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RITCHIE AWARD PRIZE ESSAY

The Function of the Air and Circulating Pumps

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Of recent years engineers have evinced considerable interest in the improvement of the design and efficiency of the condensing plant. This may be attributed to the advent of the steam turbine and the very high vacuum required to obtain economical running with this type of plant. Another reason for this improvement is the more general adoption of condensing apparatus which nowadays is becoming more and more necessary and in some cases absolutely essential, as, for instance, in many modern power stations. These stations for many reasons are situated a considerable distance away from the towns which they supply and they consequently have a very limited supply of fresh water for boiler feeding purposes, in which case a condensing plant is installed, the amount of water then required being only that lost by leakage and other sources of waste. But even when a plentiful supply of water is available it seems that engineers are beginning to look upon the condensing plant more in the light of a necessity than as a refinement or an additional complication. Of course in considering the relation between condensing plant and locality the ease of obtaining the necessary circulating water has to be borne in mind, but there are so many various types of condensers, some of which require but a small amount of water per lb. of steam per hour that when used in conjunction with a cooling tower there should be little difficulty in obtaining suitable apparatus for almost any particular case.

With this cursory glance at the present aspect of the condensing plant we must leave the condenser out of the question and confine our remarks to the air and circulating pumps.

As the name suggests the air pump is used for exhausting the air from the condenser, but this is not its only function, for it also pumps out the condensed steam and water vapour. In the jet condenser, which is now almost obsolete, it not only pumped out the water condensed from the steam, but also the injection water. This placed the air pump of that time at a considerable disadvantage in places where pure and soft water was not available for use as injection, as, for instance, in marine work, where the boiler feed was taken from the hotwell. This water was practically as salt as the sea water which was used for injection, the sea water and the exhaust steam being in the proportion of about 30 to 1 weight. This to a great extent prevented the use of boiler pressures much above 30 lb., and it was also necessary to periodically blow off a portion of the denser water in the boiler so that it could be supplied with a fresh supply of sea water and so prevent the water in the boiler becoming saturated.

With the introduction of mild steel plates and improved methods of construction, higher boiler pressures became general, and the question of using fresh instead of salt water became a serious one. This led to the introduction of the surface condenser, the great advantage of which consists in its providing feed water free from salt in solution. This is effected by keeping the cooling water and exhaust steam entirely separate, but even with surface condensers air pumps are necessary, but they may be made much smaller than would be the case with a jet condenser of the same capacity, as a considerable amount of air is brought in with the injection water.

Air pumps are always of the reciprocating type and are usually vertical in action, even when worked by horizontal engines, as this type is found to be more efficient than the horizontal, which is usually of the double acting solid piston variety. A pump of this type is shown in Fig. 1, working with a jet condenser, the whole being of very simple design and construction. *C* is the condensing chamber and *SS* are the suction valves and *DD* the discharge valves, there being two of each

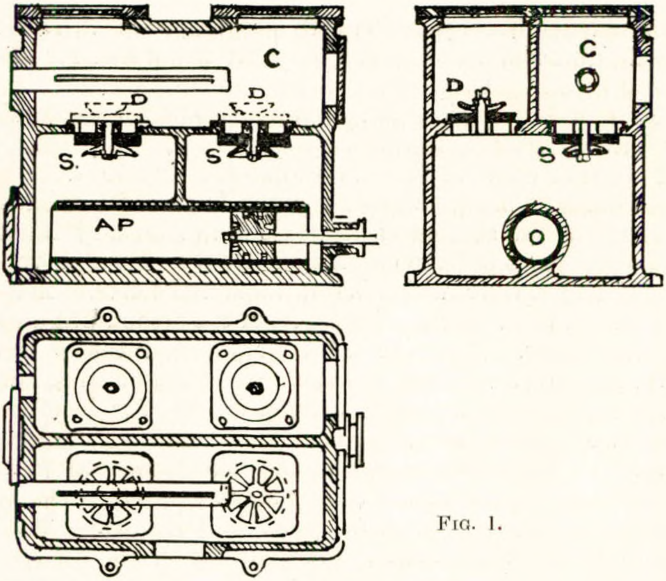
C
D
D
S.
S
AP
D
C
S

FIG. 1.

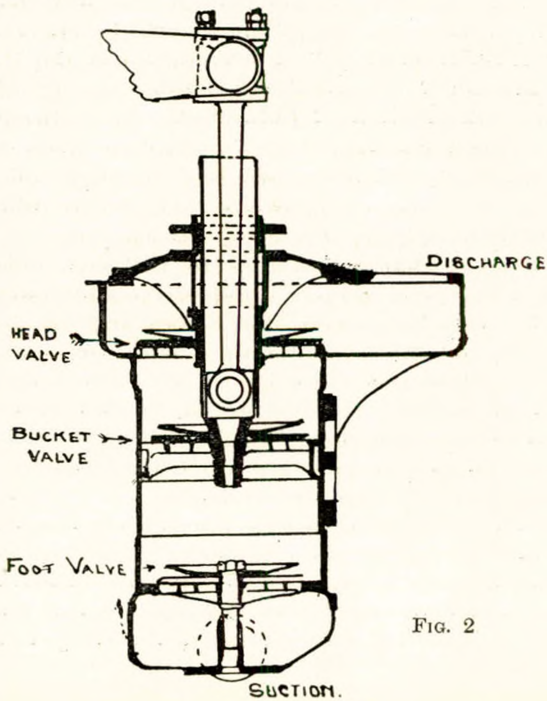
DISCHARGE
HEAD VALVE
BUCKET VALVE
FOOT VALVE
SUCTION.

FIG. 2

of the indiarubber type. The air pump, *AP*, is fitted with a gunmetal liner in which works the solid piston fitted with two rings of hemp packing. The next figure (No. 2) shows a vertical single acting bucket pump arranged for working from the L.P. crosshead of a marine engine.

The action is as follows :—On the up stroke of the bucket, *B*, a vacuum is formed in the pump chamber, *C*, causing the air and water to flow in through the foot valves, *F*, owing to the higher pressure in the condenser. On the down stroke the air and water are forced through the bucket valves, *A*, until the bottom of the stroke is reached, when the cycle is repeated and the contents of the pump discharged through the head valves into the hotwell ; at the same time a fresh charge is drawn in as at first explained.

Mention must next be made of the "Edwards Patent Air Pump," its distinctive feature being the absence of foot and bucket valves, head valves only being required. The pump is of the vertical single acting type, and the water flows by gravity from the condenser into the base of the pump, then on the down stroke of the bucket the water is projected silently through the ports in the pump barrel into the chamber above the bucket. The up stroke is now commenced and the bucket in rising closes the ports and discharges the air and water through the head valves. It will also be noticed that as soon as the ports are open there are clear air inlets, the water following immediately afterwards has the slight effect of an injector and so carries in more air than would otherwise be the case, thereby slightly increasing the vacuum.

Another point that contributes to the high efficiency of this pump is that top clearance is reduced to a minimum. This is obviously very important, for before any air pump can discharge, the pressure in the pump must be greater than that of the atmosphere, and consequently all air remaining in the pump is compressed. Now when the bucket descends the pressure is reduced and the air in the clearance water is given off and expanding occupies space which should really be available for a fresh supply from the condenser.

But efficient as is the Edwards pump there has, during the last few months, sprung up a tendency to fit very elaborate pumping equipment in turbine installations. This is due, as before mentioned, to the increased efficiency of the turbine with increased vacuum. In a paper by the Hon. C. A. Parsons, and

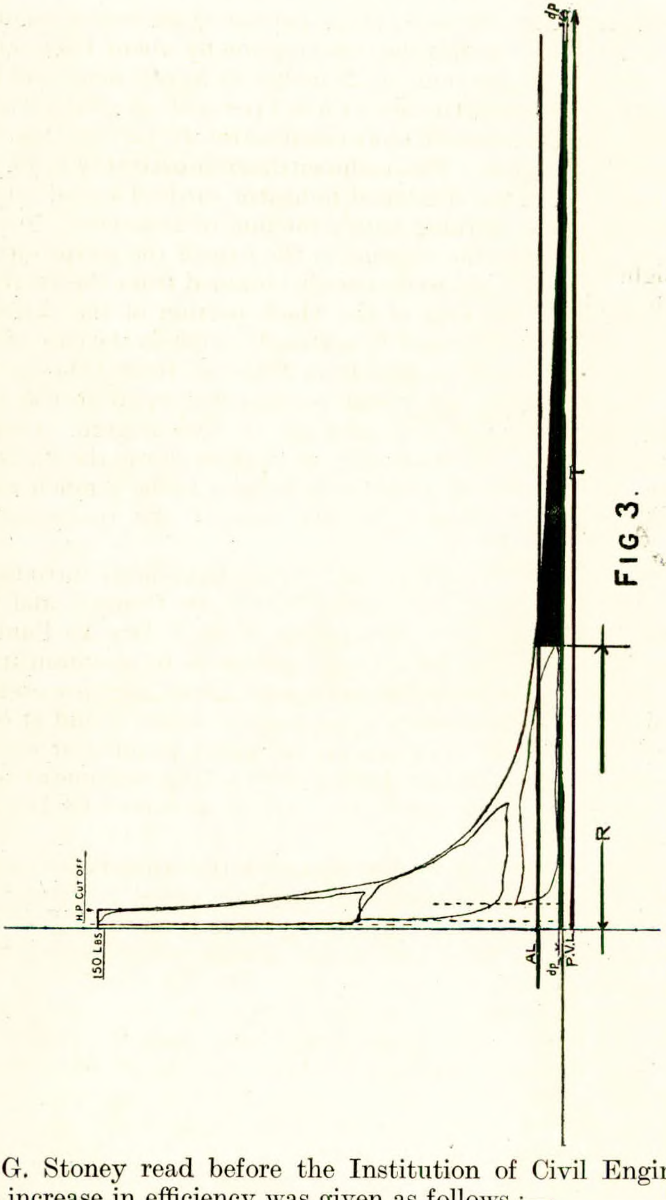

FIG 3.

G. G. Stoney read before the Institution of Civil Engineers the increase in efficiency was given as follows :—

"On a test of a 1,500 kilowatt turbine plant at two-thirds the normal output, the effect of an increase of an inch of vacuum at 26 inches is to diminish the consumption by about 4 per cent., at 27 inches by $4\frac{1}{2}$ per cent., at 28 inches by $5\frac{1}{2}$ per cent., and between 28 inches and 29 inches by 6 to 7 per cent. A good vacuum is thereby seen to be much more essential for the turbine than the reciprocating engine. This is shown diagrammatically in Fig. 3, which represents the combined indicator cards of a good triple-expansion engine, working with a vacuum of 25 inches. Now if we were to increase the vacuum in the case of the reciprocating engine to 28 inches, the extra energy obtained from the steam is represented by the area of the black portion of the diagram marked R horizontally and dp vertically, while in the case of the turbine an increase of vacuum from 25 inches to 28 inches would mean that extra energy would be obtained equal to the area of the strip of the black portion of the diagram marked dp as before but T horizontally, or in other words the $dp \times R$ portion produced to T which will be seen to be a much more considerable portion than in the case of the reciprocating engine.

To maintain this high vacuum there have been introduced two new appliances, namely the "Dry Air Pump" and the "Vacuum Augmenter." The object of the "Dry Air Pump" is not so much to obtain a good vacuum as to maintain it, as no matter how carefully the condensers, pipes, etc., are erected there is always the liability of air leakage which would at once mean loss of power, therefore an air pump running at a comparatively high speed and dealing with a large volumetric area was considered to be necessary, and so we have the Dry Air Pumps.

This pump works in conjunction with the ordinary air pump, on the suction side of which a large air vessel is fitted; the suction of the Dry Air Pump being taken from the top of this air vessel, and is fitted with a special valve which ensures that air and vapour only may reach the "Dry Air Pump." Under ordinary conditions the Dry Air Pump runs at normal speed, but should difficulty be found in maintaining the vacuum owing to a leak or other contingent reason the speed is increased until the original vacuum is obtained. A small quantity of fresh water is kept circulating in the pump for cooling purposes. The Vacuum Augmenter is connected between the air pump and the condenser and consists of a small steam jet placed in the contracted portion of a pipe which leads from the bottom of the condenser to a cooler. The jet draws the water from the condenser and through the cooler to the air pump, so reducing the air to a very small amount.

Before closing the subject of air pumps it is necessary to mention one or two of the different types of valves in more or less general use. At one time vulcanized indiarubber was used without exception, it being especially prepared to resist the action of the oils. When used for naval work the composition was as follows: Oxide of zinc 70 per cent., sulphur, $1\frac{3}{4}$ per cent., the remainder being best caoutchouc. But nowadays although often used indiarubber is rapidly giving place to metal valves, the best known type being the Kinghorn, shown in Fig. 4. These valves are made of thin phosphor bronze about $\frac{1}{32}$ to $\frac{1}{16}$ inch thick, there being three plates to each valve, one on top of the other, of gradually decreasing diameters. They are made to fit loosely on the guide spindle so as to be perfectly free to rise and fall, and it will be noticed that the two bottom plates have holes in them about $\frac{3}{16}$ to $\frac{1}{4}$ inch diameter, there usually being three to four in number drilled at different radii; this allows the valves to come back on their seats quicker and with less noise than would otherwise be the case. Another type of valve in considerable use is that known as the Beldam and which consists of a corrugated brass plate about $\frac{1}{16}$ inch thick with a valve guard corresponding in shape.

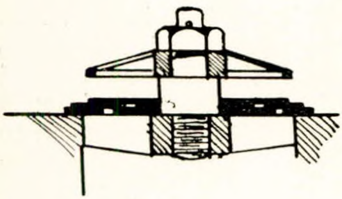

FIG. 4.

We now pass to the circulating pump, Fig. 5, which in marine work is either of the double or single acting piston type or the centrifugal pump. If the piston type of pump is fitted it usually forms part of the main engine, being driven by means of levers from the L.P. crosshead; but in a few cases it is independent, it then being of the direct-acting steam-driven type. Centrifugal pumps are always direct coupled to a high speed steam engine. The independent circulating pump has many advantages over the main engine driven type, for instance, when the main engines are stopped the independent pump may be kept going and so keep the condensers cool.

In many cases where the pump is worked off the main engines it has been found necessary to arrange connexions from one

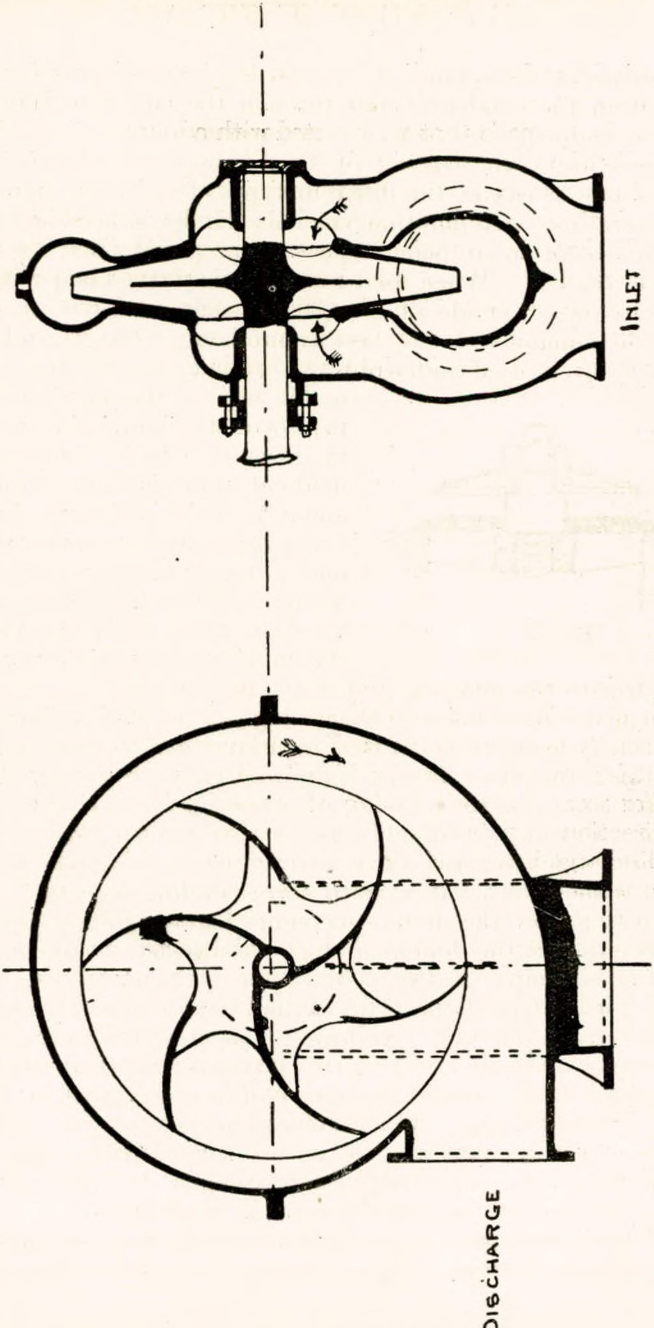

Fig. 5.

of the independent auxiliary pumps to the condenser for circulating when the ship is stopped. Another advantage of the independent type is that when fitted with a bilge suction, which is usually the case, they can be used to pump out the ship in case of emergency. The reciprocating type of pump may be either single or double acting and the stroke is usually about one half that of the main engines. The suction and delivery valves are of the same type as used in air pumps, being either of rubber or metal. The plunger is made solid and is nowadays fitted with water grooves in preference to hemp packing.

The work that the circulating pump is called upon to do is very light, there being usually no lift, as the discharge is almost always under water, so that we have only the friction of the pipes and the work required to keep the water in motion. Under such conditions the centrifugal pump is found to work admirably, it being specially adapted to deal with large volumes at small lifts. It has no valves and consequently there can never be dangerous strains put on the pumps or pipes, for should the discharge inadvertently become blocked, the impeller would simply churn the water. With such points as these to recommend it we cannot wonder that it is rapidly gaining favour on both land and sea.

The pump is very simple, consisting as it does of an impeller mounted on a shaft which is directly coupled to the shaft of the engine or motor from which it obtains its power. This impeller works inside a casing of gradually increasing area in the direction of rotation. In this casing are cast the suction and discharge branches. The water enters the impeller at the centre, either from one or both sides, the latter being almost always the case. Should, however, the water enter from one side only, it sets up an unbalanced axial thrust on the wheel, which must then be taken up by means of thrust collars. The impeller is made of brass or gunmetal to resist the action of the water, and consists of two side plates, tapering from the centre to the extreme radius, between which runs a central rib to guide the water into the vanes which are cast between the side plates and extend from the boss to the circumference.

These vanes are curved away from the centre in the opposite direction to rotation and are designed so that the water enters the impeller with the least shock. The shaft on which the impeller is mounted is made of gunmetal or steel cased with gunmetal, the impeller being keyed on. There are two bearings, one at either end fitted with lignum vitae bushes which are lubricated by the water. At the end of the outside bearing there is fitted a brass cap, the impeller shaft not passing right through. This ensures water tightness. The inside bearing is, however, more complicated, as in this case the shaft passes right through; it is therefore necessary to fit the bearing with a gland and stuffing box, sometimes a gunmetal bush is fitted inside the gland to take the wear.

This bush is split to allow of renewal without taking out the shaft. The casing is made either of cast iron or gunmetal, being divided at the centre to admit of fitting the impeller.

The pump to work efficiently must not contain any air, as this seriously interferes with its working; therefore they are always fitted with an air cock at the top of the casing which is connected to a condenser or air pump chamber so that they may be exhausted at starting. When there is no air pump or condenser available from which to obtain the necessary vacuum, a small ejector is fitted on the top of the pump and connected to the steam valve of the driving engine. Then by simply turning on the steam we can easily exhaust the pump of any air it may contain.

For land installations the air and circulating pumps are often cast together in the form of an oblong box, there sometimes being as many as three air pumps and one circulating pump in the same casting. This conduces to rigidity and compactness. Another point noticeable in modern designs is that the electric motor is becoming the favourite method of driving these plants where current is available. In conclusion we think that as far as efficiency is concerned the present day air pump leaves very little room for improvement, as I have to-day had the pleasure of seeing an Edward's double-acting air pump working at a vacuum of 29·5 inches of mercury by the mercury gauge, the barometer at the time standing at 29·8 inches.