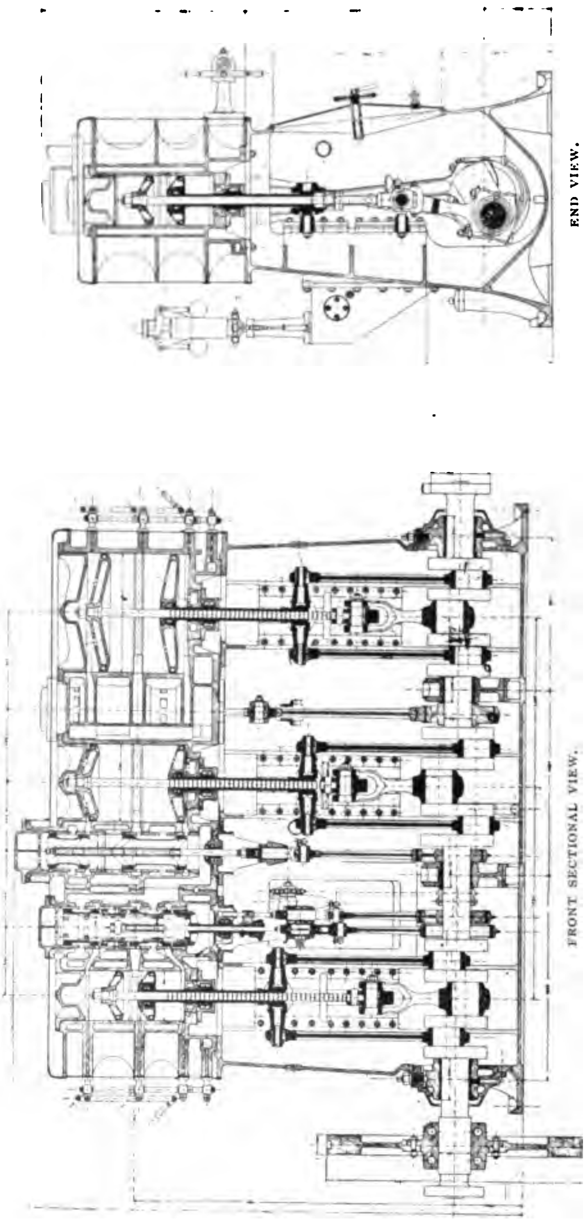



FIG. 118.—SECTIONAL VIEWS OF MERTZ'S TRIPLE-EXPANSION HIGH SPEED ENGINE.

## MERTZ'S COMPOUND ENGINE.

This engine (see Fig. 121) is of the turn-tandem expansion single action type. This includes two pairs of cylinders superposed in tandem, the coupled-up pistons of which work at 180 degrees to each other. The high pressure top cylinders are alternately supplied with steam by an admission valve common to both cylinders, and with variable expansion. The exhaust from each high pressure cylinder and admission into the corresponding low pressure cylinder are controlled by a balanced slide valve with pistons. The slide valve controls the steam exhaust from the low pressure cylinder. The

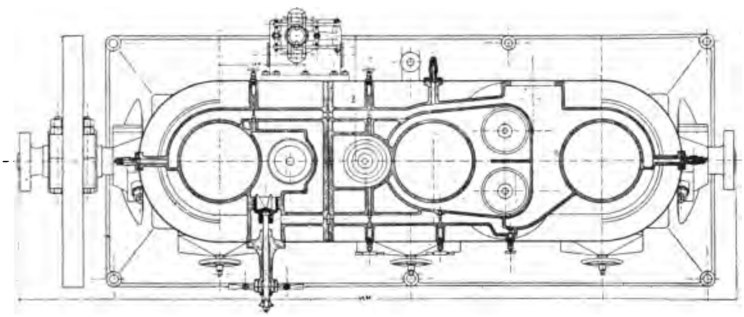


FIG. 119.—SECTIONAL PLAN OF MERTZ'S ENGINE.

central valve is controlled by a shaft governor. The lubrication of the slide valves and pistons is effected by an oil pump worked by the main shaft of engine. This engine ran very silently and almost without vibration.

## MERTZ'S SINGLE-ACTING COMPOUND ENGINE.

A novel type of vertical engine is shown by Mertz. Fig. 122 is an elevation, and Fig. 123 is a section of this ingenious engine. By referring to the illustrations, it will be seen that this engine is a single-acting compound. It consists of a framework on which two cylinders are fixed, one over the other—one for high, the other for low pressure—which act upon the same horizontal or intermediate

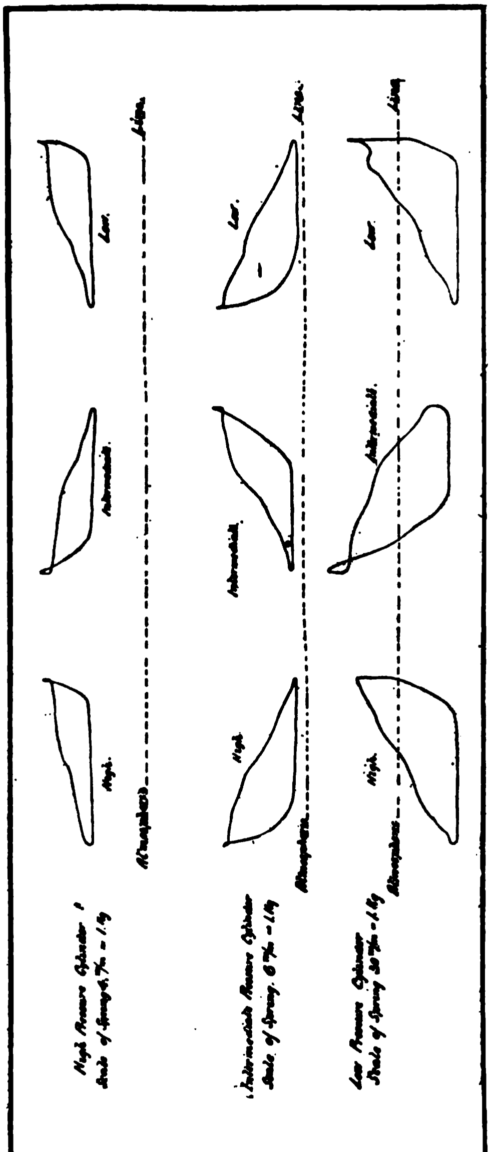


FIG. 120.—INDICATOR DIAGRAMS OF MERTZ'S TRIPLE-EXPANSION ENGINE.

shaft by an arrangement of connecting rods, which balance the reciprocal bulk, and prevent, with the aid of the compression of steam in the cylinder, the impact or concussion. The engine being of the single-acting type, the bearings only

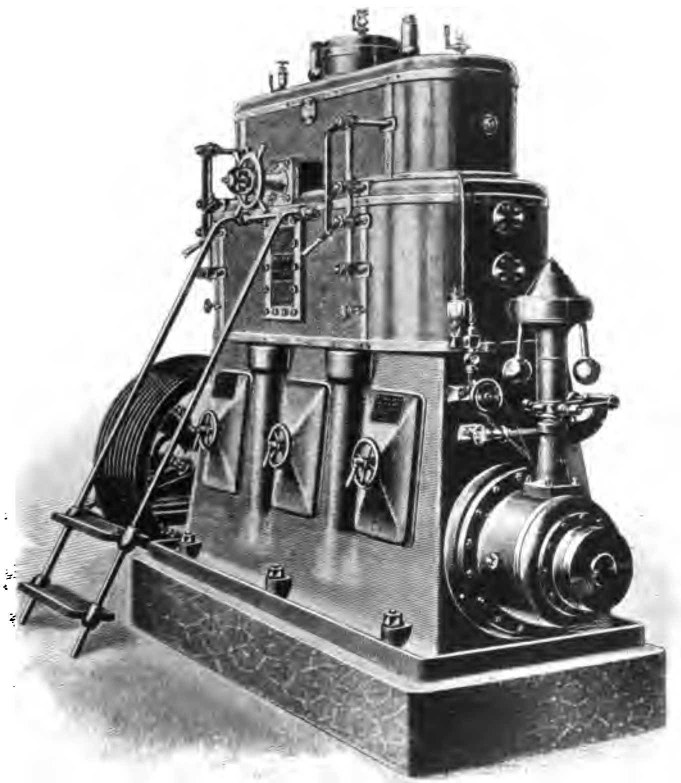


FIG. 121.—MERTZ'S COMPOUND ENGINE.

transmit the power on one side of their respective crank pins. Splash-about lubrication is employed, and a shaft governor for regulating the steam supply.

## Thune's Double-Acting Compound Engine.

Fig. 124 is an outside view, and Fig. 125 is a sectional elevation, of Thune's 55 B.H.P. Double-Acting Compound

High Speed Engine, "open" type, driving a "Schuckert" dynamo.

FIG. 122.—MERTZ'S SINGLE-ACTING HIGH SPEED ENGINE.

It will be seen by referring to Fig. 125 that the high pressure cylinder is fitted with piston valve, and the low pressure cylinder is fitted with an ordinary D valve. The steam admission is regulated by means of a "shaft" governor. The diameter of high pressure cylinder is $7\frac{7}{8}$ in., low pressure cylinder $11\frac{13}{16}$ in., both having a stroke of $7\frac{7}{8}$ in.; revolutions per minute, 350. Steam pressure, 120 lbs. per square inch.

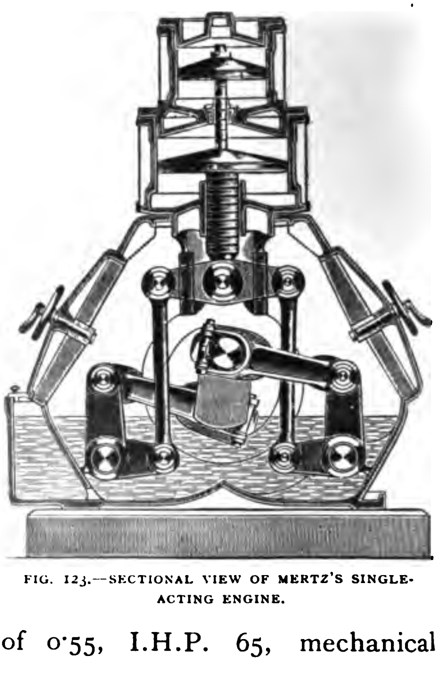


FIG. 123.—SECTIONAL VIEW OF MERTZ'S SINGLE-ACTING ENGINE.

We are indebted to the makers for the following particulars:—The consumption of steam is 28 lbs. per I.H.P. when working non-condensing with 120 lbs. of steam per square inch, running at a normal speed of 350 revolutions per minute, and developing 47 I.H.P., cut-off 0·35.

The maximum power of 55 H.P. is obtained with a cut-off in the high pressure cylinder of 0·55, I.H.P. 65, mechanical efficiency 85 per cent., and the consumption of steam 29 lbs. per I.H.P. per hour. The cut-off in the low pressure cylinder is fixed at 0·52.

The governor is of the simplest possible construction. The travel of piston valve and the angle of advance of excentric are regulated by an excentric sheave fixed on the shaft

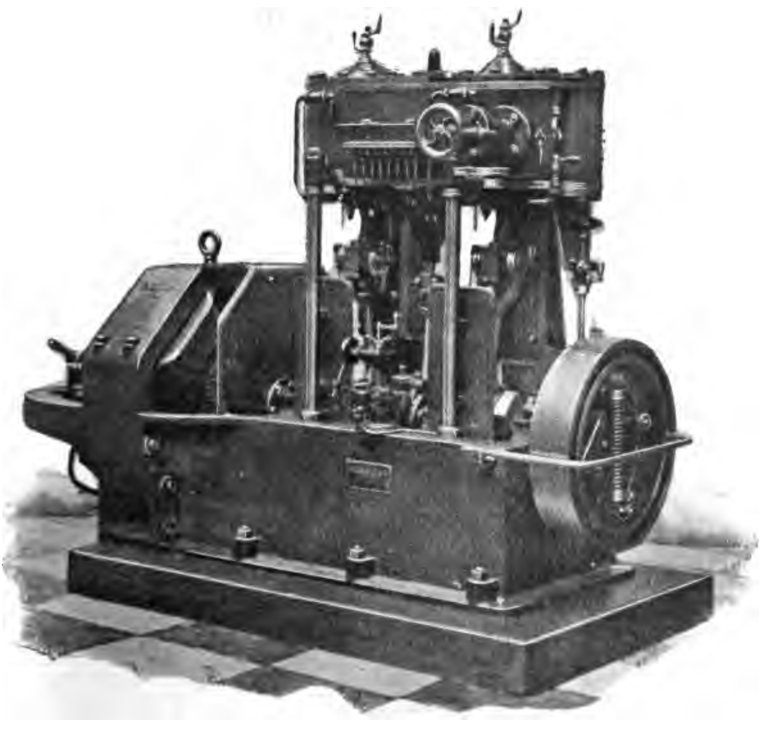


FIG. 124.—THUNE'S COMPOUND HIGH SPEED ENGINE.

and another excentric sheave connected to the governor arms The governor is designed to give a maximum cut-off in the high pressure cylinder of 0·60.

## THUNE'S DOUBLE-ACTING SINGLE CYLINDER ENGINE.

Fig. 126 is a sectional elevation of Thune's 5½ B.H.P. Double-Acting Single Cylinder High Speed Engine, " open " type, driving a "Schuckert" dynamo. The diameter of the cylinder is $3\frac{11}{16}$ in., stroke $3\frac{1}{2}$ in.; revolutions per minute, 600. Steam pressure 120 lbs. per square inch.

A shaft governor is responsible for the admission and exhaust.

This well-known firm of Norwegian engine builders have

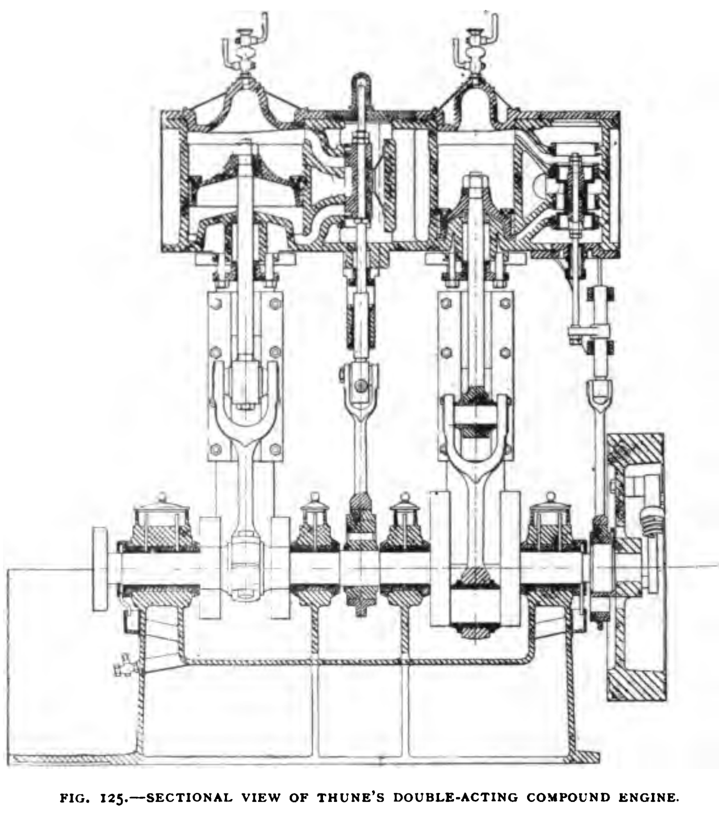


FIG. 125.—SECTIONAL VIEW OF THUNE'S DOUBLE-ACTING COMPOUND ENGINE.

held a high position for many years, during which time they have built a considerable number of high speed engines for electric lighting and torpedo boat destroyers.

## "Farcot" One Cylinder Engine.

This engine does not come under the heading of High Speed Engines, although there are many points in the design which

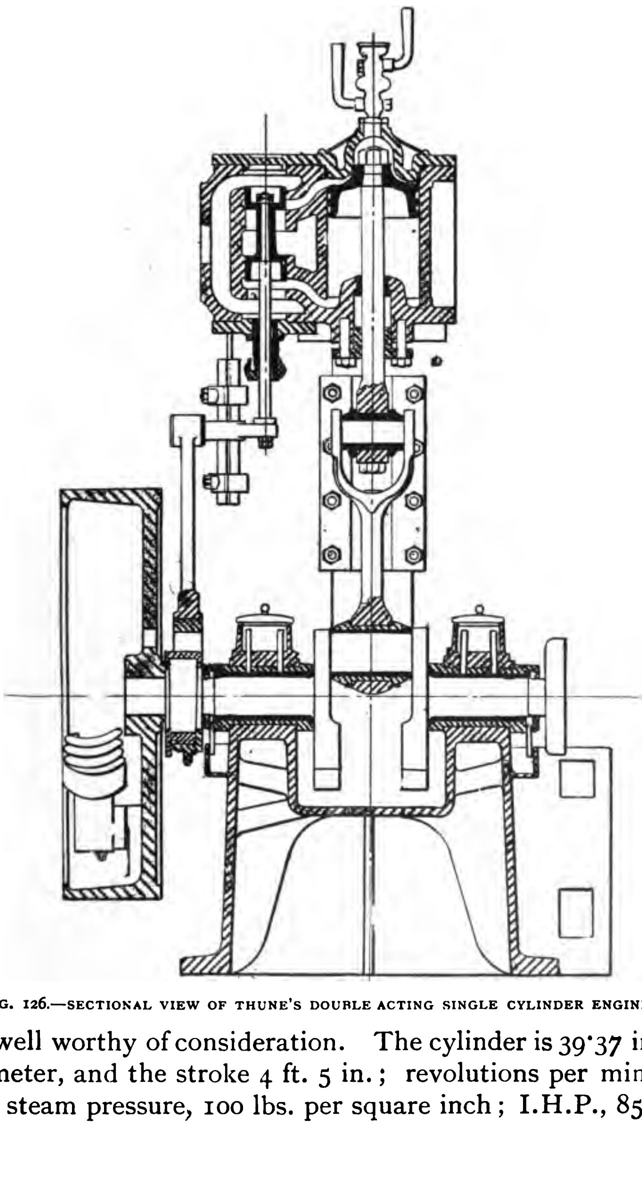


FIG. 126.—SECTIONAL VIEW OF THUNE'S DOUBLE ACTING SINGLE CYLINDER ENGINE.

are well worthy of consideration. The cylinder is 39·37 in. in diameter, and the stroke 4 ft. 5 in.; revolutions per minute, 79; steam pressure, 100 lbs. per square inch; I.H.P., 850.

The main shaft has a diameter of 17·75 in. at the crank bearing. The crank shaft bearing is 17·75 in. in diameter, and 15·75 in. at the exciter bearing, and is swelled to 25·6 in. diameter at the centre of its length, when the dynamo fly-wheel is keyed on to it. Constant automatic lubrication is provided by centrifugal force through a light return crank. In the main shaft bearings "ring" lubrication is used. Fig. 127 is a sectional view of the cylinder and "Corliss" valves. It will be seen that the steam supply from the boiler

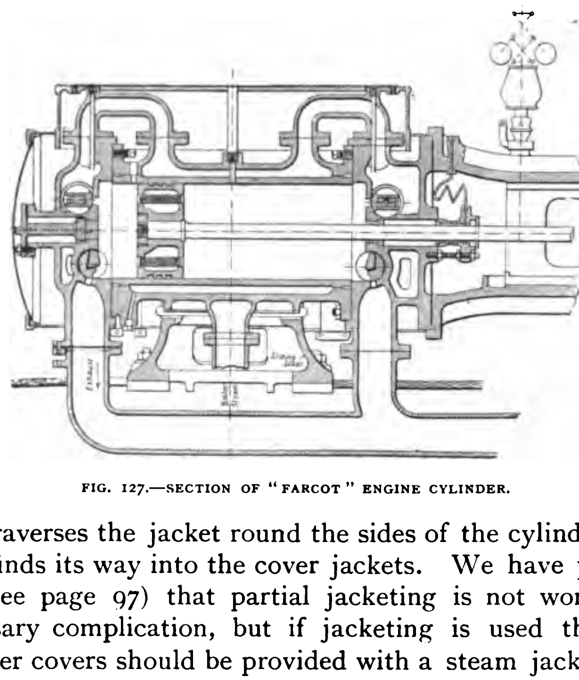


FIG. 127.—SECTION OF "FARCOT" ENGINE CYLINDER.

first traverses the jacket round the sides of the cylinder, and then finds its way into the cover jackets. We have pointed out (see page 97) that partial jacketing is not worth the necessary complication, but if jacketing is used then the cylinder covers should be provided with a steam jacket. In the "Farcot" engine this is done in a very complete manner. The valves are placed in the covers so that all the steam used passes through both the end jackets. By arranging the valves in the covers the lowest possible clearance is obtained without interfering with draining of the cylinders. The cylinder proper is of simple construction, whilst the general design and finish is excellent.

## " Borsig " Triple-Expansion Engine.

We give two sectional views explanatory of the large triple-expansion 4-cylinder " Borsig " engine, direct coupled to a three-phase 2,200 volt generator by Siemens and Halske, which was exhibited by A. Borsig, of Berlin. The cylinder diameters are 30 in., 46½ in., and 52¾ in., while the stroke is 47¼ in. The cranks are placed at an angle of 140 degrees. The engine is intended for a steam pressure of 210 lb., and for a speed of 90 revolutions. When working with condensation it will develop 2,500 H.P. The two-part crank shaft has at one end the dynamo, and at the other a disc from which the two single-acting air pumps are driven which are placed in the basement, about 8 ft. below the engine floor. The bed-plate of the engine consists of two parts, each weighing 29 tons, flanged and bolted together, and forming oil troughs, from which two small centrifugal pumps, driven by a steel wire cord from the crank shaft, take the oil up to the purifier. Each half bed-plate is made with two crank-shaft bearings. Between the bed-plate and the dynamo bearing is a 41-ton fly-wheel provided with a toothed ring, on which an electric motor acts. On the bed-plate rest two cast-iron standards with the guides, and two forged-steel columns; these carry the two low pressure cylinders, which are bolted together. The high pressure and intermediate cylinders are supported by wrought-iron columns. These platforms are so arranged that if the iron columns are removed the covers and pistons of the low pressure cylinders can be taken out. After uncoupling the crossheads the piston rods can then be lowered into recesses in the bed-plates which are usually covered in, and finally removed. All the cylinder jackets are heated with their own steam. The packing rings of the high pressure piston are of the Ramsbottom type; the other pistons are provided with " Buckley " rings. The valve gear excentrics are all mounted on a shaft, which is carried in six bracket bearings situated behind the low pressure cylinders. The pendulum governor is on an intermediate shaft which passes obliquely between the standards. The admission and

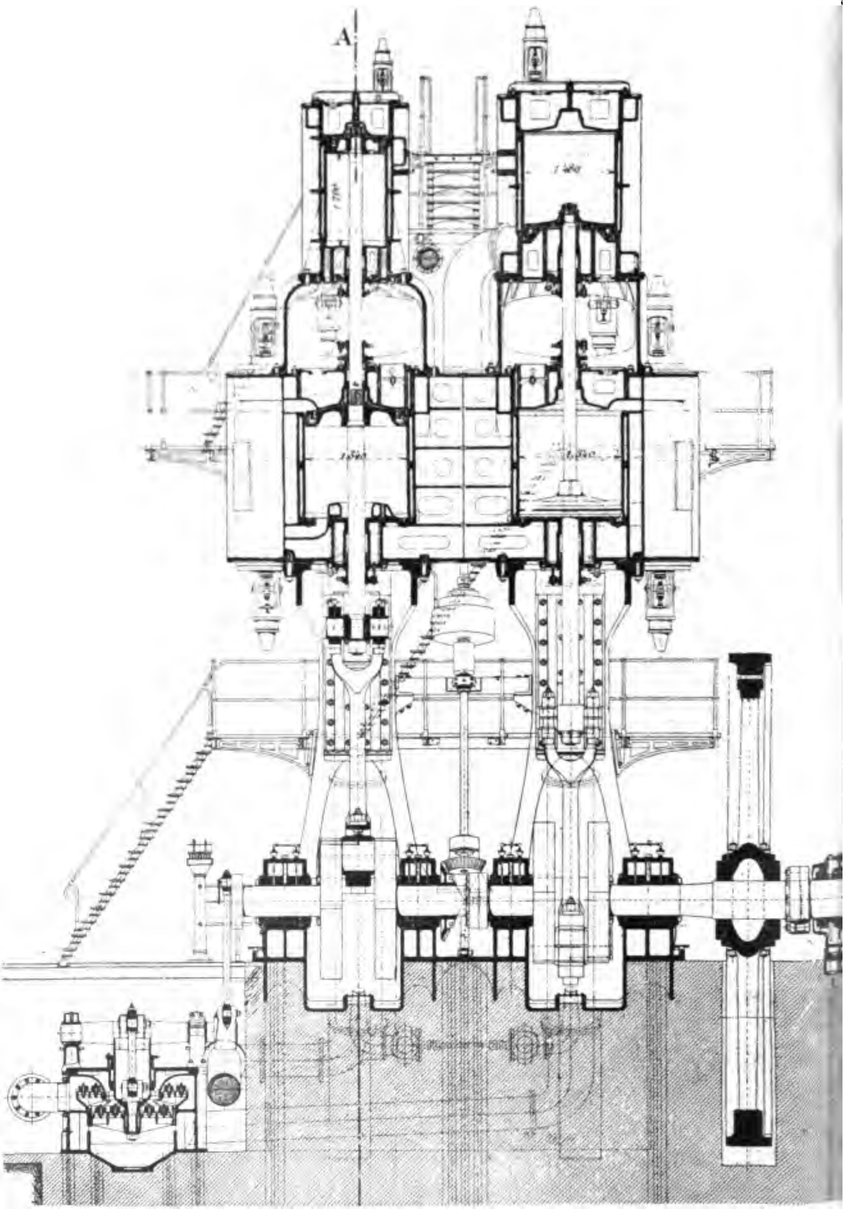


FIG. 128.—FRONT SECTIONAL VIEW OF 2,500 H.P. "BORSIG" ENGINE.

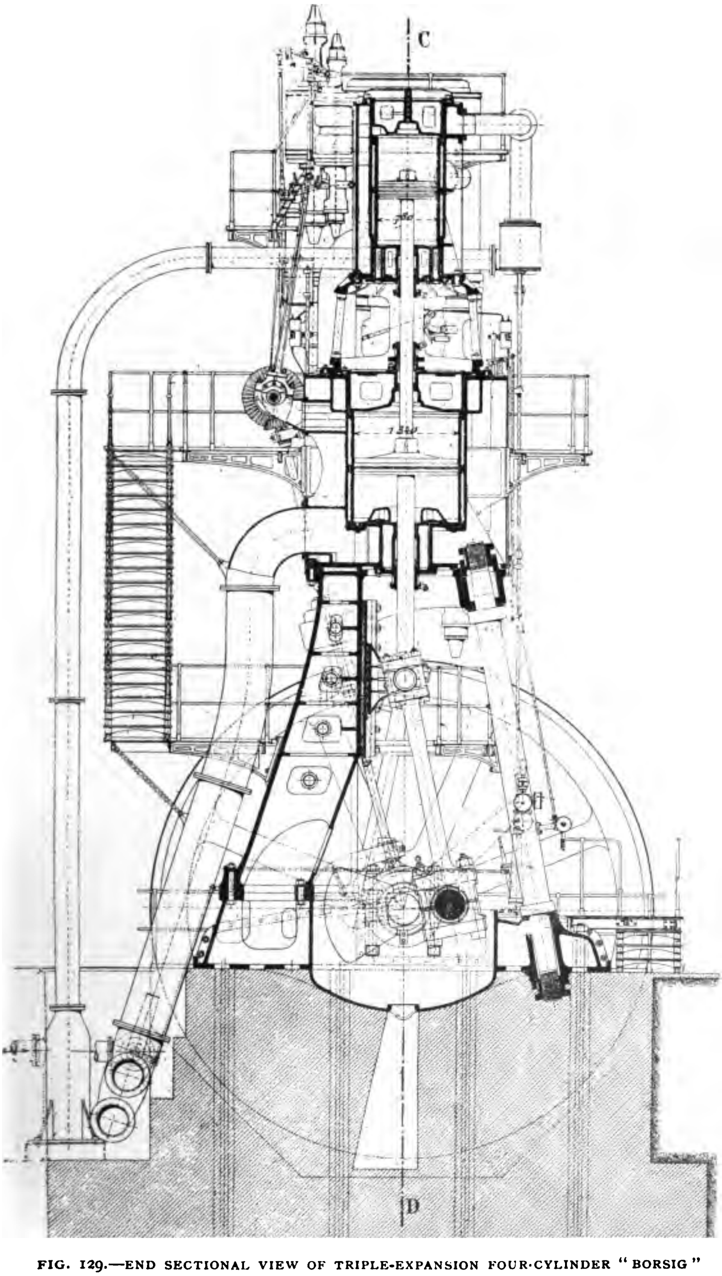



FIG. 129.—END SECTIONAL VIEW OF TRIPLE-EXPANSION FOUR-CYLINDER "BORSIG" ENGINE, DEVELOPING 2,500 H.P.

exhaust valves of the four cylinders are actuated by means of levers and pawls. In the case of the inlet valve of the high pressure cylinder, the release is controlled by a cam from the governor; in the other valves, stops have been provided for hand adjustment. The valves are all of the double-seat type, and are provided with Collmann's oil cataract. The casing of the cataract contains an additional spring, with the help of which and of a hand wheel the speed may be varied while the engine is in motion. For the high pressure and intermediate pressure cylinders, one excentric actuates both the admission and the corresponding exhaust valve; on the low pressure cylinder two inlet valves and two outlet valves are each actuated by an excentric. Lubricating oil is forced into all cylinders and stuffing boxes. Oil for the shaft bearing and for the moving pin bearings is supplied by gravity from an overhead tank, to which it is pumped from below. All the oil is collected and sent through an oil cleaner, and then pumped once more up to the tank. Though intended for a steam pressure of 210 lbs., the Exhibition arrangements only permitted of the engine running with a steam pressure of 140 lbs., and at 83·5 revolutions.

## Parsons' Steam Turbines.

The turbo-dynamos exhibited by C. A. Parsons & Co. at Paris consisted of a 500 K.W. alternator, which is shown in the illustration, and of a 50 K.W. direct current generator. The armature of the alternator is direct coupled at one end to the turbine shaft by means of squared ends and a sleeve, and at the other end is the exciter armature, the whole plant being arranged in tandem. The speed of the machine is 2,400 revolutions per minute, and the periodicity is 80, the magnets being only 4 polar, thus making both a simple design of dynamo and of armature winding; and the current, which is collected off two brass slip rings, is generated at 2,400 volts. The governor is controlled either electrically for constant voltage, or mechanically for constant speed, and so perfect is it that the voltage does not vary more than 2 per cent. if the

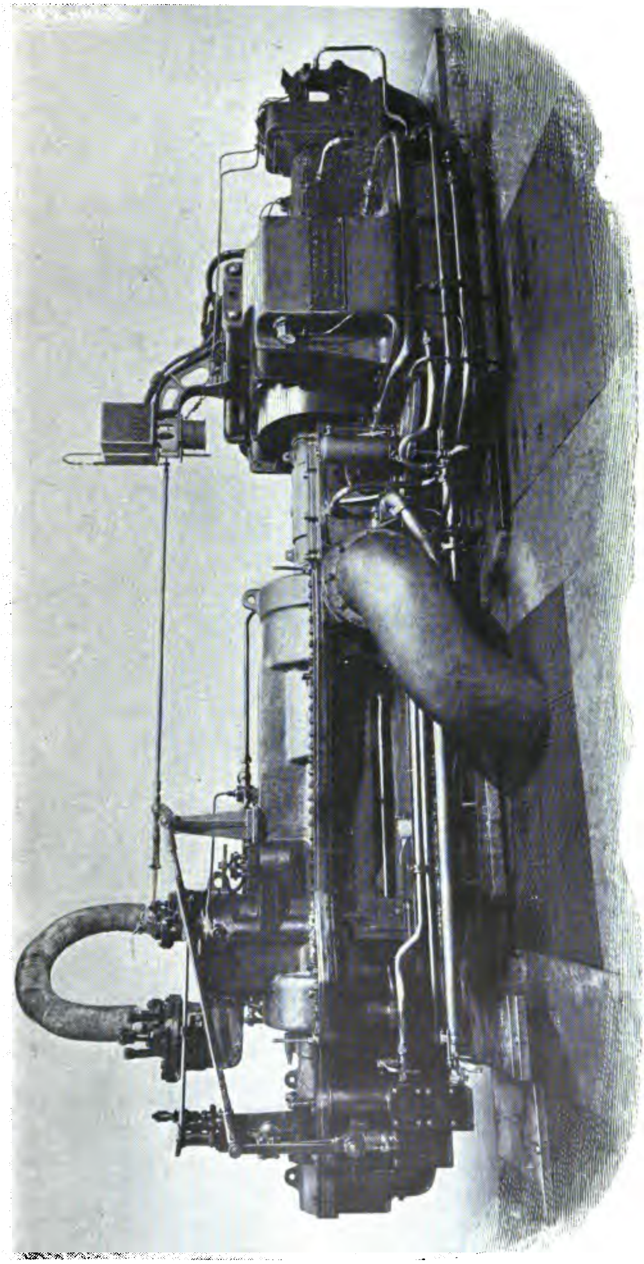


FIG. 130.—PARSONS' STEAM TURBINE DRIVING A 500 K.W. ALTERNATOR.

load be suddenly thrown off. Also, these machines run perfectly in parallel with each other and with machines of other make. The turbine is of the condensing type, and works with 130 lbs. boiler pressure, the steam expanding the full range down to about 27 in. vacuum at the exhaust. The bearings are lubricated under pressure from a small oil pump at about 5 lbs. per square inch, the oil being used over and over again. The pump is driven off the turbine shaft by means of worm gearing, which also actuates the governor. The efficiency of a plant of this size is very good, the steam consumption at full load being 16·9 lbs. of steam per E.H.P. and at half load 19·5 lbs.; though this is not the best that has been done by the firm. The size of this machine is very small considering the output, especially since the load can be exceeded by 20 per cent., the floor space occupied being only 25 ft. The weight complete is only 18 tons.

The 50 K.W. plant combines its bed-plate and condenser in one, thus making a very neat and compact plant. Such a combination is only possible with a steam turbine owing to the absence of all vibration and reciprocating motion. The pumps are bolted on to the side of the condenser, and are driven by means of a worm and worm-wheel; this also actuates both the oil pump and governor as well. The steam consumption of this plant is 24·8 lbs. of steam per E.H.P. at full load, including the steam required to drive the condenser pumps, while the boiler pressure required is 120 lbs., and the speed is 3,500 revolutions per minute. Many machines of this type have been supplied both for alternating and direct current, lighting and traction, and work most successfully. With machines of greater output than 350 K.W. it is usual to place the condenser in a pit below the turbine, but the pumps are still driven off the main shaft as before; with this arrangement machines have been constructed up to 500 K.W. output, and above this size it is found better to have a separate engine for driving the pumps. One of the great advantages the turbine holds over the reciprocating engine is the fact that no oil enters the cylinder, and thus the exhaust steam may be condensed and taken straight back into the boilers. Also a much higher temperature may be attained when superheating, since there is no oil to carbonise and so choke the cylinder, and no glands to cut. Even very moderate superheating gives a gain of efficiency of 8 to 10 per cent. in the steam consumption. Turbines are also largely used at collieries for driving fans and direct current and three-phase dynamos, and are becoming very popular for traction purposes.

## "Hult" Rotary Engine.

We have inspected the working of this engine with considerable interest. As a rule with most rotary engines with high speed, the wear caused by friction soon increases the play between the moving parts, and this is the main cause why rotary engines have hitherto made such little progress; there has either been too much leakage with loss of steam, or too tight fit with loss of power through excessive friction. A special feature of the Hult system is that rolling friction is substituted for sliding friction, with full security against leakage between the piston and the cylinder, and thereby friction is reduced to a minimum. This engine is extremely simple in construction, and works remarkably well and smoothly. The construction and operation of the engine will be understood by reference to the illustrations. The revolving piston F is fixed to a hollow shaft A, which rests upon two bearings B of elastic rings. The cylinder is excentric to the piston, and is also supported by two elastic ring bearings. The rotary motion of the piston gives by friction a revolving motion also to the cylinder C; both these have thus the same circumferential velocity. The pressure of the piston against the cylinder, at the line of contact J between them, can be regulated as desired, in order to secure always a perfectly steam-tight joint between them. A sliding shutter G moves in a groove cut along the piston, and is pressed tight against the inner surface of the cylinder by centrifugal force, so as to prevent leakage of steam. The steam enters through the hollow shaft A, and after passing through a canal H cut in the piston, acts upon the sliding shutter G, first by full pressure and afterwards by expansion (the direction of the movement is indicated by an arrow). After a complete revolution when the sliding shutter again arrives at the line of contact J between the piston and the cylinder, the space between these

FIG. 131.—THE "HULT" ROTARY STEAM ENGINE.

two parts is filled with steam which has completed its work of expansion; as soon as the sliding shutter passes the line of contact J this steam escapes through the canal I, at the same time as the full-pressure steam commences to act upon the

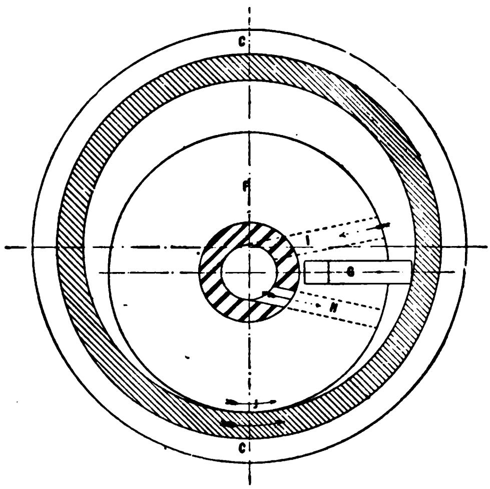



FIG. 132.—END SECTIONAL VIEW, "HULT" ROTARY ENGINE.

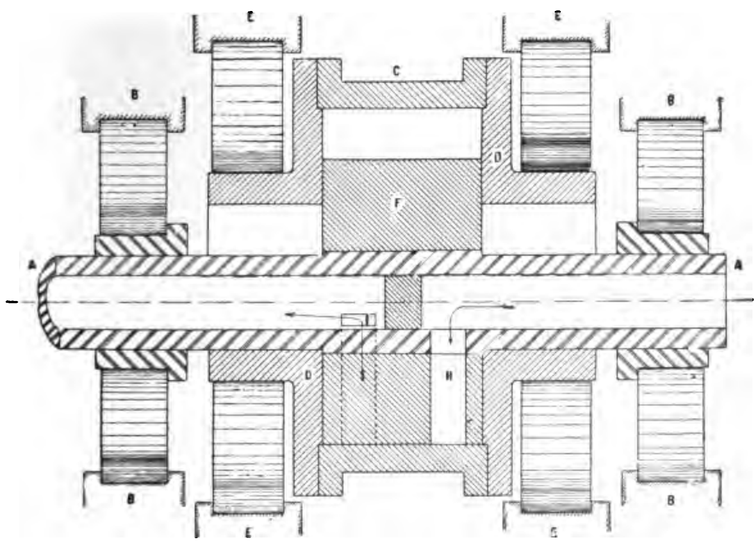



FIG. 133.—FRONT SECTIONAL VIEW OF THE "HULT" ROTARY ENGINE.

other face of the shutter. All the moving parts of the "Hult" engine are completely enclosed within its casing; the oil required for lubrication is drawn in by the steam, which circulates throughout the whole of the interior, prior to its passing to the condenser or escaping into the outer air.

## "Franco Tosi" 800 H.P. Engine.

In this four-cylinder tandem engine each pair of cylinders is cast in one piece, the high pressure cylinder being below

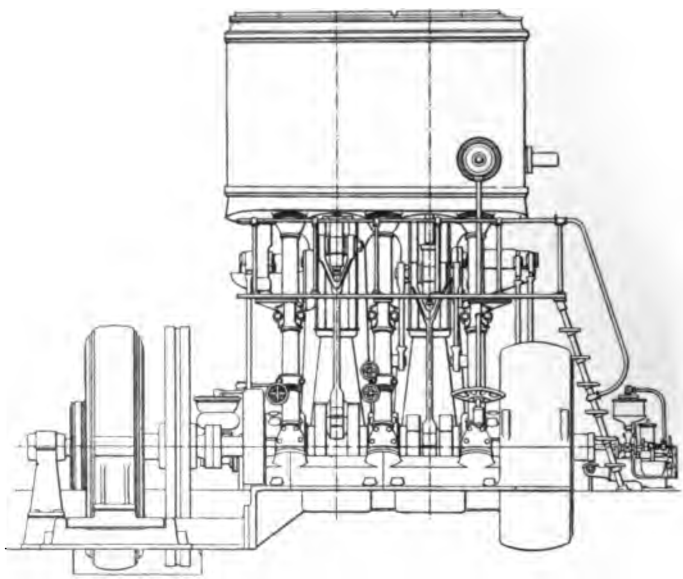


FIG. 134.—800 H.P. "FRANCO TOSI" ENGINE.

the low pressure cylinder, and an automatic metallic packing is utilised for the passage of the piston rod between the two. The first cylinder is 375 mm. (14·76 in.) in diameter; the second cylinder, 525 mm. (20·67 in.); the third, 675 mm. (26·57 in.); and the fourth, 1,000 mm. (29·37 in.); the length of the stroke being 650 mm. (25·59 in.), and the number of revolutions 160. The two pairs of cylinders are coupled to cranks at right angles, and each cylinder, with the exception of the high pressure one, is steam-jacketed. The high pressure cylinder is designed for superheated steam.

Piston valves are used for all the cylinders for the steam distribution, separate rods and excentrics being employed

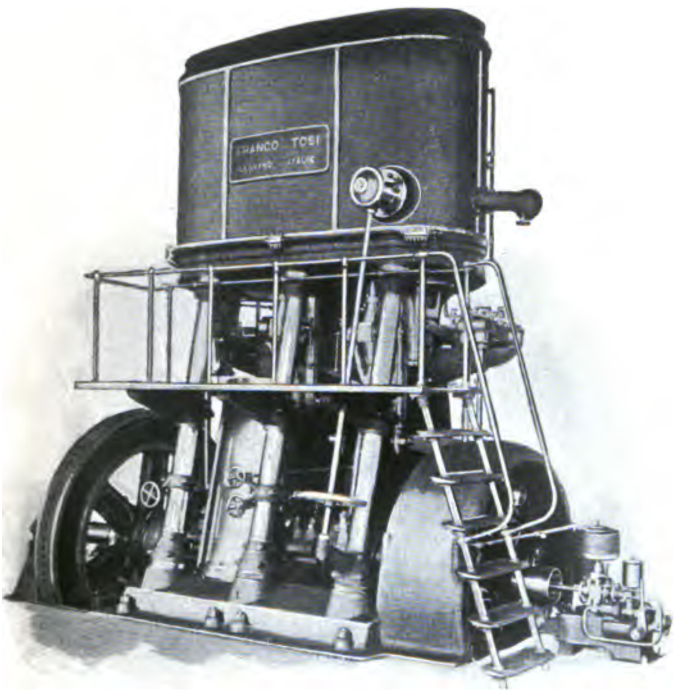



FIG. 135.—800 H.P. "FRANCO TOSI" ENGINE.

for the valves for the first and second cylinders, while one rod and excentric serve in the case of third and fourth cylinders. The pistons are made of forged-steel discs, with cast-iron piston rings. The crank shaft has a flanged end for bolting up to the dynamo shaft on which the fly-wheel is mounted. Each half of the frame, which is divided symmetrically, contains a vertical guide, also one outside and half the middle bearing.

An iron strut from the bed-plate to the underside of the head frame carrying the cylinders strengthens the frame. The air-pump, which is single-acting, is mounted at the back of the engine frame, being driven from one of the cross-heads. The speed of the shaft governor may be changed by a device in which glycerine is pumped by hand into the hollow governor weights. A multiple oil pump driven from the end of the crank shaft serves to lubricate the cylinders and valves, the remainder of the lubrication being continuous.

## HIGH SPEED STEAM ENGINES AT T
## GLASGOW EXHIBITION, 1901.

### Willans and Robinson's Exhibit.

This firm exhibited two of their standard engines, tl coupled to a "Crompton" dynamo of 700 to 960 kil capacity, and the other to a British Schuckert Co.'s m of practically the same output. Each engine, whicl their 3 V size, 3-crank tandem triple-expansion t capable of giving an output of 1,200 I.H.P. as a norn load, or 1,500 I.H.P. as a maximum overload, thi equivalent to 1,075 and 1,250 brake H.P. respe making a total of 3,000 I.H.P., or more than h combined output of all the high speed engines shown Exhibition. The engines are designed for 180 lbs. to steam pressure and working condensing.

As shown by the illustration (Fig. 136), there a cranks, which are set 120 degrees apart, and abo crank is a complete triple-expansion engine of three c arranged tandem, so that there are nine cylinders alt The dimensions of the cylinders are: 15 in. (38 23·6 in. (600 mm.), and 37·5 in. (950 mm.) in respectively, the stroke being 16⅞ in. (430 mm.). T when running at full load is 230 R.P.M., so that tl speed is 650 ft. per minute. It is not necessary for into more minute details here, as the engine is fully in the preceding pages. Large air-buffer cylinders an are provided to overcome the inertia of the reci parts, and keep the connecting rods in constant thr the whole revolution, independent of the load on th the advantages of which for this type of engine in silent running, etc., are now so well known.

Lubrication is effected on the "splash" method, the cranks and excentrics dipping into an oil bath in the crank chamber while running.

Governing is effected by a powerful centrifugal governor mounted on a vertical spindle, driven by machine-cut gear

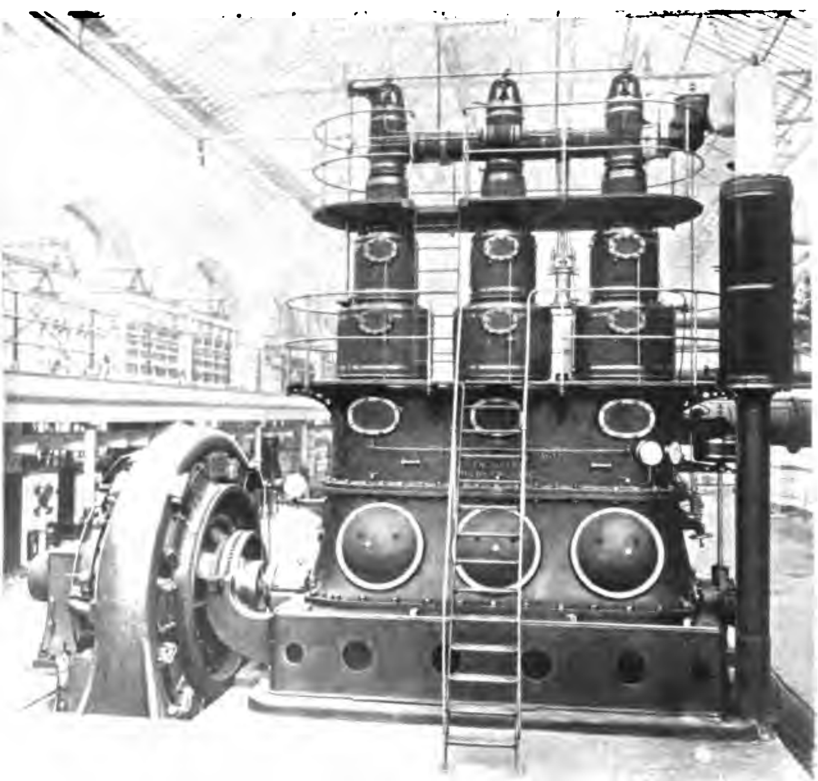


FIG. 136.—1,075 B.H.P. "WILLANS" HIGH SPEED ENGINE DIRECT CONNECTED TO DYNAMO.

wheels on the end of the crank shaft, and having positive control of a balanced piston valve. Automatic expansion gear is also fitted, so that the best economy may be obtained by a combination of the two governors. Although the engine is very high, the floor space occupied by the engine alone does not exceed 16 ft. by 8 ft. 6 in., and the total weight is about 34 tons. One engine has a small fly-wheel face form a coupling, and the other merely a coupling disc necessary fly-wheel power being provided by the rot part of the dynamo.

ALLEY AND MACLELLAN'S EXHIBIT.

Of the single-acting type of high-speed engine, M Alley and Maclellan, of the "Sentinel" Works, Gla exhibited, next to Messrs. Willans and Robinson, the l combined output, having 600 H.P. of their now well-l "Sentinel" high speed engines actually running Exhibition. These included one of 300 H.P., dri "Mavor and Coulson" dynamo as a complimentary c exhibit for the lighting of the Exhibition, and a cor output of 300 H.P. on their own stand adjoining.

One of their class G 3-crank vertical tandem-com enclosed, single-acting, self-lubricating type, having cylinders each 10 in. diameter, and 3 L.P. cylinders diameter by 9 in. stroke, was on exhibit in the L Station. The normal speed was 400 revolutions per It was designed to stand up to 180 lbs. pressure, and run either condensing or non-condensing, without any tion to the valves. As seen from the illustrations, F and 138, there are a pair of compound cylinders—H L.P.—above each crank, with a single line of valves line of cylinders, the cranks being set at 120 degree The valves are of the balanced piston type, each lir driven off a single excentric on the crank shaft, arranged that both H.P. and L.P. valves may b withdrawn for inspection or adjustment without di the cylinders.

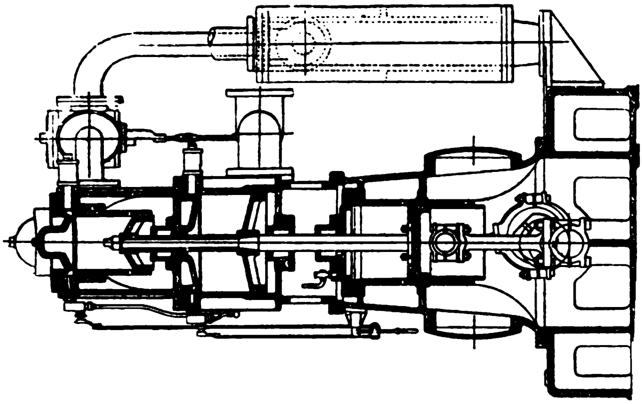
The steam distribution is on the well-known "C cycle. Perfect and automatic drainage of the cylind revolution is secured in a very simple and efficient A number of small holes drilled round the cyli uncovered by the piston at the bottom of its stroke, Lubrication is effected on the "splash" method, the cranks and excentrics dipping into an oil bath in the crank chamber while running.

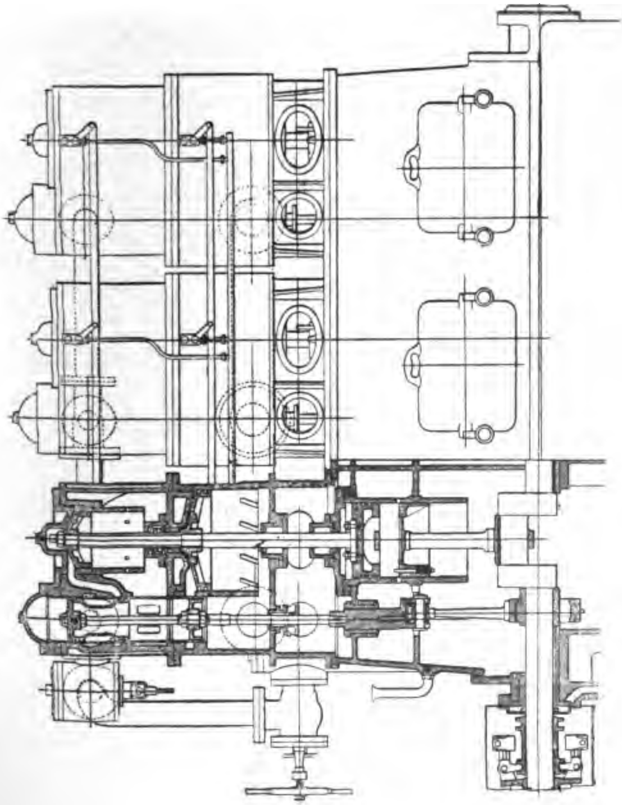
Governing is effected by a powerful centrifugal governor mounted on a vertical spindle, driven by machine-cut gear

FIG. 136.—1,075 B.H.P. "WILLANS" HIGH SPEED ENGINE DIRECT CONNECTED TO DYNAMO.

wheels on the end of the crank shaft, and having positive control of a balanced piston valve. Automatic expansion gear is also fitted, so that the best economy may be obtained combination of the two governors. Although the engine high, the floor space occupied by the engine alone xceed 16 ft. by 8 ft. 6 in., and the total weight is

Alley and Maclellan's Engine.





water in the cylinders is blown out through these by the rush of steam to the exhaust.

In order to overcome the inertia of the reciprocating parts


FIG. 137.—300 H.P. VERTICAL TANDEM-COMPOUND SINGLE-ACTING ENGINE, BY MESSRS. ALLEY AND MACLELLAN, GLASGOW.

and secure "constant thrust" or "single-action" throughout the revolution, irrespective of the load and the steam pressure, the crosshead or guide piston is made an air-buffer, as clearly shown on the sectional illustration, by means of which the air contained in this cylinder is compressed by the engine on

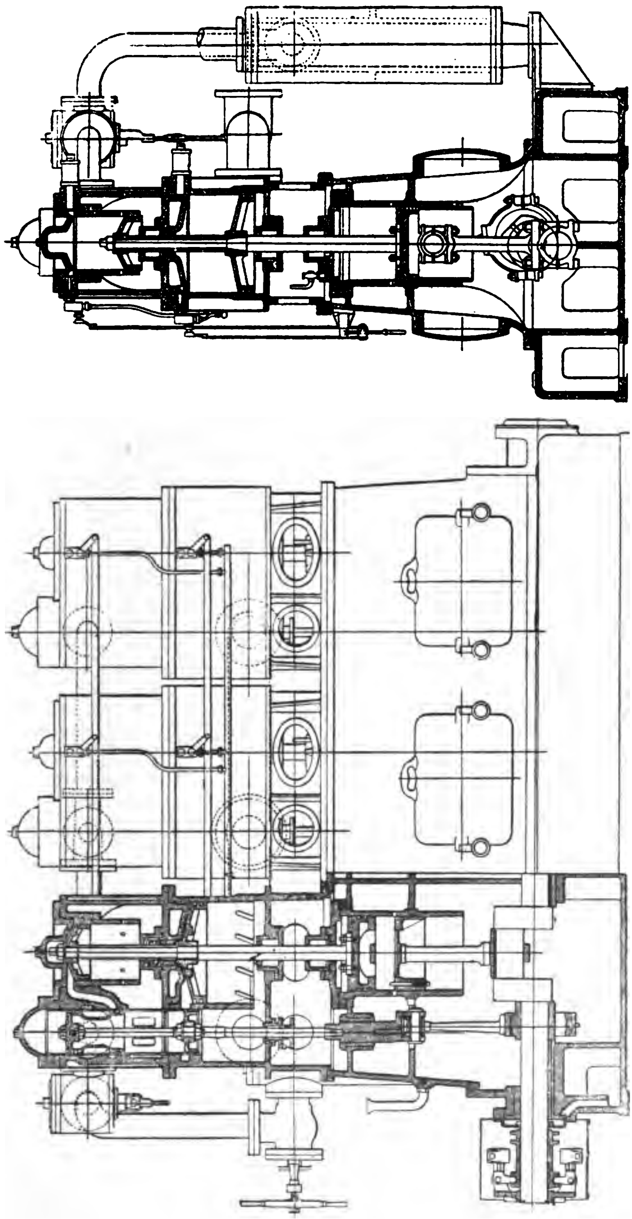


FIG. 138.—FRONT AND END SECTIONAL VIEWS OF MESSRS. ALLEY AND MACLELLAN'S 300 H.P. ENGINE.

the up stroke; but the energy thus stored is given out again without appreciable loss on the down stroke. This ingenious method of overcoming so successfully one of the greatest difficulties with high speed engines was invented by the late Mr. P. W. Willans, and is used in the "Willans" engine.

The engine is lubricated on the "splash" method, with a bath of oil and water in the crank chamber, into which the cranks and excentrics dip at every revolution, and throw the oil over all the working parts enclosed therein. This method has proved to be most thorough and economical.

The bearings are of unusually large dimensions, in fact the makers claim that the bearings' surfaces in this type of engine are more liberal than in any other engine of the same output in the market; and on this account the wear is reduced to an almost negligible quantity, requiring no adjustment for several years. All the piston rod packings are of the "floating" self-adjusting metallic type, the parts of which are all interchangeable, and easily adjusted or renewed. Those in the air-buffer and L.P. cylinder covers are open to the exterior, and easily accessible through hand holes in the "distance piece" between the L.P. cylinder and crank chamber or framing of the engine. This has the further advantage of at once being able to detect the slightest leak of air or steam, and prevents oil from creeping up from the crank chamber into the L.P. exhaust, and away to the condenser. The importance of this will be fully appreciated by those who have had the charge of engines.

Governing is effected by a powerful centrifugal governor built on the end of the crank shaft, and having direct control of a balanced throttle valve. The variation in speed does not exceed 1 to 1½ per cent. on either side of the mean, and closer governing can be obtained when necessary. The momentary fluctuation in speed on suddenly throwing on or off the load is very little more than the permanent. In order to reduce friction to a minimum amount, the bearings and joints consist of steel points bearing in little cups, and a very simple centrifugal oiler is fitted, by means of which constant and thorough lubrication is obtained. Provision is made for hand adjustment within a considerable range while running. This type of engine is made with two or three cranks—the latter for larger sizes, and where perfectly uniform turning and steady running are necessary—and in standard sizes from 150 to 750 B.H.P.

Messrs. Alley and Maclellan also showed a similar compound engine, but with only two cranks instead of three, each line of parts being exactly identical. This engine will develop 200 H.P., and runs at 400 revolutions per minute.

One of their class "H" two-crank, tandem-compound engines of 60 H.P., direct coupled to a "Laurence-Scott" dynamo, both being mounted on a combined bed-plate, was also shown. This engine differs from the "G" type in having only one line of valves, this placed between, and distributing steam to, the two lines of cylinders. These valves are mounted on one spindle, and driven by a single excentric on the crank shaft. Lubrication and governing are effected in the same way as in the larger engines. This "H" type is made in sizes of 10 to 150 H.P., and may be run either condensing or non-condensing, there being the "distance-piece" provided below the L.P. cylinders.

This engine has cylinders 6 in. and 10 in. diameter by 6 in. stroke, and runs at 525 revolutions per minute.

Besides these there were two small simple engines of their two-cylinder "Marine Auxiliary" type, the one driving a dynamo for lighting the stand, and the other a "Sentinel" centrifugal pump. Both of these sets were direct coupled, and each mounted on a combined bed-plate. They were especially designed for use on board ship, strong enough for 120 lbs. steam pressure, and may be run either condensing or non-condensing. They are fitted with a powerful automatic expansion governor, built on to the shaft between the cranks, the variation in speed between full and no load not exceeding 2½ to 3 per cent.

## Davey, Paxman & Co.'s Exhibit.

This firm showed one of their "Peache" patent high speed engines, direct coupled to a "Peel-Hawkins" dynamo.

This engine is of the three-crank, tandem-compound, enclosed single-acting type, having "splash" lubrication, the one in the Exhibition being capable of developing 360 I.H.P., with 150 lbs. steam pressure, and running at 350 revolutions per minute. The cylinders are 10½ in. and 17 in. diameter by

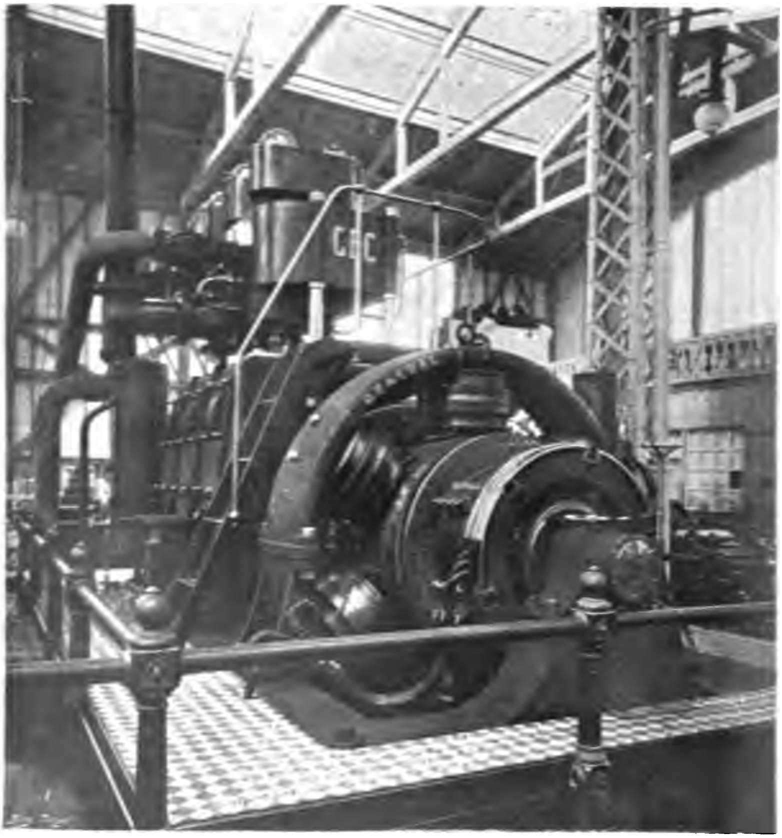


FIG. 139.—360 I.H.P. "PEACHE" ENGINE, BY MESSRS. DAVEY, PAXMAN & CO., COLCHESTER, DRIVING DYNAMO BY THE GENERAL ELECTRIC CO.

11 in. stroke. The valves, which are of the piston type, are placed at the back of the cylinders, one set for each pair of cylinders, and driven off the connecting rod, there being no excentrics. Although steam is taken on the top of the H.P. and the bottom of the L.P. piston, thus at first sight appearing

double-acting, constant thrust is obtained by a steam cushion formed by the alternate compression and expansion of the steam enclosed in the space between the two pistons, which space is of variable volume, depending on the position of the pistons, it being greatest when the pistons are at the bottom, and least when at the top. Instead of the centre line of the cylinders being in line with the shaft, it is placed behind the shaft by an amount equal to the length of the crank, the reason for this being that, the engine being single-acting, the effective stroke in the revolution takes place with the least angularity of the connecting rod, thus relieving the pressure on the guides, and also keeping this pressure always in one direction, as in a double-acting engine.

The engine is controlled by a throttle valve governor, driven by belts off pulleys on the end of the shaft. Large doors are placed on the front of the framing, giving easy access to the working parts.

## Reavell & Co.'s Engine.

This firm exhibited one of their single-acting, enclosed, self-lubricating engines, having a central valve (as in the "Willans" engine).

One striking feature in this engine is that the economy of a compound engine is obtained with only one cylinder instead of two or more as usual. The makers claim that, although the second stage of expansion in a compound engine is usually obtained by expanding the steam in a large cylinder, the same effect can be obtained by transferring only a portion of the steam which is already expanded in the first cylinder. That is to say, instead of having two cylinders of different sizes and expanding the whole quantity of steam in each, they might have two cylinders of the same size and expand a smaller quantity of steam in the second cylinder than in the first. The same effect is obtained with advantage by using the top and bottom ends of the same cylinder alternately.

The steam on the underside of the piston is approximately half that which expands on the upper side, it being obtained by having a cylinder clearance of large volume, so that, at the point of cut-off, the quantity of steam which expands on the top of the piston is divided approximately into two equal parts—first, that quantity which has been compressed into the clearance space; and, secondly, the quantity of steam which is admitted as new steam per stroke.

With this method of compounding, the high and low pressure cylinders, as it were, are the same size, and with the additional advantage that in consequence there is no drop when release takes place in the high pressure cylinder, because as the steam passes into the underside of the cylinder (which represents the low pressure cylinder in a compound engine), the volume in the high pressure cylinder is being decreased in the same proportion, but there is no change of total volume at all, and therefore no drop such as is obtained in a compound engine having cylinders of dissimilar size. This engine, which is known as the "Scott," is described in detail in another part of this book.

Governing is effected by a very simple governor, designed on the "Inertia" principle, which alters the cut-off point in the H.P. cylinder, and gives good results. The engine exhibited was one of their two-crank 12 in. by 6 in. size, capable of developing 60 B.H.P. at 140 lbs. steam pressure, condensing or non-condensing.

## Clarke, Chapman & Co.'s Exhibit.

This firm showed a number of engines on their stand, including their "Restler" high speed engine, which they make under the patents of Mr. J. W. Restler, chief engineer of the Vauxhall Water Co.

This engine, the details of which appear in another section of this book, is of the enclosed, single-acting, two-crank, tandem-compound type, lubricated on the "splash" method. A pair of H.P. and L.P. cylinders is arranged tandem-wise above each crank, the cranks being placed opposite each other, and steam is distributed by a string of valves placed in between the two lines of ports, and mounted on a single rod, and driven by one excentric. When controlled by a throttle governor, the cross-heads are made into air-buffers, to maintain "constant thrust" at all loads; but when variable expansion gear is used, the air-buffers are not necessary, as the

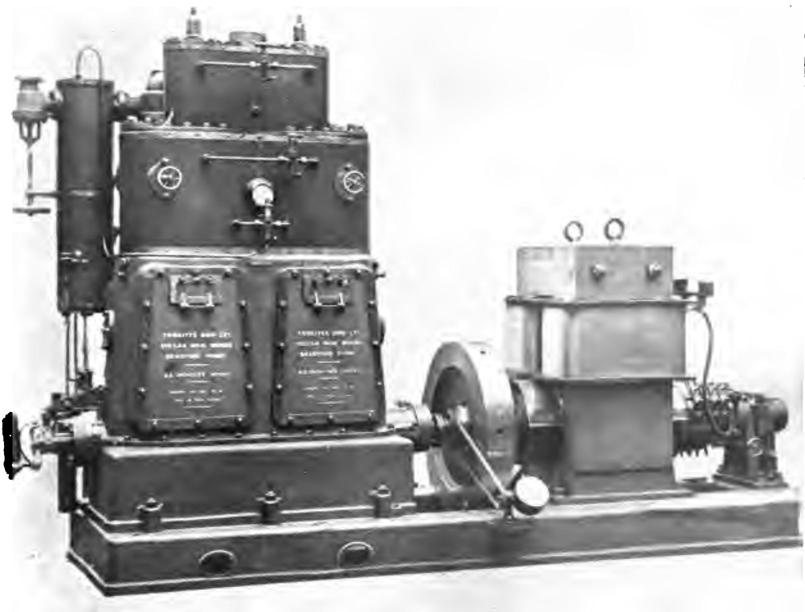


FIG. 140.—"CRICHTON" HIGH SPEED ENGINE, BY MESSRS. THWAITES BROS., LIMITED, BRADFORD.

governor, which controls all the valves simultaneously, is arranged to give considerable compression of steam in the cylinders on the up or exhaust stroke, which compression is increased at the lighter loads.

The engine exhibited was of 70 I.H.P., and runs at 450 revolutions per minute, it being direct coupled to a dynamo of their own make.

There were, besides this, two or three small single-crank engines and one two-crank of the double-acting open type, driving pumps, dynamos, etc.

## Thwaites Bros.' Engine.

This firm make the "Crichton" patent engine, and showed two or three on their stand. One was shown driving a dynamo (see Fig. 140) and another a centrifugal fan, both being of their single-crank tandem compound pattern. The engine is of the single-acting, enclosed type, and depends for its single action on the compression of the steam in the cylinders during the up or exhaust stroke; and on this account the low pressure cylinder is fitted with separate valves for steam and exhaust, so that the amount of compression can be varied by hand while running if necessary, to suit the particular speed at which the engine runs. Speed regulation is effected by a throttle valve governor adjustable by hand while running. A bath of oil and water is provided in the crank chamber for "splash" lubrication.

## Mather and Platt's Exhibit.

Messrs. Mather and Platt, Ltd., exhibited two engines of the medium speed, double-acting, open type, both driving dynamos, and two of the enclosed, high speed, single-acting type, one direct coupled to a dynamo and the other to a centrifugal pump.

The two open type engines were of the marine pattern, having cast iron back columns and turned mild steel front columns, the cylinders being placed side by side, adjacent to each other, with the valves outside. The cranks are placed opposite each other in the larger engine, which has cylinders 14 in. and 24 in. diameter respectively by 16 in. stroke, and develops 215 to 250 I.H.P. at 180 to 190 revolutions per minute, and 150 lbs. steam pressure. The H.P. cylinder is fitted with "Meyer" valve gear, in which the point of cut-off may be varied by hand while running, the L.P. cylinder having a double-ported slide valve. The governor is of the throttle type, driven by toothed gearing from the crank shaft. The smaller engine has cylinders 10 in. and 17 in. diameter by 12 in. stroke, running at 230 revolutions, and develops 120 I.H.P. The H.P. cylinder has a balanced piston valve, the cut-off of which is controlled by a powerful shaft governor, which maintains the speed within 1½ per cent. to 3 per cent. variation from full to no load. In both engines, sight-feed drop-lubrication from a large oil-box

FIG. 141.—250 H.P. ENGINE AND DYNAMO, BY MESSRS. MATHER AND PLATT, LIMITED, MANCHESTER.

is provided. This type is adopted for sizes from 100 to 1,000 H.P.

The high speed enclosed engines were both of the single-crank, single-acting type, provided with "splash" lubrication. The one coupled to a centrifugal pump was of their tandem-compound pattern, having cylinders 7½ in. and 12 in. diameter by 5 in. stroke, and runs at 480 revolutions. There are two piston valves fixed on one rod, and steam is distributed on the "Cornish" cycle.

The other engine was of the single-cylinder simple pattern, having one cylinder 17 in. diameter by 7 in. stroke, the speed being 450 revolutions, and the output about 35 B.H.P.

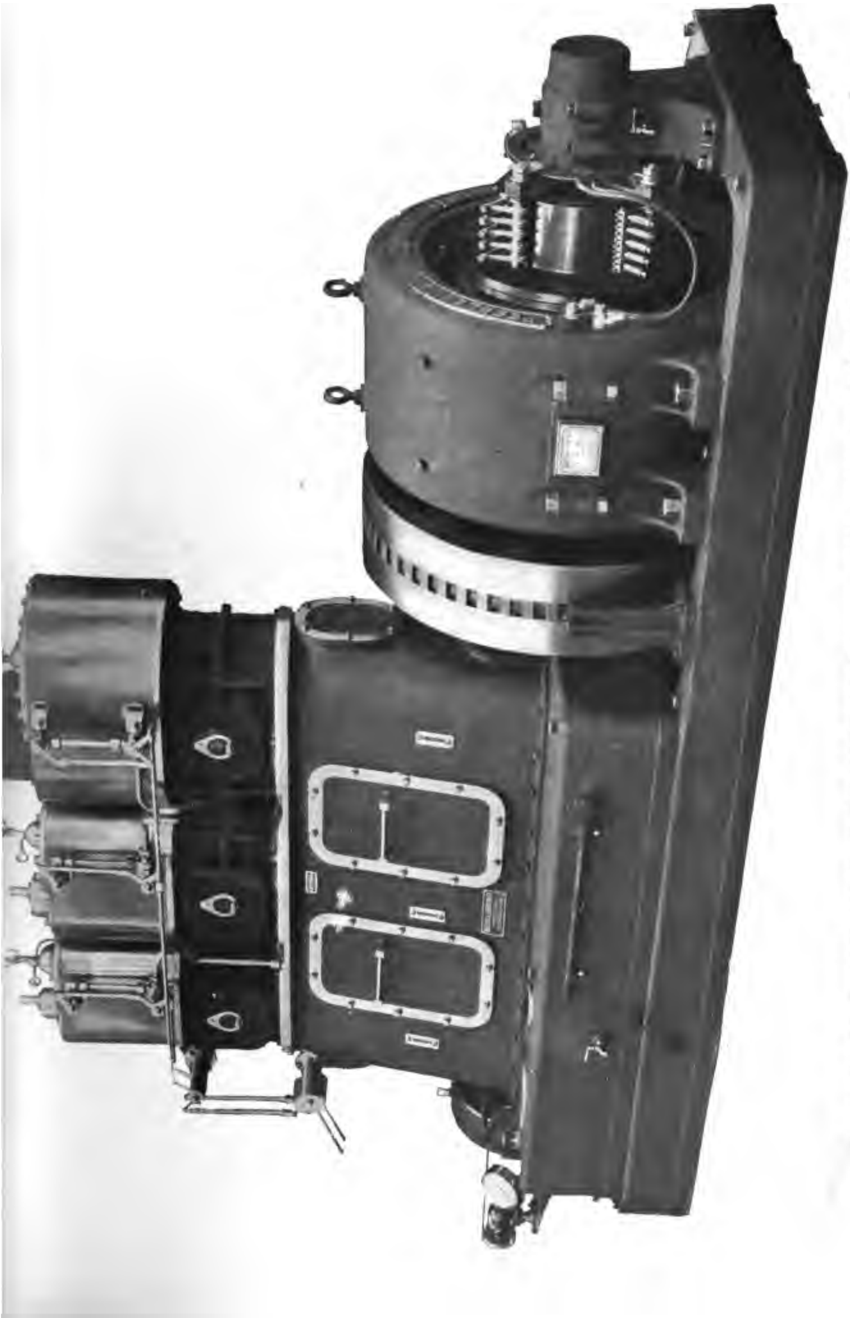
### Belliss and Morcom's Exhibit.

We have noticed all the leading single-acting types of engines exhibited, and will now deal with the double-acting engines, of which there were a large number on show. Messrs. Belliss and Morcom, Ltd., who first introduced

FIG. 142.—TANDEM COMPOUND ENGINE AND CENTRIFUGAL PUMP, BY MESSRS. MATHER AND PLATT, LIMITED.

FIG. 143.—SINGLE CYLINDER ENGINE AND OVERHUNG DYNAMO, BY MESSRS. MATHER AND PLATT, LIMITED.

about eleven years ago the enclosed type, forced lubrication, double-acting engine, and have ever since taken the lead in the production of this engine, showed one of 300 to 325 B.H.P. direct coupled to a "Bruce-Peebles" dynamo (see Fig. 142). This engine represents the firm's latest design of triple-expansion engine, which, instead of having the cylinders arranged tandem above each crank, has only three cylinders, one above each crank. By this arrangement one large cylinder for each stage of expansion is used instead of two or three smaller ones, with the result that the engine is simplified, the number of parts less, and the thermal efficiency probably increased. A balanced piston valve, driven by an excentric



g. 144.—350 H.P. TRIPLE-EXPANSION "BELLISS AND MORCOM" ENGINE, DIRECT COUPLED TO A "BRUCE-PEEBLES" 250 K.W. DYNAMO.

on the main shaft, distributes steam to each cylinder, and an improved system of automatic drainage is adopted. Even with a triple-expansion engine the turning effort is remarkably uniform at varying loads, owing to the engine having three cranks at 120 degrees apart, and the high speed of rotation. Their standard throttle valve governor is fitted, and lubrication effected by a valveless oil pump distributing oil under pressure to all the bearings, which system was first introduced by this firm eleven years ago, and, if "imitation is the sincerest flattery," with the greatest success.

The steam consumption of these engines has proved to be remarkably low, and, combined with the very high mechanical efficiency at all loads, gives excellent results. One of these engines, of 225 B.H.P., supplied to the Barnes and Mortlake Electricity Works, gave the following remarkable results, the steam pressure being 150 lb. and the vacuum 27½ inches:

| | | Load. | | |
|---|---|---|---|---|
| | | Full. | ¾ | ½ |
| Lb. steam per kilowatt hr. | ... | 25 | 26·7 | 27·2 |
| Combined efficiency $\frac{\text{E.H.P.}}{\text{I.H.P.}}$ % | ... | 84·7 | 81·8 | 80 |

Variation in steady speed from full to no load, 2 per cent.

The excellence of design and construction so well known in this firm's productions is here fully maintained. These engines are made in standard sizes up to 2,000 H.P.

## Browett, Lindley & Co.'s Engine.

What has proved to be one of the most successful engines of the double-acting, enclosed, high speed type is that made by this firm, who showed one of 250 B.H.P. direct coupled to an "Edison-Swan" dynamo. The engine was of their standard two-crank, side-by-side compound pattern, No. 9 S.L. size, and capable of developing the above output with 160 lbs. steam pressure, either condensing or non-condensing. The two cylinders are placed above two cranks set at 180 degrees apart, and are respectively 13 in. and 21 in. diameter by 9 in. stroke, the speed being 380 revolutions per minute. Details of this firm's engine are given on p. 30.

## Ernest Scott and Mountain's Engine.

This firm showed one of their two-crank, side-by-side, double-acting, forced lubrication compound engines of 250

FIG. 145.—250 H.P. DOUBLE-ACTING FORCED LUBRICATION COMPOUND ENGINE, BY MESSRS. ERNEST SCOTT AND MOUNTAIN, OF NEWCASTLE-ON-TYNE.

H.P., direct driving one of their multipolar dynamos. (See Fig. 145.) The engine has cylinders $11\frac{1}{4}$ in. and 21 in.

diameter by 10 in. stroke, and runs at 360 revolutions per minute. One balanced piston valve is placed between and distributes steam to the two cylinders. A small governor, fixed on to the end of the crank-shaft, operates a throttle

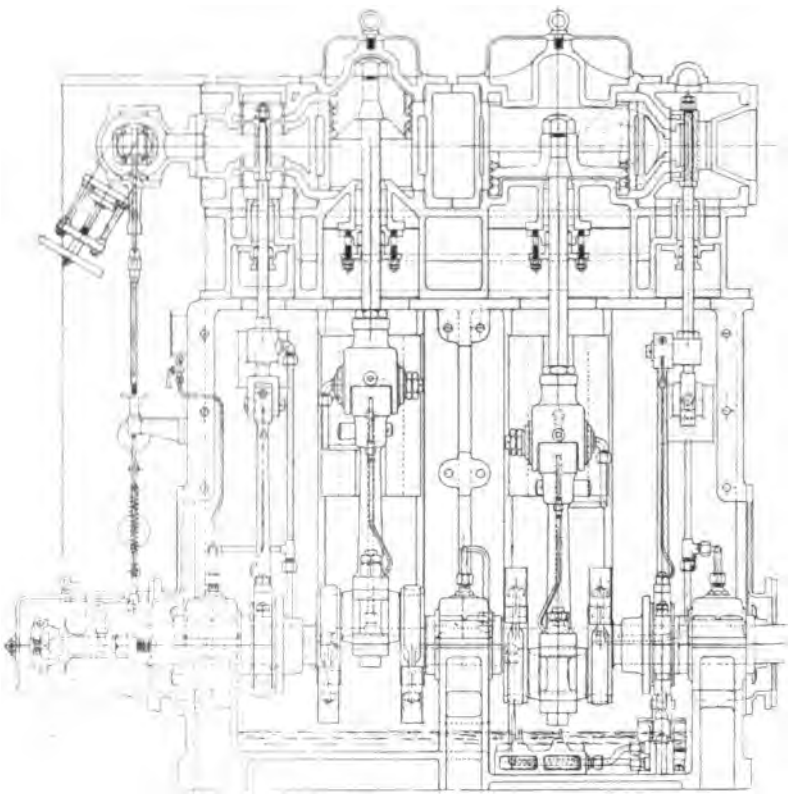


FIG. 146.—SECTIONAL VIEW OF MESSRS. ROBEY & CO.'S COMPOUND ENCLOSED, FORCED LUBRICATION ENGINE.

valve, and controls the speed of the engine within about 4 per cent. from full to no load. Lubrication is obtained by a valveless oil pump supplying oil under pressure to all the bearings.

## ROBEY & CO.'S EXHIBIT.

Messrs. Robey & Co., Limited, showed two high-speed engines. One was of their medium speed open type, and the other of their latest high speed, double-acting, forced lubrication, enclosed type. The open type engine is of the vertical two-crank, side-by-side compound pattern, has cylinders 10½ in. and 18¼ in. diameter by 11 in. stroke, and runs at 250 revolutions per minute, the normal output being 120 I.H.P. The speed is controlled by a governor, driven off the shaft by gearing, and operating the H.P. piston valve, which is driven by double-excentric link motion, the L.P. valve being driven by a fixed excentric. The enclosed engine is direct coupled to a "Scott and Mountain" dynamo, and is of 100 H.P. It it of the two-crank, side-by-side compound pattern, but has the cylinders placed adjacent to each other and the valves outside. The H.P. cylinder has a balanced piston valve, but the L.P. cylinder a flat slide valve, each driven by its own excentric. The cylinders are 8½ in. and 14½ in. diameter by 6 in. stroke, the speed being 550 revolutions. A centrifugal governor attached to the end of the crank shaft operates a balanced throttle valve. A valveless oil pump, driven by the L.P. excentric, supplies oil to all the bearings, the arrangement being, however, slightly different to that adopted in the "Belliss" engine. The design and construction of most of the details are in accordance with their standard practice. The engine is exceptionally well finished, and runs well.

## RUSTON, PROCTOR & CO.'S ENGINE.

A 100 B.H.P. engine direct coupled to a multipolar dynamo of American manufacture was the exhibit of this well-known firm. This engine was of the enclosed, double-acting, two-crank, side-by-side compound type, with cylinders 9½ in. and 15 in. diameter by 8 in. stroke, and a speed of 450 revolutions per minute, with 120 lbs. steam pressure.

As will be seen by the sectional illustration (Fig. 148), the two cylinders are placed adjacent to each other, and the valves, each of which is of the balanced piston type, are placed one at each end, outside the cylinders. The principal advantage of this arrangement, which is also adopted in the "Robey" as well as the "Musgrave" engine (described in the foregoing pages), is that the couple tending to rock the

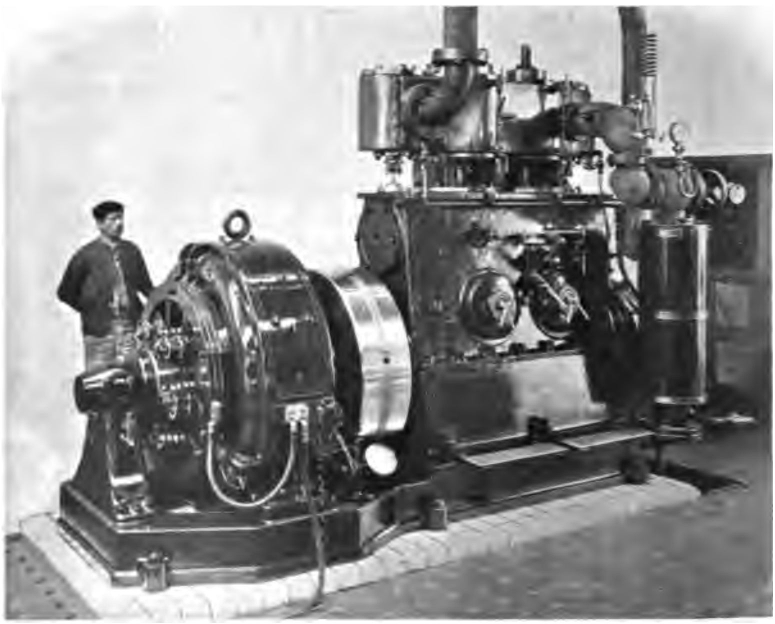
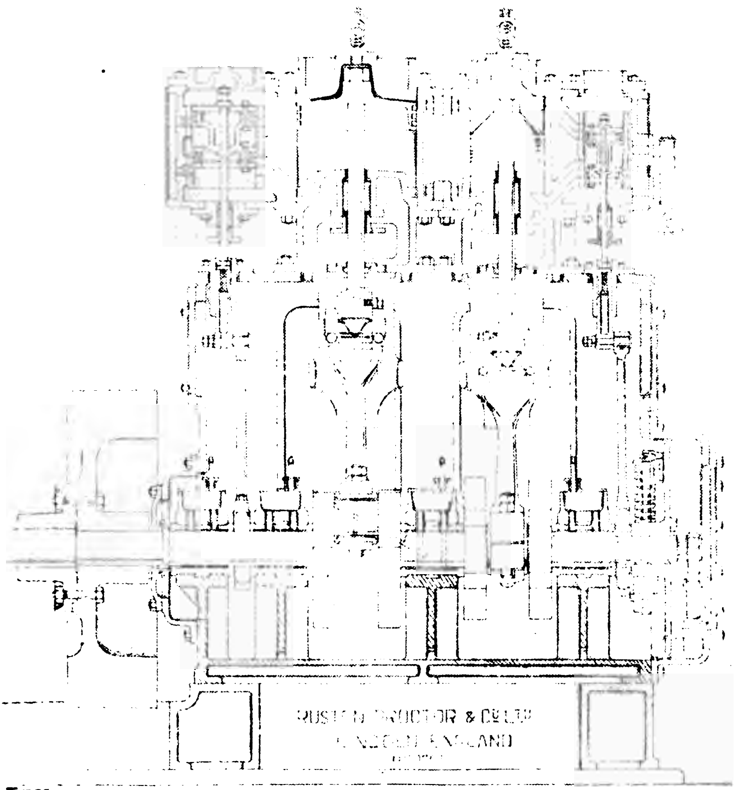


FIG. 147.—100 B.H.P. ENCLOSED DOUBLE-ACTING COMPOUND HIGH SPEED ENGINE, BY MESSRS. RUSTON, PROCTOR & CO., LTD., LINCOLN.

engine longitudinally is greatly reduced, producing a rather steadier running engine.

The H.P. valve is directly controlled by a powerful shaft governor of their own make, and closed into the crank chamber by a large end door, so that it is thoroughly lubricated while running. This door also provides easy access for examination of the governor, and large hinged doors are fitted to the side of the crank chamber, for access to the other working parts. Lubrication is effected, in the usual way, by a valveless oil pump, but in this case driven off a pin on the governor end of the shaft instead of from the excentric.



*Eng. Times*

FIG. 148.—SECTIONAL VIEW OF MESSRS. RUSTON, PROCTOR & CO.'S ENGINE.

## ANDERSTON FOUNDRY CO.'S EXHIBIT.

This firm, which has been established over half a century, have within the last year or two taken up the manufacture of high speed or quick revolution engines of the enclosed, double-acting, forced lubrication type. This engine (see

Fig. 149), though sometimes made single crank for the smaller sizes, and occasionally three-crank for triple expansion, is usually of the two-crank, side-by-side, two-cylinder compound type, and has a separate piston valve to each cylinder, both valves, however, being mounted on a fork-spindle driven by a single excentric, and placed between the cylinders. By placing the valves across the engine, the cylinders are got closer together, and the length of the engine

FIG. 149.—DOUBLE-ACTING, FORCED LUBRICATION COMPOUND ENGINE, BY THE ANDERSTON FOUNDRY CO., LIMITED, GLASGOW.

not more than the usual two-cylinder, single, middle valve type. A valveless oil pump, driven by the excentric, supplies oil under a pressure of about 20 lbs. per square inch to all the bearings. The speed of the engine is controlled by a small shaft governor operating a throttle-valve, the makers claiming very close governing under the most fluctuating load. Two large hinged doors on both sides of the engine allow free access to the internal working parts. The engine was shown running, and coupled to a multipolar dynamo.

## Alex. Shanks & Son's Engine.

This firm exhibited an engine of the double-acting, forced lubrication, enclosed type (see Fig. 150). The engine, though possessing no novel features, appears to be very well designed, and of excellent finish, as well as being compact and easily

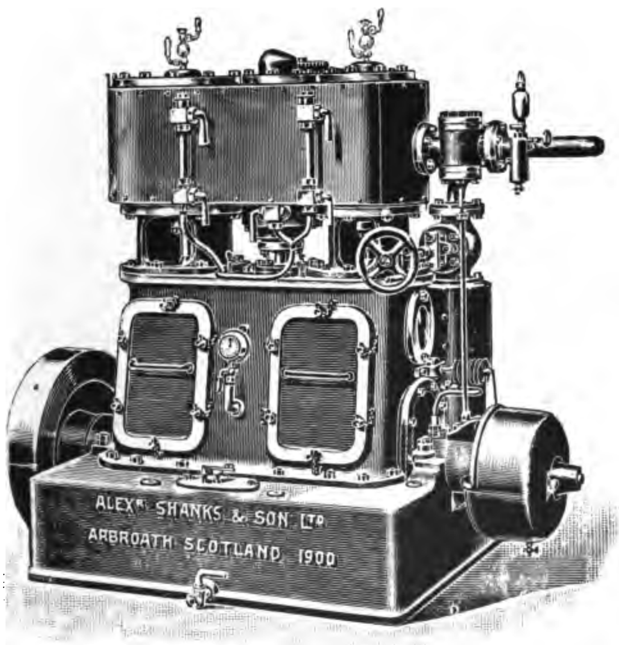



FIG. 150.—DOUBLE-ACTING, FORCED LUBRICATION COMPOUND ENGINE, BY MESSRS. ALEX. SHANKS & SON, LIMITED, ARBROATH.

accessible. It is of the two-crank, side-by-side compound type, having cylinders 8 in. and 15 in. diameter by 6 in. stroke, and when supplied with 160 lb. steam pressure, and running at 500 revolutions per minute, will develop 75 B.H.P. The two piston-valves—one to each cylinder—are placed transversely between the cylinders, and each driven by its own excentric. A valveless oil pump, driven by one of the excentrics, supplies oil under pressure to all the bearings.

These engines are made in standard sizes of 30 B.H.P. and upwards, and designed for 160 lb. steam pressure. The firm also show small, open type, medium speed engines.

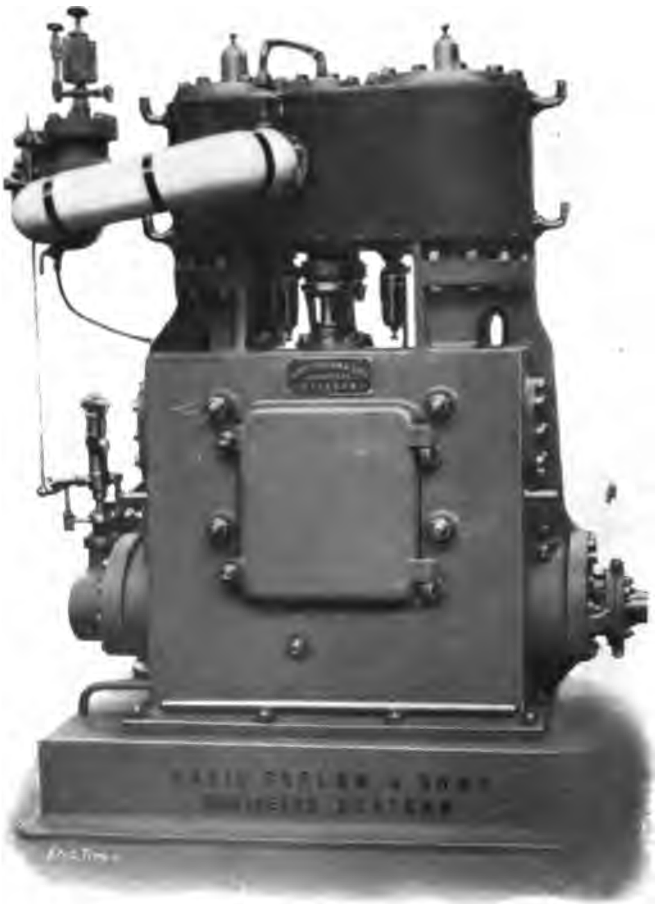


FIG. 151.—100 I.H.P. DOUBLE-ACTING, FORCED LUBRICATION COMPOUND ENGINE, BY MESSRS. DAVID CARLAW & SONS, GLASGOW.

## David Carlaw & Sons' Engine.

This firm exhibited a double-acting, enclosed, forced lubrication engine, of 100 I.H.P. (see Figs. 151 and 152). It was of the two-crank, side-by-side compound type, having cylinders 8 in. and 12 in. diameter by 8 in. stroke, and running at 350 revolutions per minute, the above output

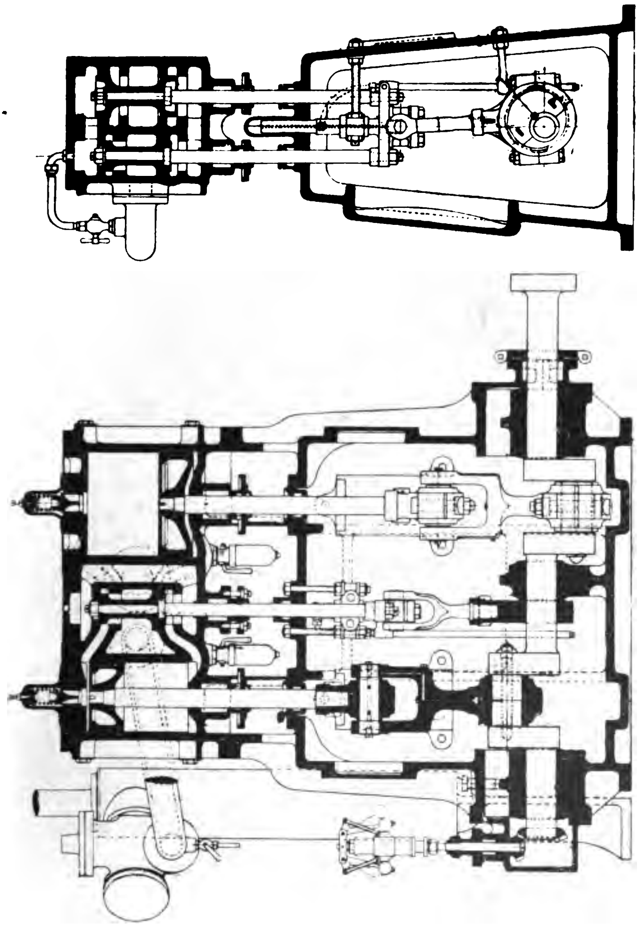


FIG. 152.—SECTIONAL VIEWS OF MESSRS. DAVID CARLAW & SONS' HIGH SPEED ENGINE.

being obtained with 150 lb. steam pressure. The cranks are opposite each other, and there are two piston valves in one common chamber between the two cylinders, but worked by a single excentric. The usual valveless pump driven off the excentric forces the oil under pressure of about 20 lb. to all the bearings. The main bearings are lined with white metal, but the crank pins and cross-heads bushed with phosphor bronze. The main bearings and guides are adjustable from the outside, but all other parts inside the crank chamber are easily accessible by means of large hinged doors.

Governing is effected by a centrifugal governor controlling a throttle valve.

## W. Sisson & Co.'s Engine.

One of the most novel of the high speed engines shown working was that of Messrs. W. Sisson & Co., of Gloucester. This engine differs from most others in almost every detail, having many original and novel features. The one shown running was a double-acting, two-crank compound engine of 125 H.P., direct driving a "Clarke-Chapman" dynamo at 400 revolutions per minute. The sectional and outside views (Figs. 153 and 154) show the general arrangement of the parts so well that a lengthy description is unnecessary. The main object of placing the cylinders and cranks so close is to reduce the couple tending to rock the engine longitudinally. The extra length of the H.P. piston rod makes up the difference in weight between the two pistons, and helps to balance the two lines of parts. Sufficient space is provided between the bottom of the H.P and top of the L.P. cylinder to allow for the removal of the L.P. cylinder cover, piston, etc. The valves, of the balanced piston type, are, as will be seen by the illustration, placed at the back of the engine, and driven off a rocking shaft, this being actuated by the excentric of a variable expansion shaft governor built on the web of the H.P. crank, and provided with means for adjustment by hand while the engine is running. A little air buffer or dash pot is provided at the bottom end of the valve rod to cushion the inertia of the line of valves. One of the most distinguishing features in this engine is that of the bearings. In all other successful double-acting high speed or quick revolution engines, the necessary lubrication is obtained by means of an oil pump forcing the oil into the bearings under a pressure of 15 to 30 lb. per square inch, thus maintaining a thin film of oil between the wearing surfaces, but in this one it is effected by a combination of the "splash" method and self-adjusting bearings in the connecting rods. This adjustment of the connecting rod brasses is

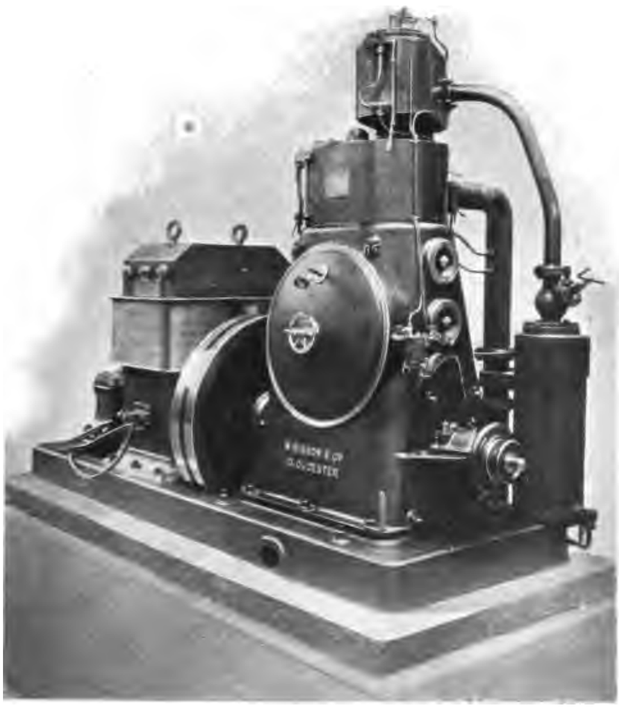


FIG. 153.—THE "SISSON" COMPOUND ENGINE, SHOWN DIRECTLY CONNECTED TO A "CLARKE-CHAPMAN" DYNAMO.

effected by means of a column strut in the hollow interior of the bored-out rod, and a transverse wedge held up by a very strong, coiled spring, so that as wear takes place, the wedge is drawn up by the spring, and forces out the brasses against their respective bearings. This also allows the brasses to yield to expansion caused by heating. This automatic adjustment is, however, only confined to the connecting-rod

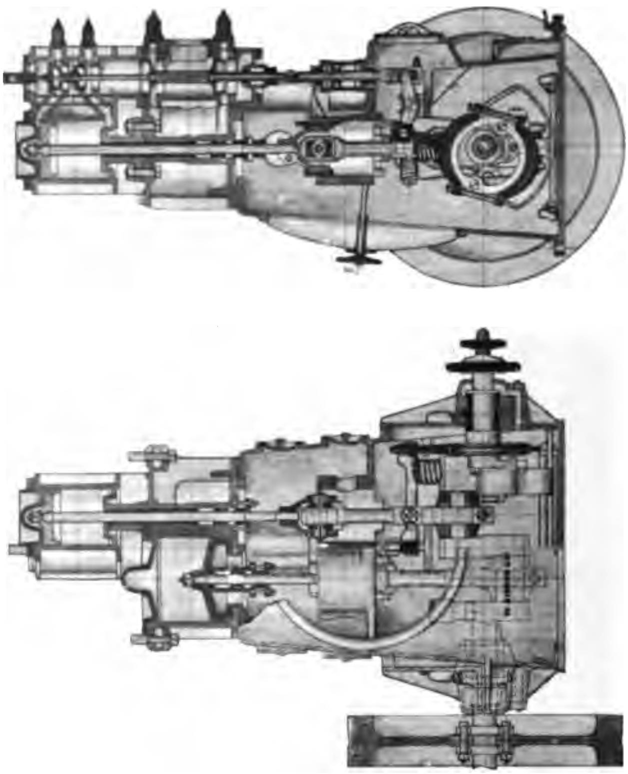


FIG. 154.—SECTIONAL VIEWS OF MESSRS. W. SISSON & CO.'S HIGH SPEED ENGINE.

and valve-rod brasses, all other bearings requiring hand adjustment.

Easy access to the working parts is obtained by a very large sheet steel door secured by a single bolt to the front of the engine, and both easily and quickly removed.

These engines are made either two-cylinder, side-by-side compound, two-crank triple, or four-crank compound. The engine we saw running at the Exhibition appears to fulfil the claims of its makers as to its steady and silent running.

The makers have supplied us with the following particulars of results obtained from an 11 in. and 20 in. by 11 in. "Sisson" engine coupled to Siemens two-pole generator:—

Steam 135 lb., exhaust atmospheric, R.P.M. 340, indicated horse-power in H.P. cylinder 141, in L.P. cylinder 149, total 290 H.P. Volts 120, amps. 1550. Electrical H.P. 250 and then comb. efficiency = 86 per cent.

Another test of the same set gave:—

Steam 130 lb., exhaust atmospheric, R.P.M. 335, indicated horse-power in H.P. cylinder 131, L.P. cylinder 134, total 265 H.P. Volts 123, amps. 1400 ∴ E.H.P. = 231 ∴ efficiency = 87 per cent.

Governing tests at somewhat lower loads were as follows, the steam pressure being 140 to 145 lb.:—

Engine running light, 350 R.P.M., load thrown on 600 amperes, momentary change 6 revs., settled change 5 revs.

Engine running light, 350 R.P.M., load thrown on 1100 amperes, momentary change 9 revs., settled change 5.

Engine running loaded 345 R.P.M., load thrown off 600 amperes, momentary change 5 revs., settled change 5.

Engine running loaded, 345 R.P.M., load thrown off 1250 amperes, momentary change 15 revs., settled change 5.

## Ransomes, Sims and Jefferies' Exhibit.

This well-known firm of general engineers showed one of their high speed engines direct coupled to a dynamo. The engine (see Fig. 155) is of the single-crank, double-acting, open type, and is designed to stand a steam pressure of

175 lb. per square inch on the piston, but will work well with any pressure above 70 lb. It is fitted with their own type "B" shaft governor, operating an equilibrium throttle valve, the total permanent variation in speed between full and no load not exceeding 2 per cent. Provision is made for

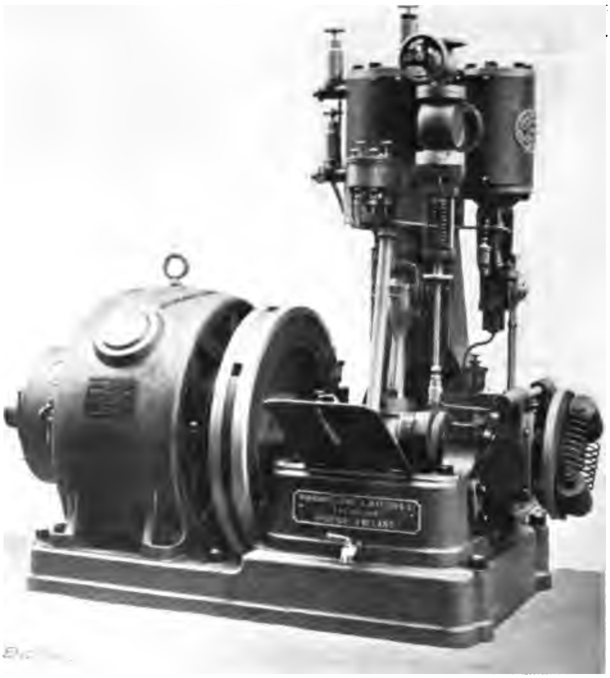


FIG. 155.—OPEN TYPE HIGH SPEED ENGINE, BY MESSRS. RANSOMES, SIMS AND JEFFERIES, LIMITED, SHOWN COUPLED TO DYNAMO.

adjustment by hand while running. Sight-feed drop lubrication, as usually adopted for open type engines, is provided, the bearing surfaces are large, and splash guards are fitted to prevent oil throwing. The accompanying illustration shows clearly the general design, which, combined with good finish, makes a very neat engine.

## Wm. Foster & Co.'s Engine.

This firm, who make high speed engines in the smaller sizes, showed one of their standard engines driving a dynamo by belt. The engine is of the single-crank, double-acting, open type, of their newest design, and clearly shown

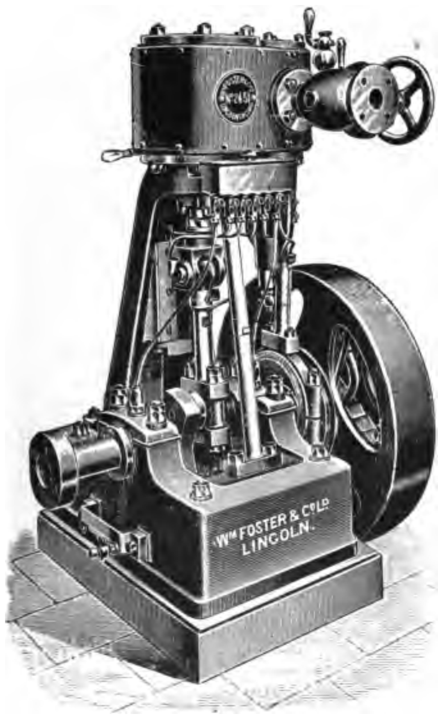



FIG. 156.—OPEN TYPE ENGINE, BY MESSRS. WM. FOSTER & CO., LIMITED, LINCOLN.

in the accompanying illustration (Fig. 156). It is fitted with Robinson's patent expansion governor, controlling direct a balanced piston valve, with a variation in speed not exceeding 2½ per cent. from full to no load. The particular engine shown was their 8½ in. by 8 in. size, capable of developing up to 40 H.P.

## Daniel Adamson & Co.'s Exhibit.

The only example of the horizontal high speed engine so commonly used in America was the exhibit of Messrs. Daniel Adamson & Co., who exhibited what goes by the striking name of the "Ideal" engine, the American makers of which are Messrs. A. L. Ide & Sons. This make of engine is fully described in a previous section.

Two engines were shown, one of the single-cylinder simple type, 12 in. by 12 in. size, running at 300 revolutions per minute, and the other of the single-crank, two-cylinder, tandem compound type, 10 in. and 16 in. by 12 in., running at 260 revolutions. Each engine was direct coupled to a dynamo, and they run very nicely, while the general design and finish are good.

## Sturtevant Engineering Co.'s Engine.

This was the only example of an American design of vertical high speed engine, and was of the semi-enclosed, double-acting type, sight-feed drop lubrication being used. These engines were shown driving dynamos and fans. The larger one is of the two-crank side-by-side simple pattern. When supplied with steam at 120 lb. pressure, and running at 490 revolutions per minute, it develops 35 H.P. The cranks are directly opposite each other. A single balanced valve, controlled by an "Inertia" shaft governor, distributes steam to the two cylinders.

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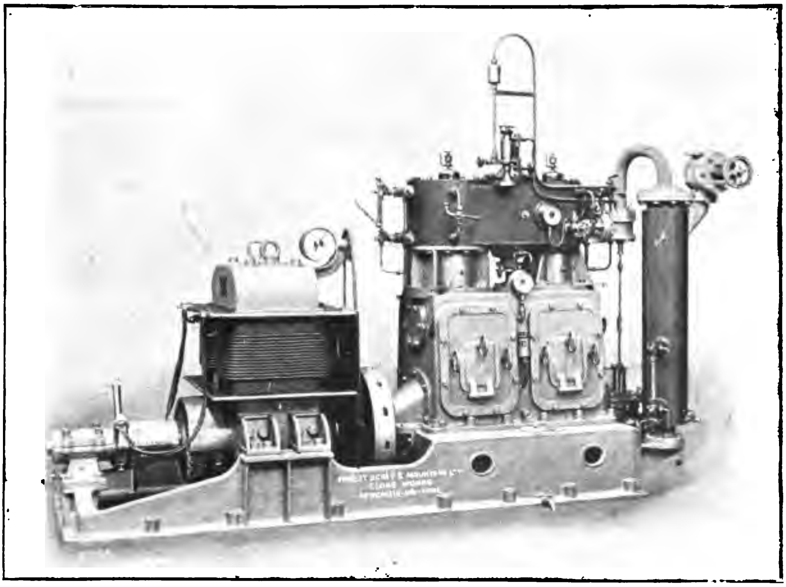

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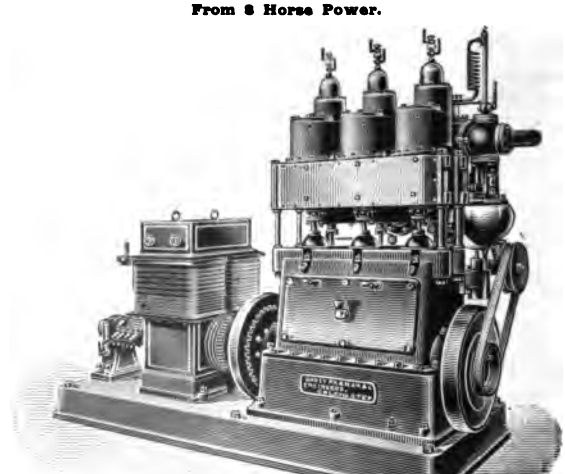

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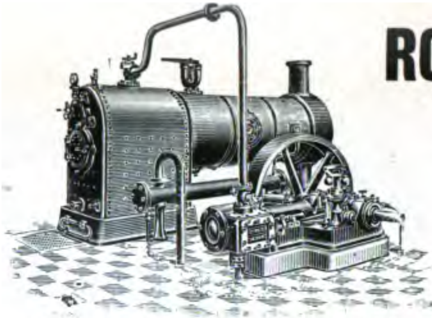

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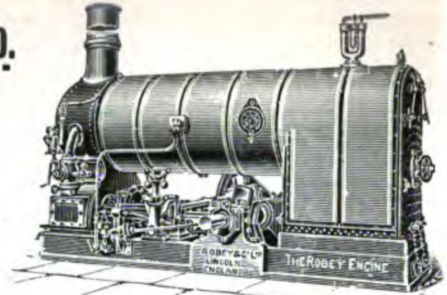


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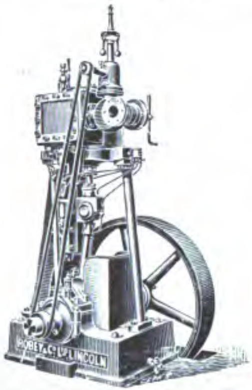


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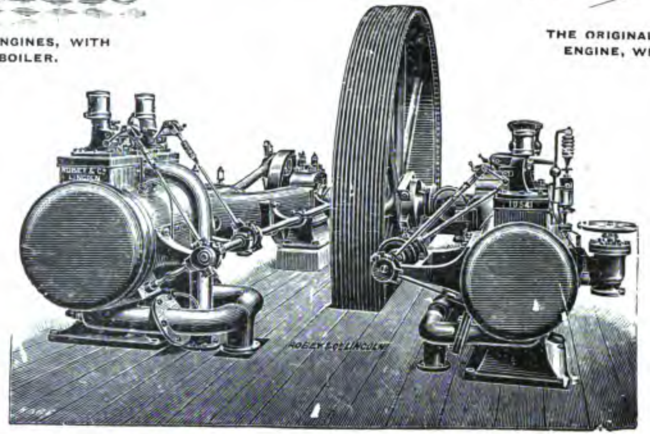


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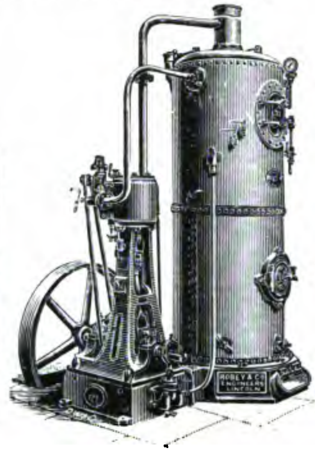

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Vols. I. and II., in connection with the Legislation and other Circumstances affecting the Condition of the People, A.D. 924 to 1853. By Sir GEORGE NICHOLLS, K.C.B., *Poor Law Commissioner and Secretary to the Poor Law Board.* New Revised Edition, with a Biography and Portrait of the Author. 2 Vols. Demy 8vo, cloth, 30*s*.

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