STEAM CONDENSING PLANTS.

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The subject of Steam Condensing Plants is recognised by Engineers as representing one of the most important questions to be discussed when considering the general lay-out of an up-to-date power plant. It is one that is always open to exhaustive argument, but the limitation of time will prevent the author dealing with more than a description of the various types of Condensers which constitute, and are accepted, as embodying high-class modern practice.

Before commencing to deal with the question as presented to us to-day, it is interesting to note that condensation, in the earliest known commercial engine, was obtained by surface cooling, that is by a jet of water flowing over the exterior of the pressure cylinders. A short time after, better results were obtained by the injection of a jet of water directly into the steam space, and at the same time an attempt was made to lessen the losses due to contact of the steam with the surface of the water to be raised.

Newcomen found the principle already practically employed, but he adopted methods whereby the power, represented by the atmosphere, could be utilised in a manner far more efficiently than his predecessors had done.

In Newcomen's engine, the cylinder of the pumping engine itself formed the vacuum chamber, the engine being single acting, and the power for lifting the water was derived from the atmospheric pressure upon the piston area, the suction stroke being effected by the weight of the pump rods, supplemented, if necessary, by weights hung on the beam of the engine. The alternate heating and cooling of the steam cylinder by the foregoing method resulted in very heavy steam consumption, and with a view to reducing this Watt invented the separate condenser, and at the same time provided a pump to withdraw the air which came into the condenser with the steam and the cooling water. It is interesting to observe that the first experimental model

made by Watt was fitted with a tubular surface condenser, and the principles he laid down in 1769 are those that are still largely adopted by Engineers.

Fig. 1, gives an illustration of Watt's experimental apparatus.

The Condenser consisted of two tubes 10in. or 12in. long, and about one-sixth inch diameter, connected at the top to a short horizontal pipe of large diameter, which communicated with the steam cylinder, and at the bottom to the air pump, the whole being immersed in a vessel containing cold water. Later, Watt found it more convenient to change the tube condenser for an empty vessel, into which was directed a jet of water, and also to enlarge the air pump to enable its dealing with the increased volume
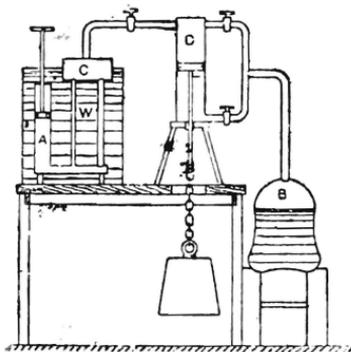

FIG. 1.

D being the Steam Cylinder.
C the Condenser.
A the Air and Water Pump and
W a water tank in which the Air Pump and Condenser were immersed.

of air and water to be displaced. This was the first introduction of the jet condenser, and, as before stated, engineers of later years have followed so closely along the lines laid down by Watt, that there are in England to-day quite a number of efficient mill engines, of considerable power, working with jet condensers of almost identical construction with that of the original inventor.

It is not uncommon to hear the statement put forward that condensing does not pay, or cannot be considered,

because of scarcity of cooling water, but where space can be found for the erection of a cooling tower or cooling pond the question of water supply is not of prime consideration inasmuch as it is only necessary to provide sufficient water to make up for the loss by evaporation and the various leakages in the cooling system. This loss will be found to be less than the amount required for the engines working non-condensing. Cooling towers or ponds undoubtedly add to the initial cost of an installation, but generally taken, it will be found that the saving effected by condensing will more than counterbalance the cost of the auxiliary plant, even including the cooling system, and most engineers recognise the necessity of adopting nowadays every means whereby working expenses may be reduced.

Previous to the introduction of high speed engines, the pumps forming a part of the condensing plant were direct coupled to the main engine, and little note was taken of the power required by the condensing plant. Guarantees asked for by purchasers were generally confined to the steam consumption per indicated horse power of the whole installation, but with the introduction of independently driven condensing plant it naturally resulted that the power required to operate this section became a separate condition of the contract, and thus more attention has been given to improvements in design with the object of reducing this, amongst other items. For low speed engines it is undoubtedly more economical to operate the pumps direct from the main engines, given always that the pumps and condenser are of equally efficient design; and while this paper deals entirely with condensing plants independently operated, it will be apparent that as regards detail of design and construction most of the points are applicable to plants of the direct or attached type.

In all references to vacuum readings in this paper, a barometric pressure of 30 inches of mercury is assumed, and all figures are given in inches of mercury.

It is generally argued that so far as reciprocating engines are concerned, there is little to be gained by working at a higher vacuum than 26 inches, it being claimed that if the vacuum is improved beyond this, then the small saving effected is neutralised by the reduction in the temperature of the feed water; but it is the writer's belief that this

saving can be more than made good by the use of exhaust steam from the auxiliaries, such as feed pumps, which will often supply more heat than the feed water can utilise. And it must be remembered that such exhaust is generally heavily charged with oil, as compared to the main exhaust, and for that reason alone is well worth keeping apart.

Steam turbines differ from reciprocating engines inasmuch that they are particularly suitable for utilising the energy in steam at a very low pressure, and a high vacuum is therefore essential to their economical working, but even with turbines there is a limit point which depends upon the temperature of the cooling water, and the head against the circulating pump.

TYPES OF CONDENSING PLANTS.

Steam Condensing Plant may be divided into two distincе types—"Surface," where the steam and cooling water is separated by a tube or plate, and "Jet," where the steam and water necome intermixed. These may again be divided into two types, counter current or contra flow and parallel current. The former is the type now generally adopted, owing to its greater efficiency. The evaporative type of surface condenser is also worthy of note, although it has many features of an undesirable nature that prevents its more general adoption. There is also the ejector or barometric type of jet condenser without air pumps, which, while simple and low in first cost, cannot be accepted as being very renable owing to their becoming very unstable if, when in action, an air leakage takes place in the system. The writer proposes, therefore, to confine his remarks to the following:—

1. Surface Condenser "old type."
2. Surface Condenser, counter-current "new type."
3. Evaporative Condensers.
4. Counter-current Jet Condenser.
5. Barometric Jet Condenser.
6. The Ljungstrom Surface Condenser.
7. Aero Condenser.
8. Cooling Tower.

Of the foregoing the surface type is more generally used, and though its initial cost is higher, it possesses many advantages, chief amongst which are the following:—

1. In localities where the water available is not suitable

for boiler feeding, the larger part of the condensed steam can be recovered and used again for the boilers. It is often found necessary in such instances to provide some method of extracting the oil carried over by the exhaust steam, before the same enters the condensers, as an oil deposit on the condenser tubes not only reduces the heat transmission, but also proves a dangerous element, when, mixed with the condensed steam, it finds its way into the boilers per medium of the feed pumps. These remarks apply more particularly where reciprocating engines and water tube boilers are in use, and it is a matter of surprise that engineers, generally speaking, pay scant attention to this question of purifying or cleaning the exhaust steam. It is not at all a difficult question to solve, and from personal experience the writer has found that an efficient oil separator placed on the exhaust steam main between the low pressure cylinder and the condenser will not only practically remove the whole of the oil, but enable the same to be recovered, and after filtration used again in the steam cylinders.

2. It is possible to keep a record of the consumption of steam by the main engines, or turbines, by measuring the quantity of water discharged by the air pump, and with an apparatus such as the "Lea" Recorder the engineer in charge is at once able to determine whether his plant is developing its power on the correct consumption of steam.

3. The surface condensing plant generally requires less power for operating than other types, especially when the circulating water is obtained from such a source as will permit of syphonic action being employed. With a river or harbour subjected to tidal influence, the end of the circulating discharge pipe should always be below water level, and syphonic action can then be taken advantage of with a consequential head on the suction side of the circulating pump.

A very popular type of surface condenser, with direct acting circulation and air pumps respectively, is that in which the surface condenser is placed immediately above the pumps, and it may be of either circular or rectangular pattern. The steam cylinders for operating the pumps are placed in the centre, and are actuated by the valve motion so well known to all engineers. This type of condenser

has, in the writer's opinion, little to recommend its adoption, excepting low initial cost. The maintenance of both air and circulating pumps is heavy, and the efficiency of the plant as a whole is not high. It will be easily recognised that with the pumps operated on this system the steam consumption is necessarily heavy, especially in cases where the circulating water has to be pumped against any appreciable head, thus requiring a fair amount of pump horsepower, and while the writer is unable to give any authentic data on the point, it appears to him extremely doubtful if any advantage, beyond the reclamation of the condensed steam, is to be gained by the adoption of this type, that is, where the consumption of steam to operate the pumps is taken into consideration. In the early days of the goldfields in W. Australia, a large number of these plants were installed, but this was largely due to the fact that at that time steam condensing so far as the goldfields were concerned was in its infancy. And, as fresh water for boiler feed could only be obtained at prices ranging from fifteen to twenty-five shillings per hundred gallons, the buyer was only too ready to accept a machine which the clever salesman claimed would prove a solution of all troubles, so far as shortness of fresh water for boilers was concerned. Furthermore, the cost of all kinds of machinery was extremely high, and there was a natural tendency to purchase such plant that compared more than favorably in price with other systems that were higher in first cost. As is too often the case in condensing plants, many installations were made without a full knowledge of local conditions, and results obtained with the early condensers were far from satisfactory. This was often due to a desire on the part of the purchaser to buy something cheap, and so plants were installed that were considered "just big enough," with the inevitable result that upon starting up it was found a difficult matter at times to obtain 15in.; and except in those cases where mines could afford to allow the circulating water to run to waste, this vacuum became quickly reduced as the temperature of the water increased and the scale began to form on the condenser tubes. It must be remembered that in many instances, the circulating water carried as much as 8oz. of solids to the gallon, and where water was not too plentiful the density rapidly increased, as eva-

poration took place, and naturally these conditions resulted in a very high hot well temperature. As in the type of condenser under review the air pump valves were invariably made of vulcanized rubber, the life of these valves was very short indeed, and it became extremely difficult to maintain anything like a decent vacuum. When, added to the foregoing conditions, the circulating water was often only available at a temperature as high as 95°, it must be evident that under such conditions it would probably be cheaper to run non-condensing, and recover the exhaust steam per medium of aero condensers. It may be interesting to mention that the cleaning of the condenser tubes under the foregoing conditions is a considerable item. One method adopted was to carry on hand a spare set of tubes which, between week ends, were cleaned by being bored through by hand with a tool shaped like an auger bit. The clean tubes were placed in position on a Sunday when the plant was shut down for general overhaul, and by this means the condenser was kept in commission through the week. If sufficient care be taken no damage need result to the tubes when cleaning them as described, and the writer does not remember a single instance of a punctured tube resulting from this process which, while tedious, need not necessarily be expensive, inasmuch as the engine drivers have ample time to perform the work while on their usual weekly shifts. An apparatus for performing the above work is now procurable in the shape of a rotary pump which pumps a 30 % solution of commercial hydrochloric acid through the condenser tubes, it being claimed that the acid will effectively dissolve the lime deposits and leave the tubes perfectly clean. After the tubes have been so treated, it is necessary to thoroughly sluice the condenser with clean water before putting it under duty again.

In this, which the writer would name the "old type" of condenser, the circulating water passes twice only through the tubes, and no provision is made for breaking up the exhaust steam when it enters the condenser.

Beyond stating that this type fills a place where low cost is a first consideration, and efficiency a secondary matter, it deserves very little thought when deciding the best system of condensing to adopt.

A well known type of surface condenser is that built by W. H. Allen, Son & Co., with three throw "Edwards" air pumps, and circulating pumps driven by independent motors. This arrangement is advantageous where the motors are of the direct current type, as the speed of the pumps can be regulated to suit any varying condition of steam, load, temperature, and head against the circulating pump.

Browett, Lindley, & Co., Ltd., build a plant in which the air and circulating pumps are driven by one motor. This arrangement proves satisfactory where the load conditions remain constant; it is somewhat cheaper in first cost, and is an easier drive for the motor, especially when starting up. It will be recognised that when starting most forms of reciprocating air pumps, there will be atmospheric pressure on the condenser side, and a higher degree of vacuum on the opposite side of the piston or plunger, and that as the vacuum is produced in the condenser the pressure on the two sides of the piston will become more equalised, therefore the maximum torque will occur on starting up and will gradually diminish as the vacuum in the condenser rises. With a centrifugal circulating pump a minimum torque is required at starting, gradually increasing until the full load is reached, thus permitting of the two conditions equalising each other.

For average capacity surface condensing plants, the "Edwards" design of air pumps is recognised as being the best. It is exceedingly simple and can be relied upon; has a good capacity, and will give as high a vacuum as any other type, excepting perhaps, the two stage dry slide valve pump. The power required for operating it is also lower than that of many other designs.

Whilst it can also be driven at high speed, and, as before stated, has a large capacity, the ports or openings allowing of easy entrance. The pump is always of the vertical type, with one or more barrels, and is placed so that there is a fall in the suction pipe leading to it from the condenser. The outer casing of the pump is usually of cast iron, the valve seating, valve guards, and bucket piston being of gunmetal, the rod and nut of bronze, and the valves of the "Kinghorn" type. As the vacuum in the air pump will always be higher than that in the condenser, it is important that the temperature of the water entering the air pump be kept as low as possible, otherwise re-evaporation will take

place in the clearance spaces of the pump. In the "Allen" condenser it is arranged that a number of the lower tubes in the condenser are kept submerged by a layer of water from the condensed steam which falls from the tubes above, so that the water resulting from condensation of steam is cooled by the incoming circulating water before entering the air pump. It is claimed that the resulting vacuum is increased by $\frac{1}{2}$ inch to $\frac{3}{4}$ inch of mercury by this device.

The clearances in air pumps should be kept as small as possible, and all glands and possible sources of air leakage should be water sealed, thus assisting in diminishing the tendency for air to leak inwards and at the same time providing an easy method of tracing any leak that may occur at one of these places. When it becomes imperative to work air pumps at high speeds, the lift of the valves should be as small as possible to ensure quick closing, thereby improving the volume co-efficient of the pump. It is also advisable to provide a water seal above the valves of from three to four inches, but this depth must not be exceeded, and in cases where the water discharged from the air pump cannot be arranged to flow away by gravity, an additional pump should be provided for the purpose of removing the water and thus relieve the air pumps from discharging against a head additional to the atmospheric pressure. Air pumps arranged to work against additional heads are not to be recommended.

With regard to the capacity of this type of pump, the following figures are given by the Edwards Air Pump Syndicate. The conditions assumed as a basis for the figures are for separate units, the barometer standing at 30 inches.

Vacuum	Air pump displacement per pound of steam condensed.
25in.	0.5 Cub. ft.
26in.	0 6 ,,
27in.	0.75 ,,
28in.	0.9 ,,

These capacities are for surface condensers and are often increased where several engines are exhausting into one condenser and the air leakage is consequently likely to be greater.

Fig. 2, snows a section through the air cylinder and valve chest of a dry air pump. The inlet of the air to the cylinder is controlled by the mechanically operated slide valve, and the ports are so arranged that
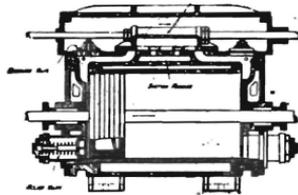

FIG. 2.

when the piston reaches the end of its stroke communication is made between the two ends of the cylinder, thus allowing an equalisation of pressure. The air discharge is controlled by voluntarily opening valves arranged in the cylinder ports.

Fig. 3 gives a sectional arrangement of the "Leblanc" rotary dry air pump, which consists primarily of a reversed Pelton turbine wheel in conjunction with an ejector. Sealing water is introduced through the branch
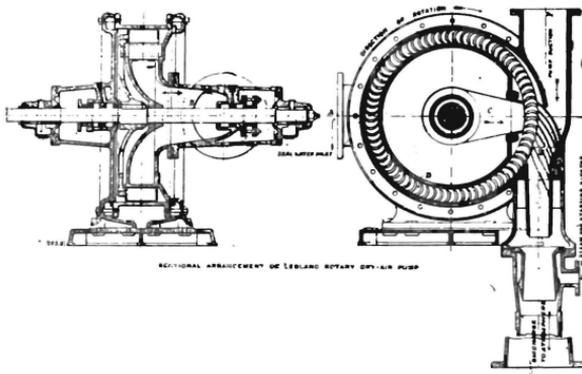

FIG. 3.

A into the central chamber B, from which it passes through the port C. It is then caught up by the blades D of the Pelton wheel, which is running at a suitable speed, and ejected into the discharge cone E, in the form of thin sheets

having a high velocity. These sheets of water meet the sides of the discharge cone and form tight water pistons, which entrap the air and incondensible gases coming from the condenser through the suction pipe F, and carry them out against atmospheric pressure. It is claimed that the sealing water in passing through the pump is not increased in temperature to any appreciable extent, and may be used over and over again, or it may be passed through the condenser as circulating water without lowering the efficiency of the plant. There is no doubt that this form of air pump is very attractive to engineers, especially those in charge of turbine stations, on account of its simple rotary motion, being especially suitable for direct coupling to either a high speed engine or electric motor. Foundations and space required are reduced to a minimum, and maintenance is low; but it is doubtful if this type of pump can compare in air displacement efficiency with a well designed reciprocating pump. Even under the best conditions with a minimum quantity of air in the condenser it would appear that the rotary air pump as at present developed will take considerably more power for driving than the reciprocating pump, while should extra air leakage take place the vacuum will fall much more rapidly with a rotary in comparison with the reciprocating type. It is not uncommon when this type of rotary air pump is used to find it necessary to water seal the flanged joints of exhaust pipes, but this, however, is an extreme refinement, and only resorted to where the pumps have a very low air capacity. It is of interest to note that rotary air pumps have been installed in England in conjunction with plants handling from 3000 to 85,000 pounds of steam per hour, and this fact is sufficient to show that the pump has already found many supporters.

Circulating pumps are either of the reciprocating plumger (or piston) or the centrifugal type, and both designs are so well known as to call for little, or no explanation. There are still many advocates for the reciprocating circulating pump, owing to its greater overall efficiency and thorough reliability, but as against this, the high duty centrifugal type has of late years been brought to such a high state of efficiency that it seems probable in a very short time the

reciprocating circulating pump will have to give way to its. cneaper and simpler opponent.

It is usual to allow from 40 to 50 lbs. of circulating water per pound of steam to be condensed, but this is largely determined by the temperature of the cooling water, and the vacuum it be desired to obtain.   Where the initial temperature of the cooling water is high, say 80° Fah., the quantity required per pound of steam condensed will often reach as high as 60 lbs., and even with this increased quantity a liberal allowance of cooling surface in the condenser and air pump displacement respectively will need to be provided.

In recent years a considerable amount of attention has been given to improvements in the design of surface condensers, the chief aim being to obtain a high rate of condensation per square foot of tube cooling surface. Obviously tue most efficient condenser will be that in which each square foot of surface transfers in a given time, all other conditions being equal, the largest number of heat units from the steam to the water. This will be the condenser which not only registers the higher vacuum, but will maintain it at the least cost of condensing or circulating water, and with the smallest surface and cubical capacity per pound of steam condensed.

To obtain these results it is necessary that the steam should have free and intimate contact with the whole of the tube surface on the one side, and that the circulating water shall come into direct and efficient contact on the other side.   If these conditions are to obtain, it is evident that special arrangements should be made to prevent the incoming steam missing contact with any appreciable amount of cooling surface, and further, that as the greater amount of condensation takes place in the upper portion of the condenser, the condensed water provided thereby must be prevented from covering, even intermittently, the lower batteries of tubes on its passage to the suction of the air pump.   On the water side it also becomes apparent that if the circulating water is permitted to flow through tubes of large diameter, there will be a considerable amount of water which will pass through the cores of the tubes without doing useful work, leaving it to the water travelling near the surfaces of the tubes to collect from the steam the heat units

necessary to ensure condensation. Any system that will obviate the abovementioned difficulties must result in several economies.

In the first place, the greater the efficiency of the cooling surface, the less quantity of circulating water required per pound of steam to be condensed. This, in land installations, often means a considerable saving in the amount of money spent annually in purchasing water. Again, less water will need to be pumped, resulting in a further economy in pump horse power which, at times, is a considerable item when cooling towers or other artificial
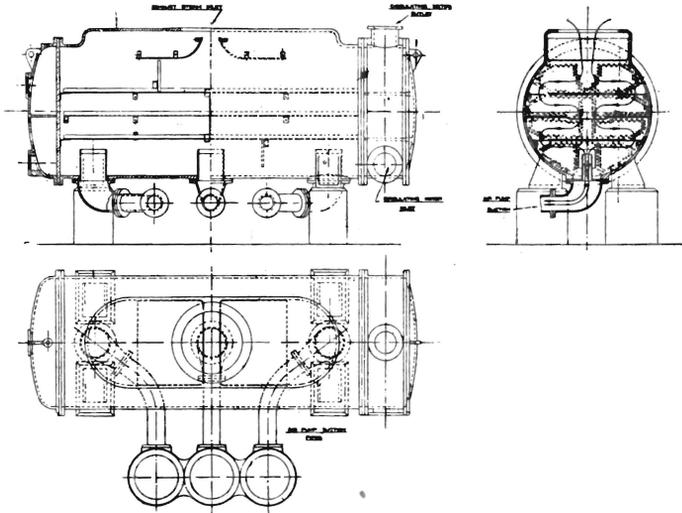

FIG. 4.

means are employed for reducing the temperature of the water. Another advantage to be gained by the condenser so designed is that its first cost should be considerably less than that of its more bulky competitor, while the saving in space occupied is an important point not to be overlooked.

To obtain the maximum rate of condensation per square foot of cooling surface many means have been adopted, chief amongst which are as follows:

Contra Flow, or counter current surface condensers, are those in which the exhaust steam entering through a

rectangular opening, preferably extending the full length of condenser, is made to circulate transversely through the various nests of tubes, the condensed water being withdrawn from the bottom of the condenser by the air pumps.

Fig. 4 shows a condenser built on this system by W. H. Allen & Co., and it will be observed that special provision is made for an even flow to the air pumps by means of the three outlets to same.

Directing Plates.—Many authorities contend that the advantage claimed for the contra flow system may be obtained by the introduction of directing plates at the steam inlet, for the purpose of distributing the steam evenly over the tube surface.   Against these baffle plates, it is argued that their introduction interferes with the velocity
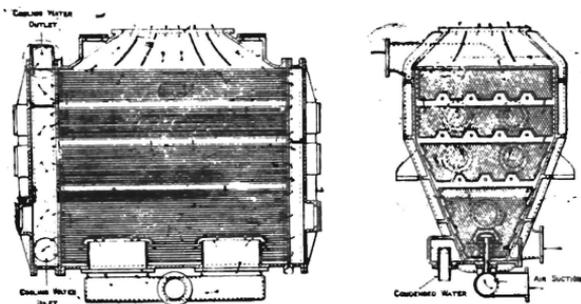
DIRECT FLOW TYPE SURFACE CONDENSER.

FIG. 5.

of the steam, which could be utilised in sweeping the condensed water off the surface of the tubes, thereby adding to their efficiency.

Fig. 5 gives a sectional illustration of what may be called the Direct Flow Type Condenser, the circulating water in this instance traversing the length of the condenser four times, the tubes being divided into four groups by means of partitions in the condenser ends.

Compartmental Drainage.—This system has for its object the removal of the condensed water from the tubes immediately it is formed, thus preventing films of water intervening between the steam and the cooling tubes. It has also the further advantage of permitting the condensed water being conveyed directly to the air pump at a

*h*igh temperature, resulting in a higher hot well temperature.

Professor R. L. Weighton carried out a series of exhaustive tests at the Armstrong College, Newcastle-on-Tyne, the results of which proved conclusively that "compartmental drainage" has much to recommend it. From a paper read by Professon Weighton, before the Institute of Naval Architects, it was learned that the tests, which extended over a considerable period, consisted mainly in comparing the efficiency of the old type of surface condenser with that of the new, or one provided with compartment drainage. The "old type" had a total condensing surface
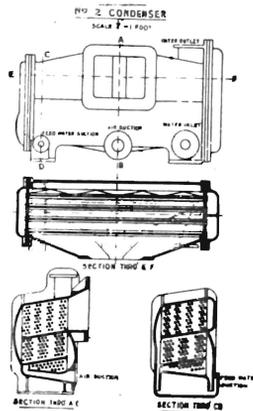

FIG. 6.

of 170 sq. feet, tubes ¾in. external diameter by 4 feet long, the water circulating through them twice, giving an effective length of 8 feet.

It was found necessary to construct no less than three of the "new type" of condensers, the first one containing 170 sq. ft. of surface and tubes of the same length and diameter as in the "old type," but in this case the circulating water was made to circulate five times through the tubes, thus giving an effective tube length of 20 ft. This condenser proved too large for the maximum quantity of steam the engines could take, and No. 2 was made contain-

ing only 100 sq. ft. of surface and having tubes $\frac{3}{8}$in. diameter by 4ft. long, 1in. pitch.   In this condenser the water circulated four times, giving an effective tube length of 16 ft.   This condenser is shown on Fig. 6, which will suffice to illustrate the new type generally.   On tests this condenser was found to be more than ample for the steam available, and a still smaller condenser was built of exactly the same transverse section as No. 2, but with tubes only 2ft. 6in. long and a total surface of 62 square feet, the water circulating four times through them, giving an effective tube length of 10ft.

It will be noted that the condenser is divided into three compartments by two diaphragms somewhat inclined to the horizontal, and the water of condensation in each of the three compartments is drained off directly from that compartment, so that the surfaces in the lower compartments are unimpeded in their condensing action by water from the upper compartment flowing over them.

The number of individual trials made amounted in all to some 400.   The results of these trials may be briefly summarised as follows:—

Condensers.	Surface in square feet.	Steam condensed per sq. ft. per hour in pounds.	vacuum in inches.	Condensing water per lb. of Steam (Tem. 50 F.)
Old Type Condenser	170	10	28	43
No. 2 New Type ,,	100	20	28	24
No. 3 ,, ,, ,,	62	23	28	32

The enhanced thermal efficiency of the new type as compared with the old type is due to the method adopted in the former for removing the water of condensation as soon as possible after it is thrown down from the steam, thus preventing its trickling over the comparatively cold tubes towards the bottom of the condenser.

Tests were also made with the use of tube cores, thereby reducing the quantity of water that generally passes through condenser tubes without doing useful work, and the results went to show that the smaller the diameter of tube employed the more effective it became.   This is a point in condenser design which must be largely governed by local conditions, for where water likely to deposit incrustation has to be used for circulating purposes tubes having a small cross sectional area would be sure to give trouble,

Where good clean water can be depended on, tubes of 5-8in. external diameter appear to provide the practical limit in this direction, but in installations where water heavily charged with solids held in chemical solution, has to be used, it is not advisable to fit tubes of less diameter than $\frac{3}{4}$in., and it is often advantageous to increase this dimension by $\frac{1}{4}$in. The cooling water should always flow in a direction contrary to the steam, and experience has gone to show that a velocity of from 3 to 5ft. per second through the tubes will give best results.

From the foregoing results the following conclusions are drawn by Professor Weighton:—

1. It is conducive to efficiency in a surface condenser that the water resulting from condensation should be intercepted and removed from the condenser as soon as possible after it is formed.

2. It is conducive to efficiency that the condenser capacity should be a minimum consistent with the accommodation of the necessary surface, and that the design should be such as to secure a pervading and uniform flow of vapour throughout the condenser section, thus utilising the whole of the condensing surface provided, as well as obviating stagnant recesses in which air might be retained.

3. It is conducive to efficiency that the condensing water should travel at a fairly high speed through the tubes, and that it should enter at the bottom and leave at the top of the condenser.

4. With suitable condenser design and proportions, the temperature of the condensing water at the discharge point may be equal to or slightly higher than the temperature due to the vacuum. This holds true up to a vacuum slightly over 29 inches.

5. With suitable condenser design and proportions, the temperature of the hot well may be from 3 to 5 degrees higher than the temperature due to the vacuum. This holds true for vacua up to slightly over 29 inches.

6. With suitable condenser arrangements, and a reasonably airtight system, there is nothing gained

in efficiency by the use of air pumps exceeding in capacity 0.7 of a cubic foot per pound of steam condensed, up to a limit of close upon 29in. vacuum.   For vacua exceeding this limit, or for cases in which air-leakage is considerable, the air pump capacity must be increased or else the vacuum efficiency will fall.

7. With suitable condenser design and proportions, and in conjunction with "dry" air pumps, a condensation rate of at least 20 lbs. of steam per square foot of surface per hour will be maintained in association with a vacuum of $28\frac{1}{2}$in., and a quantity of condensing water equal to 24 times the feed water, at an inlet temperature of 50 degrees.

8. With suitable condenser design and proportions, and in conjunction with "dry" air pumps, a condensation rate of at least 36 lbs. of steam per square foot of surface per hour will be maintained in association with a vacuum of $28\frac{1}{2}$ inches, and a quantity of condensing water equal to 28 times the feed water, at an inlet temperature of 50 degrees.

Fig. 7 gives a diagramatic illustration showing a "Parsons'" turbo generator with surface condenser and vacuum augmentor. The "Augmentor" consists of a small steam-jet placed between the condenser and the air pump, with an additional cooler, the operation or action being likened to that of an exhaust ejector. The steam issuing from a contracted pipe or nozzle at a high velocity, draws from the condenser non-condensible air and vapour, passing it through the small cooler on the way to the air pump.   This system has the effect of increasing the density of the air and vapour considerably, thus enabling the air pump to handle it, and the capacity of the latter is largely increased.   It is claimed that in condensers fitted with the "Augmentor," an increased vacuum results that would be equivalent to that obtained by an air pump having three or four times the volumetric capacity.

At the Ultimo Power Station, Sydney, a "Parsons'" condenser, fitted with a "Vacuum Augmentor," is giving the following results :—