STEAM-ENGINE THEORY AND PRACTICE

BY

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CHAPTER XXII.

THE CORLISS ENGINE.

THIS engine was the invention of the American engineer Geo. H. Corliss, and first appeared in 1850. It has been much used since, especially for the larger sizes of high-class mill engines in all countries, and very generally for ordinary mills and factories in America.

The Corliss valve gear possesses the following important advantages :—

1. Reduced clearance volume and clearance surface, owing to the shortness of the admission and exhaust passages obtained by placing the valves close to the ends of the cylinders. In such cylinders the clearance will vary from 3 to 5 per cent. of the piston displacement.

2. Separate valves are used for steam and exhaust, the steam-valves being at the top corners of horizontal cylinders and the exhaust valves at the bottom corners, by which means, during the flow of the steam from the cylinder, the exhaust surfaces are swept clear of water and a natural system of drainage is thus provided. This advantage applies more especially to horizontal cylinders.

3. It maintains a wide opening during admission of steam with a sudden return of the valve at cut-off, thus preventing wire drawing of the steam during admission.

4. It permits of independent adjustment of admission and cut-off, release and compression.

5. It provides an easy and effective method of governing engines of large power, by regulation of the cut-off, through the action of a governor on the comparatively light working parts of the valve disengaging gear.

It is frequently claimed for the employment of separate steam and exhaust valves that condensation is reduced because the entering steam coming through a separate passage, and not through that through which the steam is exhausted, does not come into contact with surfaces which have just been cooled down by the comparatively cold exhaust steam, as is the case when the port is common to both admission and exhaust; but this claim is only valid if the area of clearance surface is reduced by the arrangement of separate valves, because in any case, all the surface up to the exhaust valve must be heated up each stroke whether the steam is admitted through the same or through a separate port. One important objection to the Corliss valve gear is the limitation of the speed of rotation of engines fitted with it owing to its action being dependent upon the engagement and tripping of catches.

About 150 revolutions per minute is probably nearly the limit of speed (though speeds as high as 240 revolutions per minute are known in America). To avoid this limitation, the valve gear is now made for high 200 rotational speeds without the trip-gear, the connection between the wrist-plate and the steam-admission valve being direct, and the regulation of the cut-off being obtained by varying the travel of the wrist-plate motion through a governor and link.

Fig. 383 is an illustration of the general arrangement of a Corliss engine with a single eccentric for both admission and exhaust valves.

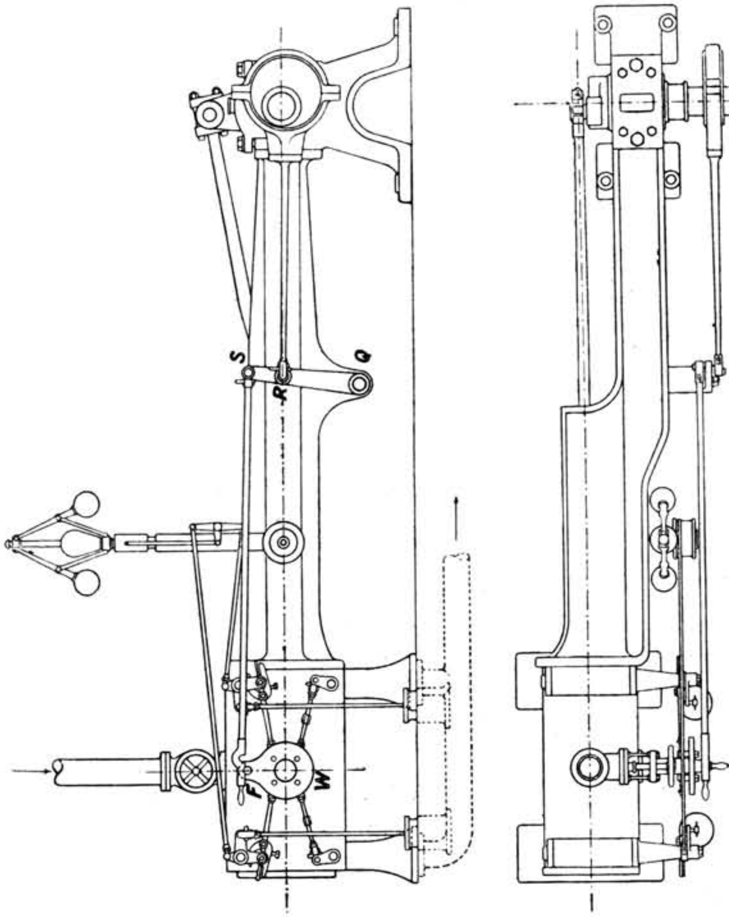

Fig. 383.

Fig. 384 shows in skeleton the arrangement of levers by which the valves are driven. Motion is obtained in the first place from an eccentric on the crank-shaft which is connected by its rod to a vertical rocker-arm, QRS. Attached to the rocker-arm is the hook rod or lever FS which drives the wrist-plate W, and causes it to oscillate about its centre of motion O.

Attached to the wrist-plate are four valve rods, two marked BB,

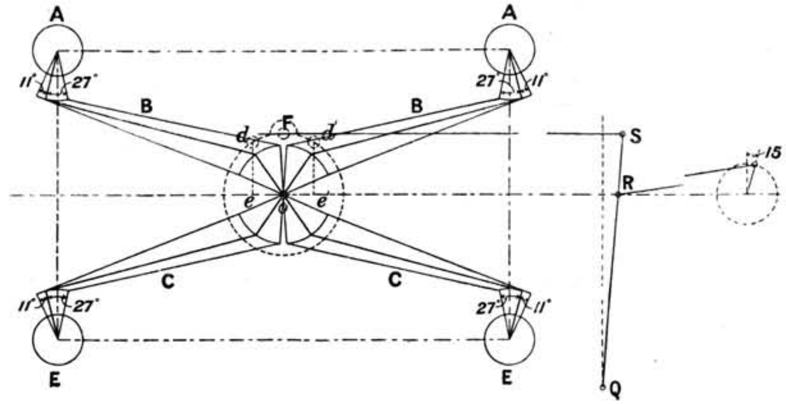

Fig. 384.

attached to the two upper or steam-admission valves AA, and two marked CC, to the two lower or exhaust valves EE. The valve rods and levers are shown in three positions—in the middle, and at the two ends of their stroke.

The exhaust-valve rods are connected directly to the exhaust-valve spindles, but the admission-valve rods work loosely on the bosses of the valve-stem brackets. These levers engage the admission valve by means of a trip or catch, and the steam-port is thereby opened during the first portion of the piston path, after which the trip disengages the lever and the valve suddenly closes the port by means of the weight or spring of the dash-pot plunger.

The admission valve remains closed and at rest during the remainder of the stroke, also during the return or exhaust stroke, until it is again engaged by the catch so as to move the valve in time for the new stroke of the piston.

Fig. 385 is a longitudinal and sectional view of a Corliss steam valve.

Fig. 386 illustrates the trip-gear as used on the early Corliss engines, and as still used by many American engineers, and which is known as the "crab-claw gear."

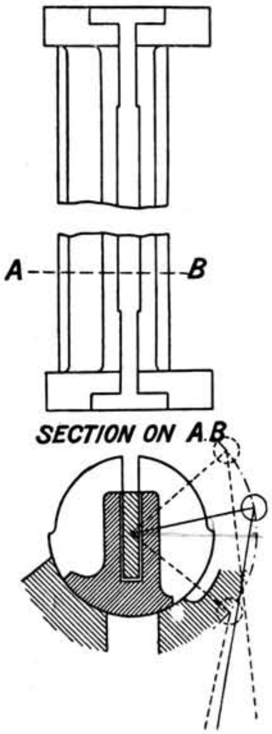

Fig. 385.

The valve-rod B (Fig. 386) is driven from the wrist-plate. The bell-crank lever AA is securely attached to the valve spindle C. A square-headed bolt D, with a hole through the square head, is attached to the lower lever of the bell-crank A. The valve-rod B passes freely through the hole in the pivoted nut D. To the rod B a fork EE is pinned at F, and the lower limb of the fork is kept up to its work by a spring G as shown. A steel plate H is fixed in the upper face of the lower limb of EE, by which it catches the sleeve D of the lever A.

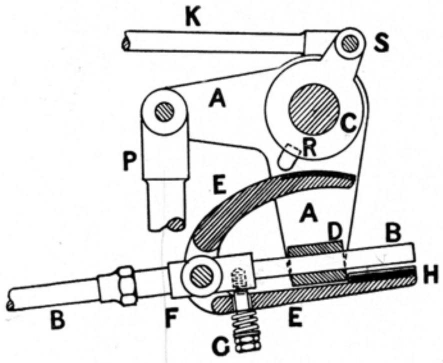

Fig. 386.

When the catch H and sleeve D are engaged, as shown in Fig. 386, then the movement of the valve-rod B to the left pulls also the bell-crank lever AA, and turns the valve on its spindle C, so as to open the steam-admission port. Cut-off at any required point is obtained by means of a disengagement of the catch H which liberates the bell-crank lever, and the valve is suddenly closed by the pull of the lever P.

Disengagement of the catch is effected by means of a projecting pin, R, on a separate lever, S, which rides loose on the valve spindle C, and which is connected to the governor by the rod K.

At a given speed the position of the projecting pin R remains constant, and as the lever A is pulled by the catch H towards the left, the curved upper limb of the lever EE comes into contact with the pin R and is depressed, and the catch H is disengaged from D.

The valve spindles are rectangular where they pass through the valves (Fig. 385). The valves may thus be easily twisted as required, and at the same time be free to move outwards relatively to the spindle as wear takes place.

Fig. 387 shows an arrangement of Corliss valves for a vertical engine. S, S are the steam-admission valves, and E, E are the exhaust valves. The steam enters the cylinder through the port *a*, and leaves the cylinder through the opening *b*, when the exhaust valve uncovers the exhaust port *c*. The valves are here shown for mid-position of the eccentric, that is, the exhaust valves are just about to open or to close their respective ports, and the steam-admission valves overlap the ports, the amount of overlap in this position being the true "lap" of the valve as in the ordinary slide-valve. In addition to this lap, the valve, when liberated by the trip gear, swings further and covers the port by an amount greater than the lap, as shown by the dotted positions in the figure. This additional movement is called the "seal" of the valve, or the "dwelling angle."

To set the Valves of a Corliss Engine.—Usually marks are placed on the ends of the valves and on the valve-box, showing the relative positions of the working edge of the valve and of the port. Thus in Fig. 387, 2 is the working edge of the steam-valve and 3 of the steam-port; also 4 is the working edge of the exhaust valve and 5 the working edge of the exhaust port. A centre line is drawn on the boss of the wrist-plate, and three lines are drawn on the periphery of the wrist-plate support, corresponding with the middle and two end positions of the wrist-plate centre line (see Fig. 390).

First the wrist-plate is set in its middle position with its centre line vertical. The steam-valves are then set so that they each have the required amount of lap. In the Fig. 387, the amount by which the edge 2 of the valve overlaps the edge 3 of the port when the wrist-plate is in mid position, is the lap of the valve.

The amount of lap given depends upon the size of the engine, and may vary from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. in small engines, to $\frac{5}{8}$ in. or more in larger engines.

The amount of lap can be varied by shortening or lengthening the valve rods by means of the adjustable nuts on the valve rods.

Similarly, when the wrist-plate is in mid position, the exhaust valve edges 4 are adjusted equally in both exhaust valves to the exhaust-port edges 5. When the exhaust valves have no lap, as is often the case, then the edges 4 and 5 coincide for both the exhaust valves when the wrist-plate is in mid position.

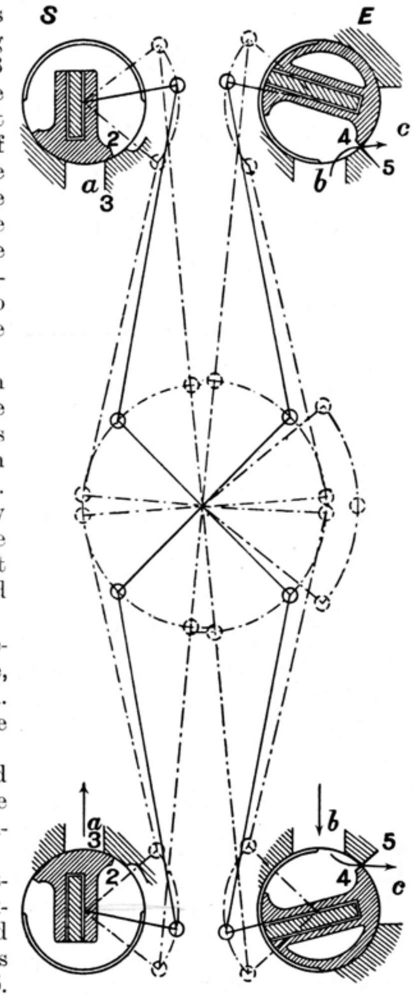

Fig. 387.

The rocker arm—to which the eccentric rod and wrist-plate lever are attached—stands vertical for horizontal engines (see QRS, Fig. 383), or horizontal for vertical engines, when the wrist-plate is in mid position.

Fig. 388 gives a wrist-plate diagram. OD and OB show the extreme positions of the levers, and OC mid position. This is a case in which a double reversal of stress takes place in the levers and pins during each forward and backward stroke of the wrist-plate. This is shown by the passing of the levers AB and OB outside the dotted line joining the centre O of the wrist-plate, and drawn tangent to the valve-lever arc, thus reversing the angle between the radius of the wrist-plate and the valve-rod. This is an objectionable arrangement, and should be avoided where possible.

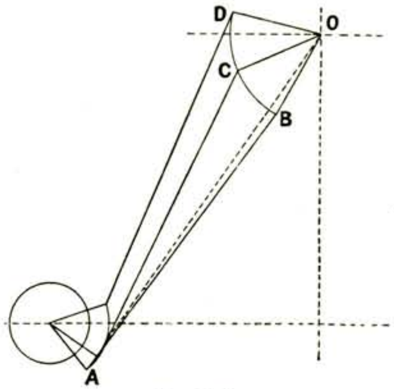

FIG. 388.

Setting of the Eccentric, for a single eccentric and one wrist-plate working both admission and exhaust valves. If the steam-valves and the exhaust valves have no lead, that is, admission and release take place at end of the stroke, and there is no compression, then the eccentric is set at right angles to the crank and it has zero angular advance. In this case the latest point of cut-off possible is at half-stroke of the piston, because the eccentric controls the valve during 90° rotation of the shaft as a maximum, past the point of opening of the valve. At or before the end of the valve stroke the trip gear, which is worked by the governor, liberates the valve, which suddenly closes and cuts off the steam-supply. The trip gear can only act during the movement of the gear through some portion of this angle. In order to obtain lead of the valve, an early release, and moderate compression, the eccentric is given angular advance. This still further reduces the number of degrees during which the eccentric has control of the valve, and the maximum point of cut-off is at some point earlier than half-stroke.

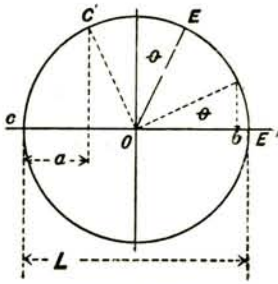

FIG. 389.

Thus, if the eccentric, Fig. 389, is set with an angular advance θ, then the eccentric is at E when the crank is at C.

When the crank has moved through an angle COC', the eccentric has reached E', the position of maximum opening of the valve, and the trip gear must have acted at or before this point. Hence crank position C', that is, cut off at $\frac{a}{L}$ of the stroke, represents the latest point of cut-off possible with this arrangement.

If the valve lever were connected to the wrist-plate without any

trip gear, then the valve would gradually return and the port be closed when the piston is at some point, *b*, near the end of the stroke as with an ordinary slide-valve without lap, but in that case the special feature of the Corliss gear would disappear, as it was designed to provide an efficient means of obtaining a range of early cut-off points to secure economical expansion of the steam in the cylinder.

If a larger range of expansion is required than that provided as above, it is possible to secure it by the use of two eccentrics and a

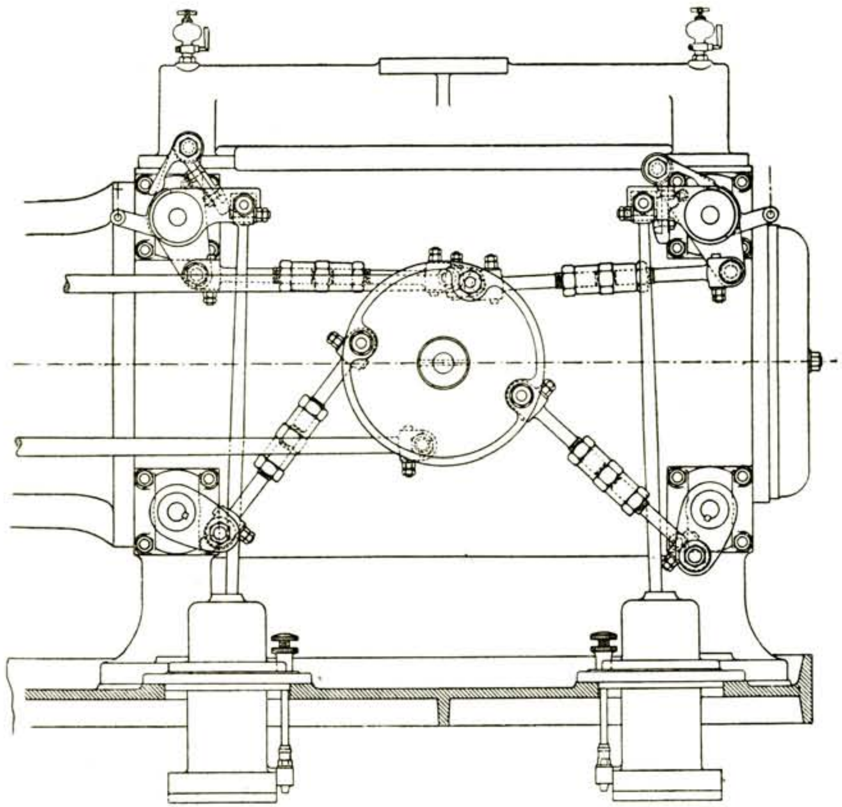
FIG. 390.

double wrist-plate: one for the admission valves and the other for the exhaust valves, as shown in Figs. 390 *et seq.*

Considering further the case of the single eccentric, from Fig. 384, it will be seen that the wrist-plate pin, F, travels through an arc *dd'* about its centre *o*, this angle being bisected by the vertical centre line through *o*. If vertical lines be projected from points *dd'* to the horizontal centre line through *o*, and cutting it at *ee'* respectively, then ee' is the diameter of the virtual or equivalent eccentric giving the movement dd' to the wrist-pin, and the throw of the actual eccentric $= ee' \times \dfrac{\text{QR}}{\text{QS}}$

The movement at the edge of the valve, for a given angular movement of the valve lever, is measured on the valve circumference.

An important point to notice is the means which the wrist-plate

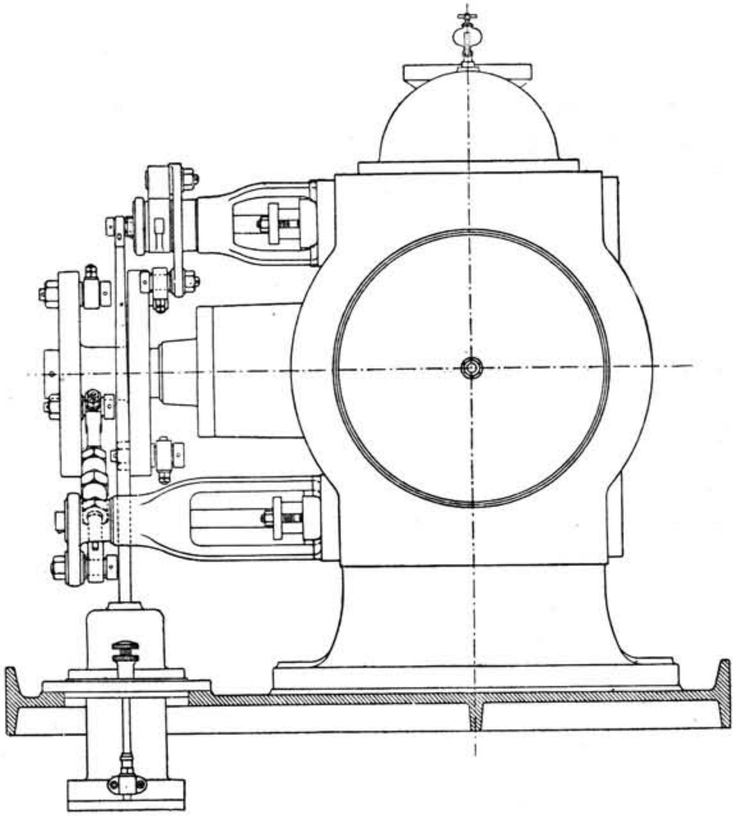

FIG. 391.

provides for giving the valve small movements when closed, and large, and therefore quick, movements when the port is open. This reduces the power required to drive the valve gear to a minimum. Thus, in the example, Fig. 384, during the movement of the wrist-plate through the first and second half of its total arc, the steam-admission valve moved through 11° and 27° respectively, and the exhaust valve 11° and 27° respectively. For ordinary engines of

the type illustrated in Fig. 383, the angular advance of the eccentric is made about 15°.

The diameter of the valve $= \frac{1}{4}$ diameter of cylinder. The length of the steam-admission port = diameter of cylinder, and the width of the port, as for all ordinary engines of the slide-valve type, =

$$\frac{\text{area of piston in square feet} \times \text{piston speed in feet per minute}}{6000 \times \text{length of port in feet}}$$

The width of the exhaust port is made about $1\frac{1}{2}$ times that of the admission port.

Figs. 390 to 393 show Corliss cylinders in elevation and section

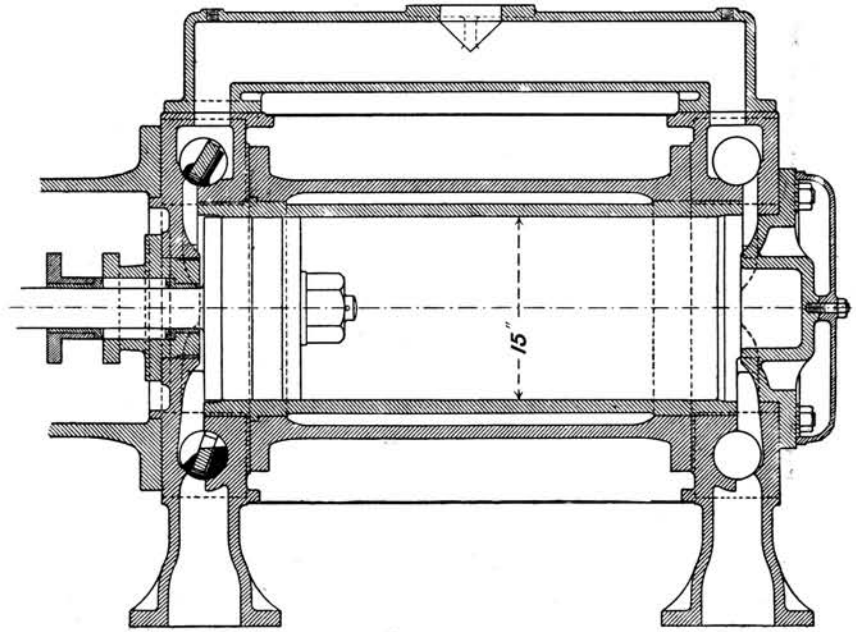

FIG. 392.

for a 15 in. × 28 in. × 36 in. cross-coupled compound engine, main bearings 9 in. × 16 in., running at 105 revolutions per minute, developing 340 I.H.P. as a regular load, and 425 I.H.P. with an overload, 160 lbs. boiler pressure, 26 in. vacuum.

Figs. 392 and 393 are longitudinal and transverse sections of the high-pressure cylinder; the low-pressure cylinder is of similar design, but of larger diameter, and is not shown.

The Corliss valve gear, shown in Figs. 390 and 391, has a double wrist-plate, one for operating the steam-valves and one for the exhaust valves. This arrangement allows the steam to be admitted with a suitable lead, and it provides a range of cut-off which may be varied from 0 to $\frac{5}{8}$ of the stroke. It also enables the compression to be adjusted to the varied requirements of the speed and load of the engine without interfering with the steam-admission arrangements.

We have already seen that with the ordinary single wrist-plate gear, driven by one eccentric, when we have a small amount of lead and moderate compression, the point of cut-off cannot be later than about $\frac{1}{3}$ of the stroke. But for smartly handling considerable changes of load with minimum change of speed, the ordinary single eccentric gear is not so good as the double wrist-plate gear.

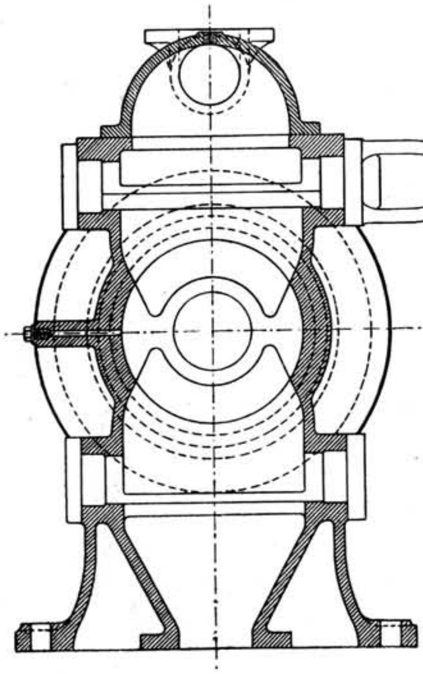

Fig. 393.

In the latest examples of Corliss engines for central-power stations, double wrist-plates are used on both high- and low-pressure cylinders, and the cut-off in both cylinders is regulated by the governor. By cutting off early in the low-pressure cylinder at light loads, as well as in the high, and by having a large receiver volume, the pressure in the receiver may be maintained practically constant and kept fairly high, by which means this storehouse of steam is instantly available for duty in the low-pressure cylinder to promptly take up any large increment of load that may occur at any moment, without any serious change of speed; whereas, in an ordinary engine with a small receiver and a cut-off on the high-pressure cylinder only, the steam in reserve for the low-pressure cylinder is practically nothing at light loads, and time would elapse before the low-pressure cylinder could help to deal with a sudden increase of load, and this would necessarily result in the mean time in considerable falling off of speed.

Details of Trip Motion (Fig. 394).—The trip arrangement consists essentially of four pieces: (1) the valve-driving lever A, keyed direct to the valve spindle C, and which carries a hardened steel block, B, on which the trip catch D engages; (2) the double-armed driving-lever EE receiving motion from the wrist-plate through rod J, and mounted loosely on the overhanging wrought-iron tube in valve

bracket, and which has a stud in the upper boss carrying (3) the hanging trip catch DD. The trip catch is arranged to fall in its place by gravity when the lever EE, on which it is mounted, moves into its extreme forward (anti-clockwise) position, and on the return (clockwise) stroke of the lever the catch then engages with the hardened steel block B on the valve-driving lever A, the effect of which is to move the valve on its own axis, C, and open the steam-admission port.

The catch is liberated by coming into contact with a detaching cam (4), marked F, which is formed on a ring working loose on the boss of the driving-lever, and having an extended arm, which is attached by a rod K to the governor. The upper arm of the trip catch DD is shaped to a suitable angle, and slides up against the detaching cam, F, by which means the hardened edge D of the catch is disengaged from the block B, the valve spindle is liberated, and the valve is immediately returned by the pull of the dash-pot lever M to its position of rest, closing and overlapping the steam-port.

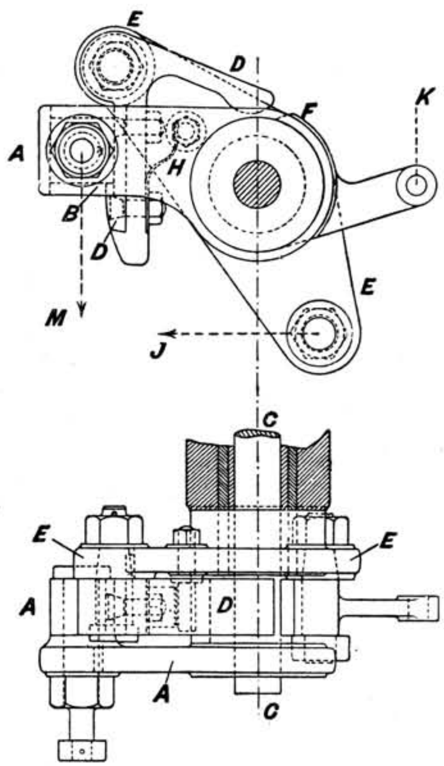

Fig. 394.

A supplementary spring, H, is placed behind the trip catch to assist gravity and to make engagement certain. The governing cam is moved as required by the governor through rod K, and it varies the point of cut-off by varying the position of the point of contact F from zero to the maximum capacity of the gear. The period of impact of the detaching mechanism is very short, and a moderately powerful governor is unaffected by it. The governor is free to move during the admission of steam, and can be made extremely sensitive, say within 1 per cent. variation.

The Dash-pot.—The function of the dash-pot is to return the steam-valve quickly and noiselessly when the governor releases the trip catch. The dash-pot piston is sometimes pressed down by atmospheric pressure, a vacuum being formed under the piston as it is raised by the valve-gear during steam admission. The dash-pot (Fig. 395) is controlled by a spring in preference to depending on vacuum. The speed of closing can be accelerated or retarded by regulating the air-escape plug A, which gives a less or greater compression of air as the escape plug is opened or closed.

The lower cover of the dash-pot holds in place two pieces of leather which form a pad or buffer, and finally bring the valve and dash-pot piston to rest.

The ball-joint is provided so that the connection between the pin in the steam-valve lever and the dash-pot piston can adjust itself to the line of least resistance, that is, the line of least friction.

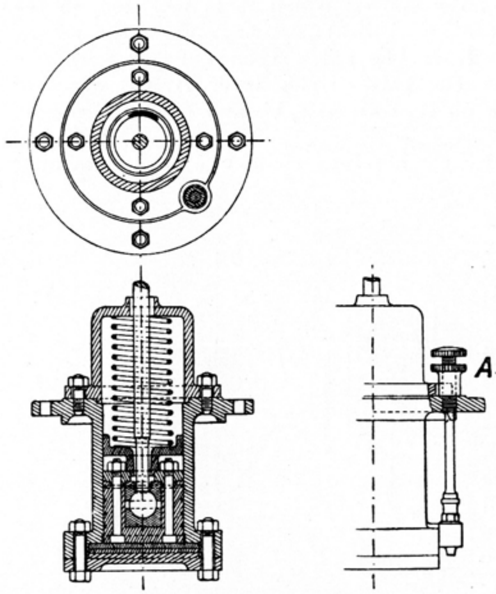

Fig. 395.—Dash-pot Details.

Fig. 396 shows an enlarged view of the air-escape plug.

The details of the other parts of the gear explain themselves.

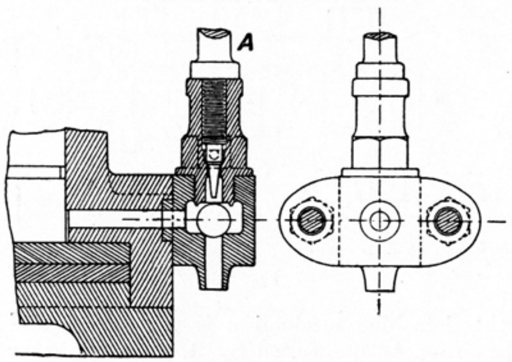

Fig. 396.—Dash-pot Details.

Diagram of Steam-valve Movements.—Fig. 397 shows a geometrical analysis of the movements of the steam-admission valve gear. Arcs A, B, C, and D represent respectively clearance movement of valve lever to effect engagement of trip with valve lever, steam-lap, lead, and admission.

The point of cut-off is determined by the governor, and the maximum is made as great as is consistent with the certain disengagement of the trip. The relation of crank-pin to eccentric is seen by following the successive positions of the periods A, B, C, and D from the valve-lever, through the top and bottom pins of the wrist-plate, to the circle of the eccentric path.

It will be seen that the eccentric has negative angular advance θ, that is, the eccentric has not moved through 90° from its extreme position when the crank is on the dead centre, but through an angle θ less than 90°.

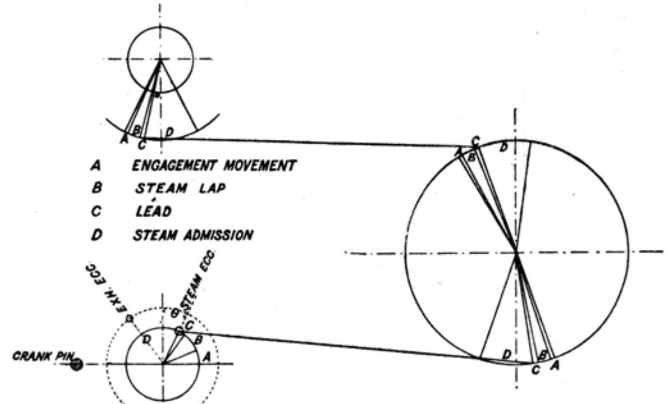

Fig. 397.

Diagram of Exhaust-valve Movements.—The theoretical indicator diagram, Fig. 398, is first drawn to decide upon the points of release and compression, and the respective position of these points is projected to the crank-pin circle below the indicator diagram.

Radial lines are drawn showing the crank positions at release and compression, that is, when the exhaust port opens and closes. If the angle between these crank positions be bisected, the crank position is obtained at which the exhaust valve is at the extreme end of its travel; in other words, this is the crank position when the eccentric is on the dead centre, or *vice versâ* it is the eccentric position when the crank is on the dead centre, and thus the relative positions of crank and eccentric are as shown in Fig. 398.

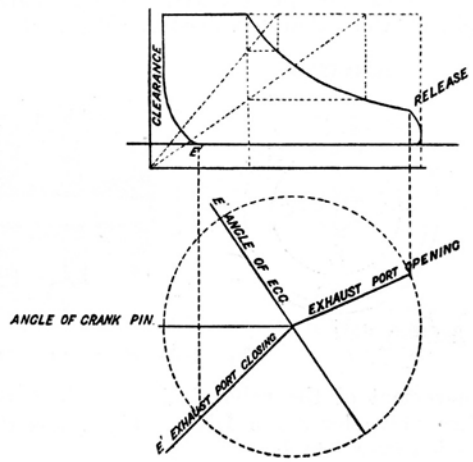

Fig. 398.

Fig. 399 is a diagram showing the respective positions of crank, eccentric, wrist-plate, valve-rods, and levers for the exhaust valve.

The circle of eccentric travel is first drawn on centre A, and the circumference divided into any number of equal parts numbered consecutively. These points are projected to the centre line, and with the length of the eccentric rod as radius corresponding points

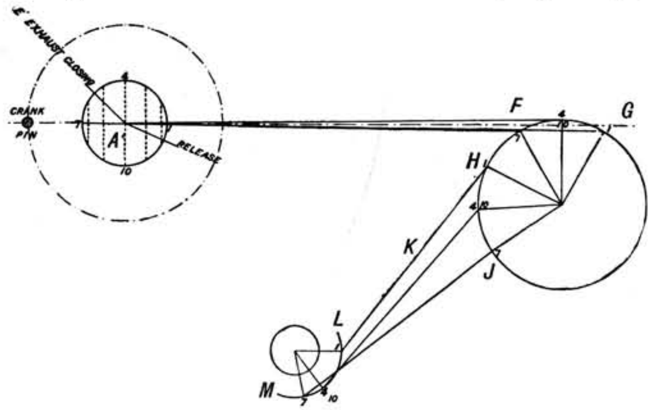

FIG. 399.

are transfixed on the travel arc FG on the wrist-plate. The distances thus obtained are then marked on the path of the pin HJ, and with the length of the exhaust valve-rod K as radius the movement of the exhaust pin on wrist-plate is marked off on the path of the pin of the exhaust valve-lever LM. It will be noticed that the

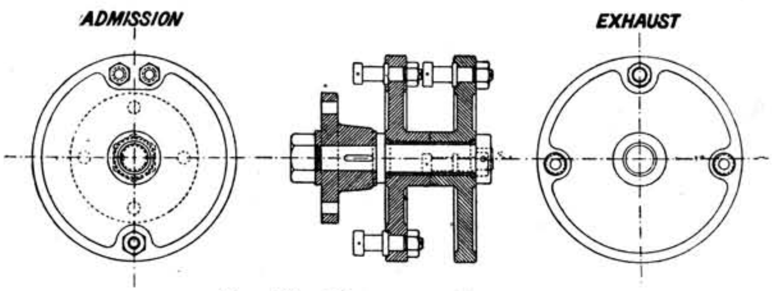

FIG. 400.—WRIST-PLATE DETAILS.

movement of the valve during the half-period from 4 to 7 position (see valve lever arc LM) is much less than that during the half-period from 1 to 4.

The pin on the vibrating lever from which the wrist-plate is driven is taken to represent the travel of the valve. The real travel of the eccentric is proportionately less, depending on the length of the lever connections.

Fig. 400 is a drawing of the wrist-plate details, showing the admission and exhaust wrist-plates on the same spindle.

Fig. 401 shows details of valve spindle gland and bracket. Fig. 402 shows in detail the adjustable head of the valve-rods.

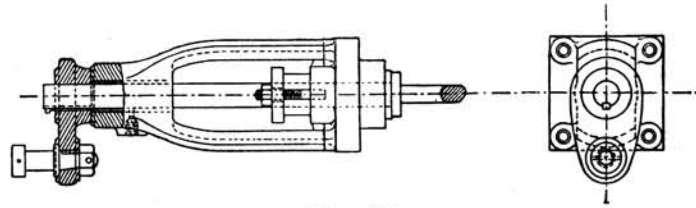

FIG. 401.

As an example of the performance of engines of the compound Corliss class, the following results are given from a test of a pair of

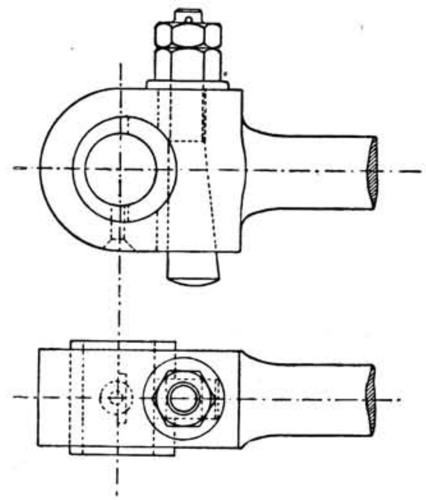

FIG. 402.

compound horizontal Corliss engines, made by Messrs. Hick, Hargreaves & Co., of Bolton.

Diameter of piston, high pressure	30 in.
" low pressure	56 "
Diameter of piston-rods	6 "
Stroke	5 ft.
Clearance of high-pressure cylinder	4 per cent.
Clearance of low-pressure cylinder	5 "
Diameter of air-pump	25½ in.
Stroke of air-pump	20 "
Diameter of air-pump rod	3½ "

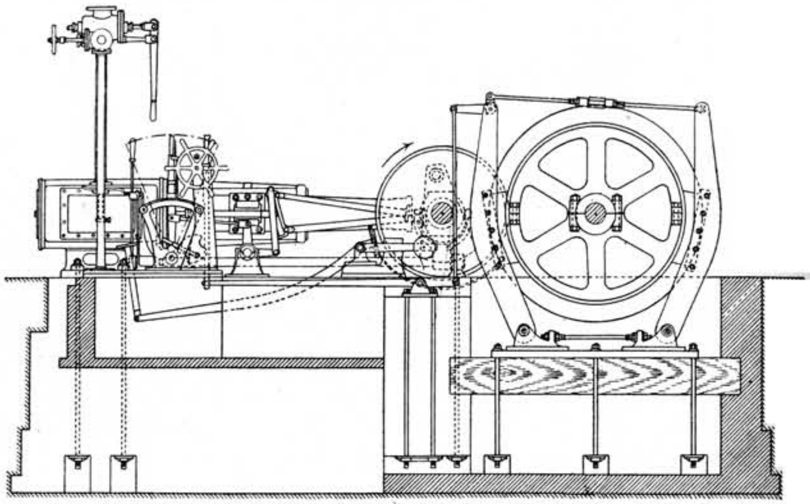

FIG. 403.

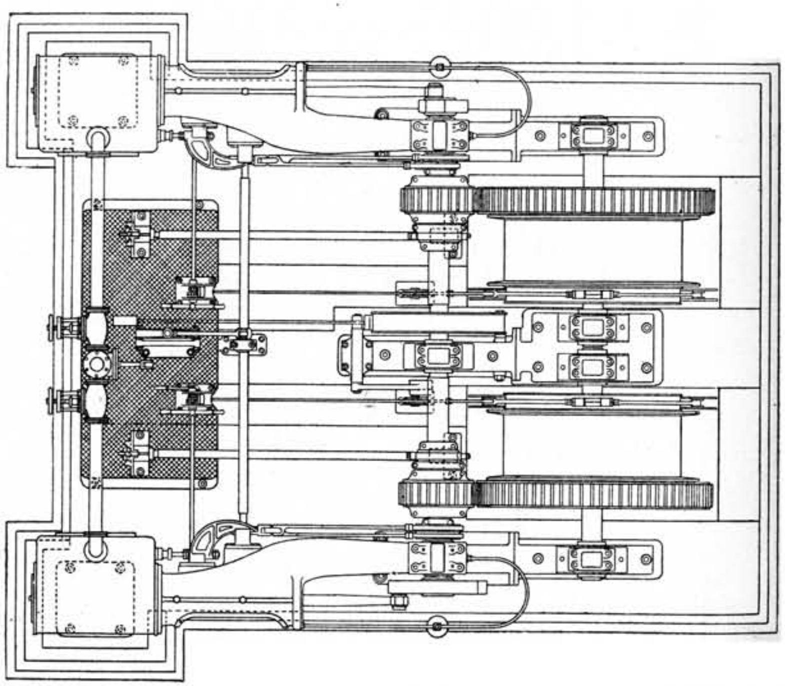

FIG. 404.

Diameter main steam-pipe	12 ins.
Flywheel diameter, grooved to receive 30 ropes ...	26 ft.
Volume of receiver between high-pressure exhaust valves and low-pressure admission valves ...	117·12 cubic ft.
Boiler pressure	112 lbs.
Piston speed	606 ft. per min.
Total I.H.P.	882·2
Dry steam per I.H.P. per hour	14·42 lbs.
Dry coal per I.H.P. per hour	1·74 „

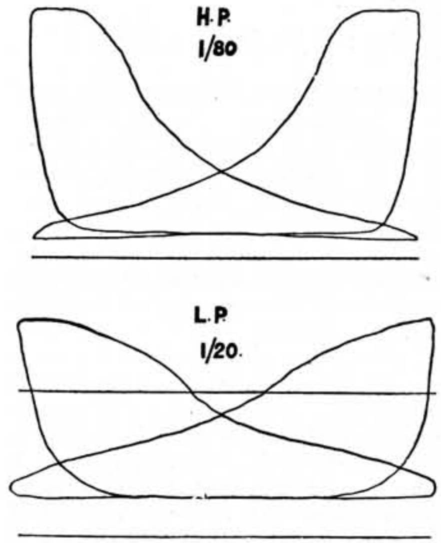

FIG. 405.

Fig. 405 gives reduced copies of the indicator diagrams.

Figs. 403 and 404 are the elevation and plan of a pair of 13-in. × 26-in. coupled geared winding engines suitable for sinking and winding in auriferous countries.