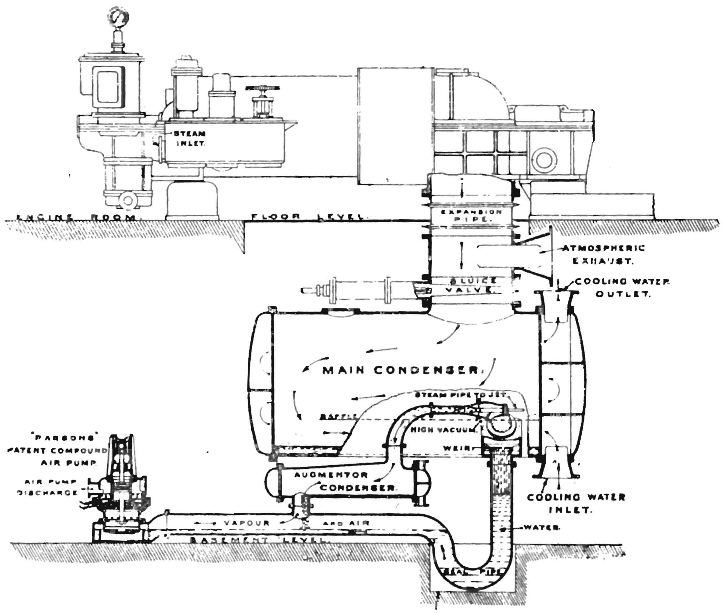
The steam from a 5000 kilowatt turbo generator, at full load, amounts to 80,000 lbs. per hour.

The condenser has a cooling surface of 7700 square feet.

The circulating pump of the centrifugal type is handling 480,000 gallons per hour, the temperature of the incoming water varying from 70° to 80° Fahrenheit. The air pump is of the Edwards' type, and an average vacuum of 28in. is maintained.




DIAGRAMMATIC ARRANGEMENT OF VACUUM AUGMENTOR.

FIG. 7.

The vacuum of 28in. certainly looks attractive, but from the liberal cooling surface provided, the writer would have thought no difficulty would be experienced in maintaining the same without the "Augmentor."

From the figures given, it will be noted that one square foot of cooling surface is dealing with 10.3 lbs. of steam per hour, by no means an extraordinary performance when taking into consideration that to obtain this result sixty pounds of cooling water per pound of steam condensed is passed through the condenser.

The writer cannot give authentic figures as to the consumption of steam by the "Augmentor," but in a discussion which took place on a paper read by Mr. R. W. Allen, before the Institution of Civil Engineers, some six years ago, the Hon. C. A. Parsons stated that the consumption of steam in the jet was about 1½% of the total. If this is correct, taking the case of the local plant, a debit is to be set down against the "Augmentor" of 1200 pounds of steam per hour, which should be sufficient to operate an air pump of fairly large proportions.

The figures quoted relative to the "Augmentor" are not of recent date, and it is possible that since then the steam consumption has been considerably reduced.

A combination of a "Parson s" condenser and turbo generator is sometimes adopted, the condenser forming the bedplate of the plant. The writer believes, however, that it is not usual to adopt this design, except for moderate-sized plants. The matter is mentioned principally to emphasise the fact that a modern condensing plant need only absorb a limited amount of space.

In the "Pearn" condenser, with compound steam operated pumps, an exhaust oil separator is placed immediately above the condenser, the oil trapped being dealt with by an automatic discharger. These dischargers are arranged to automatically close the connection between themselves and the separators, opening at the same time a valve to the atmosphere, which destroys the vacuum and permits of the oil collected being discharged. The action is simple and at the same time effective. The air pumps made by this firm are generally of the "Edward s" type, and the circulating pumps generally of the outside packed ram pattern.

The same firm also adopt a design with the pumps electrically operated, the one motor providing the necessary power. Such a plant is installed at the Great Boulder G.M., Kalgoorlie. The cooling surface is 2826 square feet, and there are two air pumps, each 17in. diameter by 15in. stroke, and a circulating pump 18½in. diameter by 15in. The circulating water is cooled by means of an open type cooling tower which, on fresh water, gives satisfactory results. This condenser deals with the exhaust steam from a large air compressing plant, and first motion compound hoisting engine. Hoisting engines probably try a condenser's capacity more severely than any other type of prime motive power, the steam being delivered in spasmodic quantities. At times it is rushing into the condenser in a big volume, and in the fraction of a second the whole supply ceases. Conditions such as these must necessarily be severe, and it is always wise to provide a condenser somewhat in excess of the maximum load, if a hoist of any size is to be dealt with. A method often adopted in connection with condensers handling exhaust steam from hoisting engines is to place an expansion chamber between the low pressure cylinder and the condenser. This has the effect of breaking down sudden rushes of steam and thereby mini mise any likelihood of the air pump sustaining damage through an overplus of condensed water.

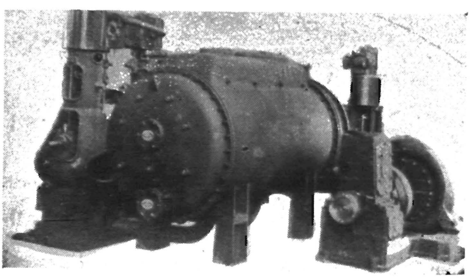


FIG. 8.

Fig. 8 shows a complete surface condensing plant, manufactured by Messrs. Kelly and Lewis, of Melbourne. As will be observed the pumps are operated by compound steam engines, the air pumps being of the "Edward s" type, the circulating of the centrifugal pattern. This firm is laying itself out to manufacture condensing plants that will compare both in efficiency and workmanship with those produced by the better established firms of the old world. Consequently with the purpose of reaching the desideratum, the principals have given the question considerable time and thought, and it may therefore be accepted that their practice is based on sound lines.

From experience, they advise when dealing with circu-

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lating water of a high temperature, 80° Fah., such as may be derived from a cooling tower, it is necessary to provide not less than one square foot of cooling surface for every five to five and a half pounds of steam per hour, and not less than 110 lbs. of circulating water per pound of steam per hour if a vacuum of 28in. is desired. As the handling of such a large quantity of circulating water against a head of say 50 feet, must necessarily require a considerable amount of pump horse power, they prefer rather to recommend the adoption of a vacuum of from 25in. to 26in., for which is allowed one square foot to every 10 lbs. of steam, the circulating water averaging from 60° to 75° temperature, and the quantity 45 lbs. per pound of steam.

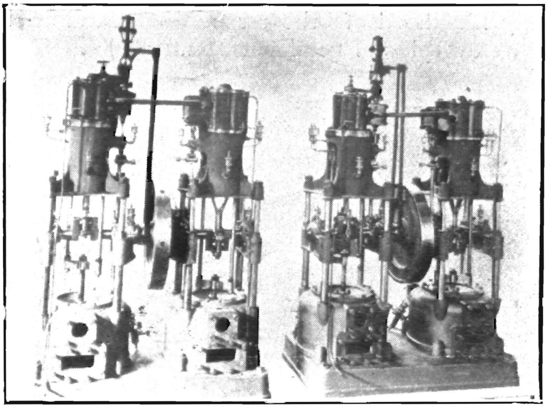

FIG. 9.

Messrs. Kelly and Lewis allow .60 to .75 cubic feet capacity in the air pumps, per pound of steam, but if long lengths of exhaust piping enter into the question this capacity is increased. The firm are much in favour of both the contra flow and compartmental drainage systems, and invariably embody these points in the condensers manufactured by them. The members will, the writer thinks, agree that it is gratifying to learn that an Australian engineering firm are using every endeavour to produce plant of this description on the lines laid down by the highest authorities.

The firm also adopts, in some cases, electrically driven pumps.

Fig. 9 shows this firm's standard type of steam driven air pumps. The arrangement, the writer thinks, is particularly neat, and shows that careful consideration has been given to the question of cutting down unnecessary weight.

In a design by Messrs. G. & I. Weir, Ltd., of Glasgow, the pumps are operated by a pair of reciprocating engines, and are capable of running at a comparatively high speed and so sweeping a large volumetric area. Weights are reduced to a minimum, and the space taken up by this type is not excessive.

These pumps can be fitted to any existing condensing plant without making any change in the condenser. On the suction side of the pumps a large air vessel is fitted to the dry air pump. The suction is taken from the top of this air vessel, which is fitted with a special valve to ensure that air only and no water reaches the dry air pumps. A small quantity of fresh water is kept circulating in the dry air pump for cooling purposes, but this is usually taken from the reserve feed tank and returned thereto, after passing through the pump. The writer regrets not being able to show a cross section of the air pump chambers, as particulars of same were not available.

Evaporative Condensing Plant.—This type has many points in its favour for situations where only a limited amount of fresh water is available for condensing purposes.

Fig. 10 shows the general arrangement of a modern evaporative condenser constructed on the contra flow principle. It consists of a number of eccentrically corrugated cast iron tubes, used in connection with a central draining duct, with end connectors forming a continuous core. The exhaust steam is led to the condenser inlet main and thence through branch connections to the condenser coils. In this particular design the tubes offer a large effective exterior and cooling surface, and the form of tubes employed prevents the flow of a core of non-condensed steam, thus resulting in the greater part of the exhaust steam being brought into contact with the cooling surfaces.

The condensed water travels direct along one unit, and does not, therefore, impair the efficiency of the other tubes, but permits of the rapid transfer of heat from the steam to the film of water on the outside of the pipes. Over the outside of the coils is allowed to flow a thin film of water, a portion of which is evaporated carrying away with it the heat of the steam, while the remainder falls back into the tank to be used over again. The exhaust steam enters the coils at the bottom, flowing onward through the coils to the outlet end, whilst the cooling water is distributed from the top and flows downwards, thus embodying the true contra flow principle. Some excellent results were obtained from one of these condensing plants erected at the "Bermondsey"

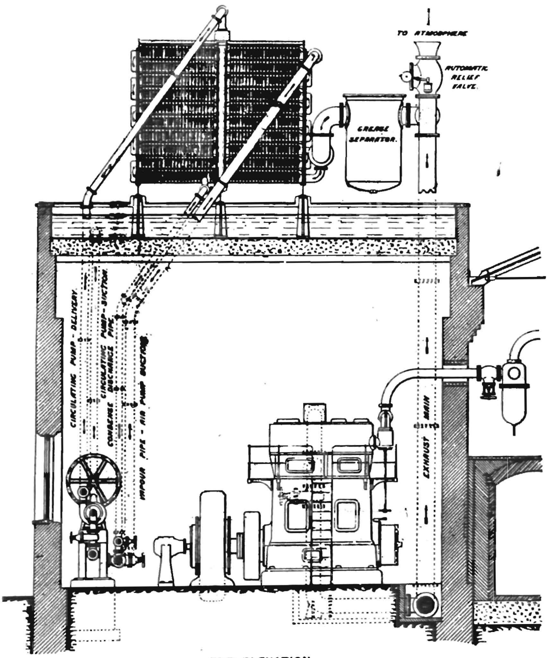


FIG. 10.

electric power station in England. With a maximum load of 1000 kilowatts the plant was guaranteed to maintain a vacuum of 25in. and a hot well temperature of 128°. This guarantee was exceeded when running with a 10 per cent. overload, the minimum vacuum recorded being 25.5in., whilst a vacuum exceeding 28.5in. was logged for considerable periods. The amount of water lost by evaporation was very low, not amounting to more than three-fifths of the weight of steam condensed. It is usual to allow one square foot of surface per pound of steam condensed per hour, with a water circulation of 10 lbs. per pound of steam, and at half loads it is possible to cut out the circulating pump, the condenser continuing to work satisfactorily by giving off its heat to the atmosphere.

These plants are very bulky and take up considerable space; it being often found necessary, when adopted in crowded communities, to erect them upon the roof of the power house. Their chief recommendation lies in the small quantity of circulating water required per pound of steam condensed, and in territories where water is purchased at a high figure, this is undoubtedly deserving of consideration. They are however quite unsuited for localities where the cooling water is heavily charged with mineral salts. Numbers of this type of condenser were installed on the Kalgoorlie Goldfields in the early days, and the results obtained were very unsatisfactory, largely for the reason mentioned. With a limited supply of cooling water, a month's run, or even less, was sufficient for the normal profile of the condenser to become entirely obliterated, resolving itself into a veritable pillar of salt. The cost of cleaning a plant of this description, under these conditions, can be easily conceived, and it is here mentioned to emphasise the necessity for circulating water to be of good quality.

Counter Current Jet Condenser.—In localities where the circulating water contains a considerable amount of salts held in chemical solution, and it is not considered necessary to save the condensed steam for boiler feed, the "Jet type of condenser offers an alternative to the surface condenser, and is often accepted owing to its lower initial cost. Most condensers of the "Jet" type are worked on the parallel flow system, the water being introduced in the nature of spray in close proximity to the steam inlet, the injection water and condensed steam falling together to the bottom of the condenser, and then being colleced or drawn off by the air pump.

The contra flow jet condenser, an illustration of which is shown by Fig. 11, takes considerably less water than the older concurrent type as just described. In the contra-flow condenser it will be noticed that the exhaust steam enters near the bottom, and the cooling water near the top.

The water is passed through a series of trays, which are perforated with a large number of holes of elongated shape, and in falling through the whole length of the condenser, in fine streams, is brought into close contact with the exhaust steam. The air and incondensible gases rise through the stream of water to the top of the condenser, and are then taken care of by the air pumps, and having passed through the first shower of injection water they are considerably cooled thereby, and pass to the air pump at a minimum volume. As the injection water passes through the condenser it is gradually taking up heat from the steam, and as it makes its exit in close proximity to the incoming steam, it naturally follows that the water attains a temperature very

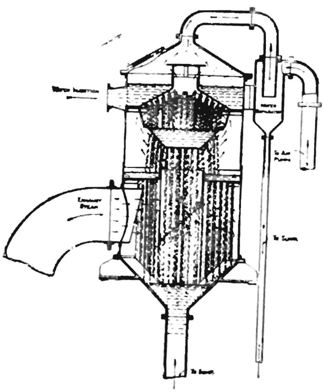

FIG. 11.

nearly equal to that of the exhaust steam. Under these conditions it will be found possible to run a counter current jet condenser with mucn less cooling water than the ordinary surface condenser of an equal capacity. If dry air pumps are to be used, it is necessary to fit a water separator in the air suction pipe to trap any water that may be carried over from the condenser.

Barometric Jet Condenser.--This type is fixed at a height equivalent to a barometic column, above the ground level, and consequently may be accepted as most reliable, as there is no risk of the water flooding back into the exhaust steam main.

If a barometric condenser is arranged to take its injection water from a natural source, such as a river or harbour, one pump only is required to deliver the cooling water to the condenser, the hot and condensed water being carried away by an overflow from the sump tank.

For a similar type of plant, working in conjunction with a cooling tower, two pumps are often installed, one to deliver cold water to the condenser, and the other to handle the hot water from the pump and deliver it to the cooling tower.

This is not a suitable arrangement for large stations which may be made up or formed of a number of units, inasmuch as a considerable amount of space is occupied, and long lengths of exhaust mains become necessary, which, apart from being expensive, will result in quite an appreciable difference in the vacuum registered at the condenser and that at the low pressure cylinder. Provision should be made accordingly.

With a low level jet condenser, in which is embodied the same arrangement as that just described, an additional pump is provided for removing the condensed steam and cooling water. This pump is often of the centrifugal design, being connected to the condenser just a few feet below it. This makes a complete and self-contained plant, and would come out somewhat cheaper in first cost than the barometric type, as no staging is required to support the condenser, and the piping arrangements would also be considerably curtailed.

The water pump should be of liberal proportions, and provision should be made to give the water a clear and unrestricted flow to the pump, thus minimising any possible air lock. In the event of the water pump failing at any time, the water would flood back into the condenser and thence to the exhaust pipe, with probably disastrous results to the engine, and it is advisable that only one motor, or engine, be provided to operate both the air and circulating pump. Should the latter cease to work, the air pump is affected in a similar way, and the vacuum will be more quickly destroyed.

The quantity of circulating water required for Jet condensers necessarily varies according to the temperature of the water and the vacuum desired.

In the counter current type, owing to the fact that the cooling water is last in contact with the entering steam, it is possible to raise the temperature of the water to within about

5° of that of the steam, and when dealing with cooling water of a high temperature and working on a high vacuum, the quantity of water to be circulated is very considerably less than for the parallel flow type. For instance, with a vacuum of 28in., and cooling water at 50°, 22 lbs. of water is required per pound of steam condensed, as against 25 lbs. with the parallel type; while with cooling water at 80°, the counter current condenser would need 66 lbs., as against 96 lbs. for the parallel flow type. That is, for the same vacuum, there is only 70 per cent. of the quantity of water to handle in the counter current condenser that is necessary in the parallel flow type.

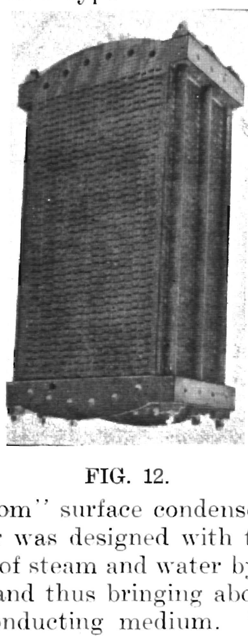

FIG. 12.

The "Ljungstrom" surface condenser is shown by Fig. 12. This condenser was designed with the object of breaking up the volumes of steam and water by passing them over irregular surfaces, and thus bringing about a more intimate contact with the conducting medium. These brass plates, corrugated at an angle of 45°, form the cooling surface, and as they are piled together to form the unit, the plates which are adjacent to each other have the corrugations running in reverse directions. This arrangement gives ample support to the flat plates, and renders unnecessary any further staying to provide resistance to the atmospheric pressure. The spacing of the plates is effected by brass frames placed between each plate, and serrated in turn, on what may be termed the end and side edges. These serrations, or grooves, form the inlet spaces for the steam and water respectively, and when the plates and frames forming the complete unit have been assembled, cramping plates and through bolts bring the jointing surfaces together, and a good joint is secured by means of strips of paper soaked in oil. As many units as may be necessary for the duty required are placed in a frame casing, machined so as to make the joints between the individual units, and provided with the usual branches for the induction and eduction of the exhaust and condensed steam. This type of condenser is very effective, and in marine practice, where an unlimited supply of cold water is available, no difficulty was experienced in condensing 20 to 25 lbs. of steam per square foot of cooling surface per hour.

An interesting installation came under the author's notice some years ago, where one of these condensers did good service when employed in the dual capacity of an evaporator and condenser respectively. Approximately, about 20 per cent. of the exhaust steam from a compound non-condensing engine was taken through the condenser and then passed on its way to the aero condenser, of which mention will be made later. Circulating water, carrying about 8oz. of solids to the gallon was pumped through the condenser, and thence to the top of a closed tower, the water falling to the bottom or sump tank, through brush wood. A small centrifugal blower, giving a pressure of a few inches, kept a continuous current of air passing through the tower, collecting on its way the vapour given off from the circulating water, the vapour ultimately being condensed in the aero condenser, and stored for make up feed water. Care was taken to prevent the circulating water becoming too dense through its continued use. This make up system gave excellent results, for despite the heavy expense entailed in cleaning the condenser plates, and rejointing same, etc., it was possible to produce the water at approximately 3/6 per 100 gallons, and although this may appear high, the saving effected will be appreciated when remembering that in the locality referred to, and at that time, fresh water could not be purchased, even in large quantities, for less than from 15/- to 20/ per 100 gallons. The whole of the make-up water was produced by this plant, and an additional surplus quantity was provided which enabled a boiler being "blown down" once every six weeks.

Aero Condensers.—Time will not permit of the author dealing with this type, excepting in a very brief manner. The best condenser of this design is that known as the Fouchè, taking its name after the inventor, and consists of a large number of small, vertical, light gauge tubes expanded into top and bottom cast iron headers, the whole being enclosed in a wrought iron casing. The exhaust steam was distributed through the various nests of tubes by manifold pipes, and the condensed water was drawn off at the bottom by the air pump. A fan of considerable displacement forces a continuous current round the outside periphery of the tubes, thus abstracting the heat from the steam necessary to bring about condensation.

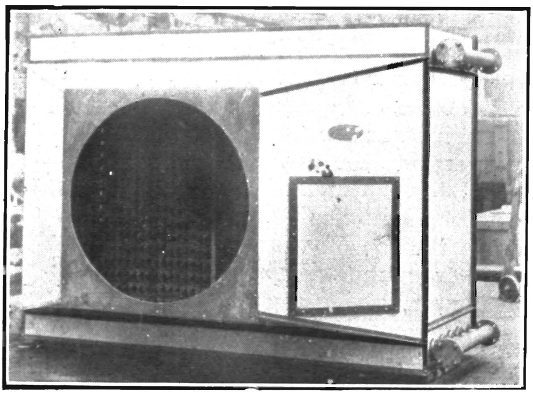

FIG. 13

Fig. 13 shows a plant, with the casing in position, but the fan removed, which will give members a very fair idea of this type of condenser. Strictly speaking, the plant, as illustrated, was not primarily designed for the purpose of a condenser, though it could be effectively used as such, but in the absence of a "Fouche" itself, it serves the purpose desired. The writer regrets being unable to quote any figures relative to this type of condenser, but from personal observation of several of these plants installed on the Kalgoorlie Goldfields, he has formed the opinion that its use leaves much to be desired. The maintenance is very heavy, especially at the point of tube connections with the headers, while the power absorbed in operating the fans renders the vacuum quantity very often a minus one.

Fig. 14 shows a type of condenser which was almost universally adopted on the W.A. Goldfields in the early days of their existence, and might be accepted as being peculiar to that locality. The illustration is from a photograph of a plant installed a few miles from Coolgardie, and was specially erected for providing fresh water for the Government locomotives, its capacity, speaking from memory, being 20,000 gallons of fresh water per 24 hours. This

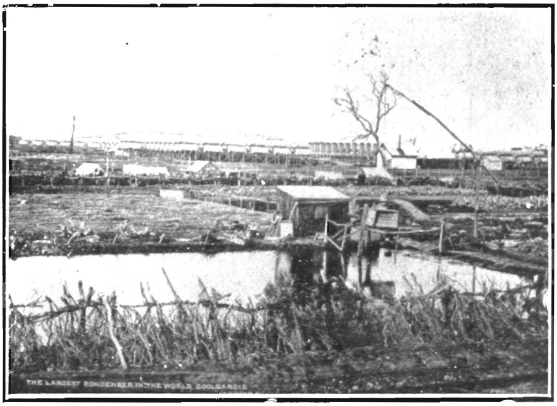


FIG. 14

plant is brought under members' notice for the purpose of showing how steam was condensed, whether the same was being dealt with from that of a power plant or when used as an evaporator. A number of circular drums or cylinders, formed from corrugated galvanised iron, each cylinder carrying an internal flue of approximately eighteen inches less diameter than the outer circle, were mounted upon wooden supports, and were connected together by plain galvanised iron piping. The cylinders, or perhaps a better term to apply, expansion chambers, were carried either in an inclined position or vertical, the steam entering at the highest point, and conducted in turn to number two chamber, from such a position as would ensure its being deflected or spread over the greater part of the cooling surface. From the bottom of each cylinder a pipe was connected to carry off the condensed water, a trap being provided in the shape of a U bend, to prevent steam making its escape. The method adopted of making joints on the galvanised pipes consisted of slipping one into the other and then covering the junction with a broad strip of calico well soaked in household flour, which when it became thoroughly dried, or part baked by the steam, proved quite effectual in preventing leakage. As may be expected, the efficiency of this type of plant was anything but high, results depending largely on the temperature of the atmosphere, but the system proved of great assistance in enabling engineers to supply the boilers with feed water, which while often far from being of best quality, was sufficiently so, to permit of "carrying on." Maintenance is a heavy item with this type of plant, especially in exposed positions, where a dust storm accompanied by a high wind, appeared to take special delight in mixing things up. There still remain engineers on the goldfields who insist that this type of plant is the most economical one to adopt, when compared with the high initial cost of surface condensers, cooling towers and consequential loss of cooling water. It was usual to provide not less than from 60 to 80 square feet of cooling surface per lb. of steam to be condensed, but on a hot still day with the thermometer registering 100° to 120° in the shade, the engineer often found himself wishing that he could, for the time being, double the cooling surface of the condenser. As can be imagined these plants are very susceptible to atmospheric changes, and their efficiency practically falls and rises in the reverse ratio to the thermometer.

Cooling -Methods.—Before concluding, it will be of interest to briefly describe the different methods adopted for cooling the circulating water, the most popular of which is undoubtedly the cooling tower. There are various forms of towers, but they one and all embody the same principle, differing only in the method adopted to achieve the desired result. No matter what method of cooling may be adopted, all depend principally on the evaporation which takes place. Thus a certain amount of water must be lost. As all systems depend on atmospheric conditions, they are only in a measure within control. Still, dull and muggy weather, when the atmosphere is heavily charged with vapours and is motionless, will render most systems ineffective. Without going deeply into the question, which involves such points as moisture carrying properties of the atmosphere, quantity of air required, amount of heat taken up in heating the air to a temperature more or less approaching the inflowing water, amount of heat expended in evaporation, it will suffice so far as this paper goes, to say that the main points forming the basis of any system of cooling is fine distribution of the water, accompanied by a low velocity and a thorough and intimate contact of the same with the atmospheric currents.

As a typical example embodying the foregoing points, the Worthington Cooling Tower might be mentioned. The water is carried up the tower in a central pipe ending in a cap, to which a number of radial arms each fitted with a number of nozzles closely pitched, from which the water issues in a large number of fine jets. The cap is revolved by the reaction of the issuing jets, at a slow rate. From these jets the water is distributed over rolled iron pipes, stood on end, and so rolled as to leave an open slit, thus permitting of the pipes being interlaced. This method makes it possible to get much more cooling surface into a given space than could otherwise be possible, and yet provide ample area for the passage of air currents furnished by the fan at the bottom of the tower.

This type of "Cooler" is undoubtedly very effective, and takes up a limited amount of space for the water handled, but it has one great disadvantage. viz., the power absorbed in driving the fans, which often amounts to $2\frac{1}{2}\%$ of that of the main engine. This added to the power taken by the circulating pump in delivering the water to the top of the tower, forms a considerable item in plants of large proportions.

A great many cooling towers work on a system of natural draught, and as the sides of the tower are thoroughly closed in this arrangement, it is often alluded to as a "Chimney" cooling tower. The water is delivered at the top of the tower, and is conveyed into a series of parallel troughs. The water overflowing from these troughs is conducted over a number of suspended vertical mats, which may be constructed of either woven steel, wire, canvas or plain galvanised iron. There are generally several tiers of these mats, the individual tiers being arranged at right angles to each other. This method has the result of spreading the water in broad "filmy" sheets, thus exposing a comparatively large area to the air currents. Many engineers prefer breaking the water up by what is known as the splash principle, which consists of a number of cast iron bars of triangular section, with a convex surface top, arranged in tiers, the water falling from tier to tier in finely divided particles, thus ensuring intimate contact with the air currents. This is a very effective type of tower, but like the others just previously described absolutely useless, unless the circulating water is of good quality and free from chemical salts. Several towers of both the "Mat" and "Bar" type came under the writer's personal observation on the goldfields, and the results when using salt water were disastrous.

In the "mat" type, plain galvanised iron plates were used, and after three months' run the only effective way of removing the deposit was to bake the plates thoroughly over an open fire, which cracked the scale and allowed of its being scraped off by an iron bar. After a few operations of this kind, you can imagine the profile some of those plates had forced upon them.

With the "bar," or splash type of tower, results were even more disastrous, most of the bars becoming so thoroughly wedded one to another, as to make it impossible to separate them without the use of an axe. In this case, the verdict was accepted as final, and the bars were replaced by eucalyptus boughs, supplied by 'the adjacent bush. This practically gave as good results from a cooling point of view as previously obtained, and had the advantage of costing very little for cleaning and renewals. Several towers are still in operation on the goldfields, using boughs as a breaking up medium, but the necessity to-day does not obtain, inasmuch as fresh water pumped from the Coast is now universally used for circulating purposes.

Fig. 15 shows a type of nozzle which is suitable for application to cooling towers. It works with a very low head, has a big capacity, gives a fine spray, and is low in first cost. With this nozzle it is usual to place the distributing pipe at the bottom of the chimney tower,

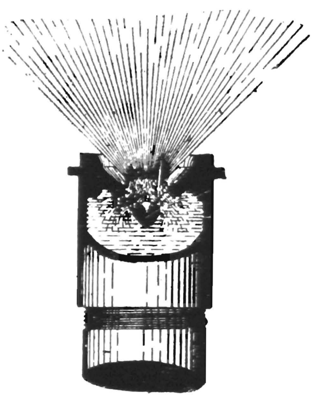

FIG. 15.

each nozzle so arranged as to prevent overlapping. A tower erected on this system, at the Associated Northern Gold Mines, Kalgoorlie, gave very good results, and so far as the writer knows to the contrary, is still in operation. On a test taken from this tower, with a sun temperature of 94°, the circulating water was reduced from 120° F. to 92° the loss by evaporation being $\frac{3}{4}$ lb. of water per pound of steam condensed. This nozzle offers a big advantage owing to its working with a very low head which considerably reduces the pump horse power required by the circulating pump, as compared when the latter are often called upon to deliver against a head of 50ft. or more. They are also very easily cleaned, and are therefore suitable for dealing with heavy water.

A large number of cooling ponds in Great Britain have been fitted with these nozzles, and have, the writer understands, given excellent results. The author has to acknowledge valuable information obtained from papers read by Professor Weighton before the Institute of Naval Architects and Mr. W. A. Dexter, read before the Manchester Association of Engineers.

Thanks are also due to Messrs. Noyes Bros., Ltd., Fyvie and Stewart, Hellicar and Brown, W. J. Adams and Co., Ferrier and Dickenson respectively, for the supply of catalogues and illustrations.

In conclusion, the author recognises that much more could be said upon the subject of the present paper, but the limit of time prevented his giving but little more than a brief summary which, while intended to be comprehensive, must necessarily include many faults of omission. He, however, submitted it to the Association in the hope that it may prove interesting and possibly instructive to the members.