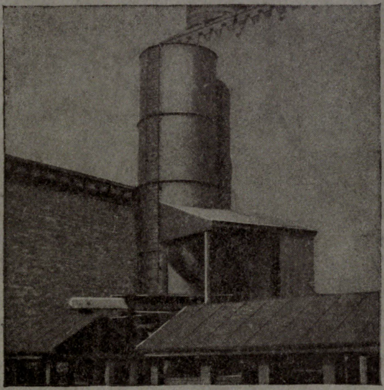
Cooling Towers

BY

OSWALD GUETH, M. E.



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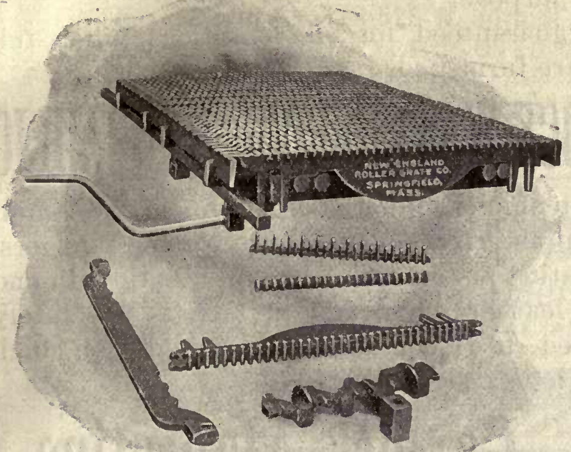

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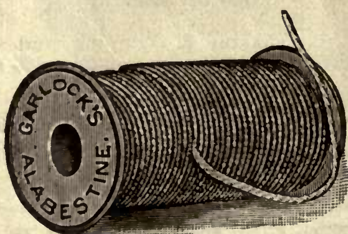

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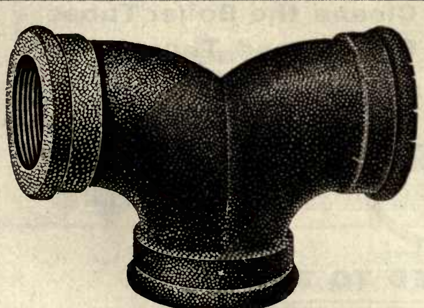

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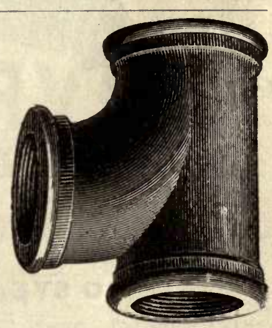

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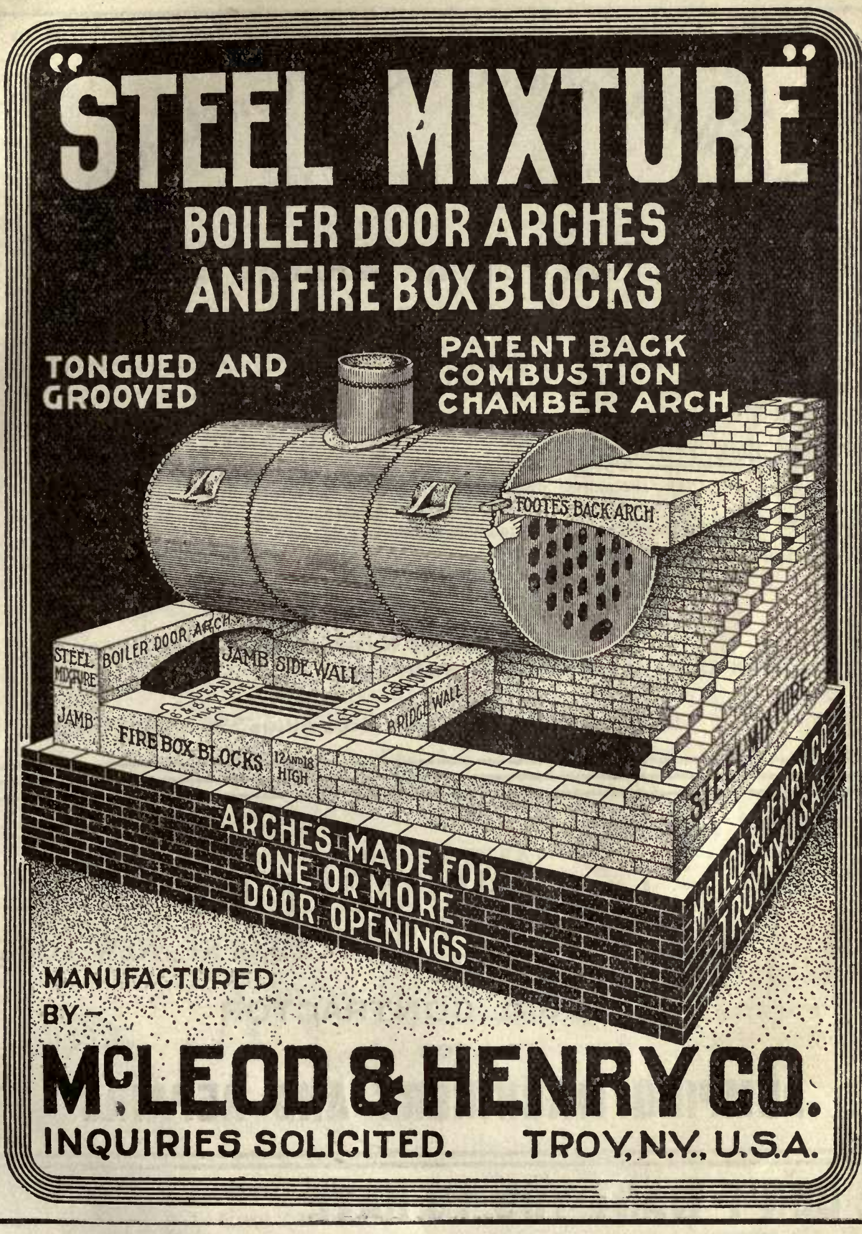

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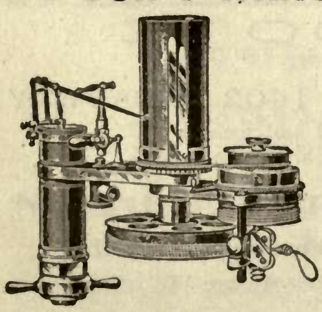


THE ENGINEERS' LIST

PUBLISHED BY Engineers' List Publishing Co.

 Published Monthly.

Vol. XVI. No. 3. MARCH, 1907. 10c. Copy. 50c Per Year.

COOLING TOWERS.

Their Prominence—Theory—History and Development—The Open Type—The Forced or Fan Draft Type—The Natural Draft Chimney Type—Advantages of Cooling Tower—Economy and Results in Cooling—Capacity and Size.

BY OSWALD GUETH, M. E.

AMONG the many marvelous devices which have been brought forth by great engineers tending towards a greater economy in industrial enterprises, the modern Cooling Tower undoubtedly takes a most prominent place.

Unfortunately the literature on this important subject is very scanty, although articles have appeared from time to time in various magazines, dealing with one or the other system of a cooling tower and praising its particular merits.

In presenting this article, it has been the aim of the writer to offer to the readers of THE ENGINEERS' LIST, many of whom have manifested a keen interest in this question, a comprehensive treatise on cooling towers, not with the intent to bring forth anything absolutely original, but to give a summary of the best that has ever been written on the subject, embodying at the same time the opinions of the foremost men in this particular field, together with the practical experience of the writer, a number of practical results and illustrated descriptions of the leading types of cooling towers.

Prominence of Cooling Towers.

The ever increasing number of large electric light and power plants with their highly economic condensing engines, the constantly growing demand for refrigerating machines in breweries, packinghouses and cold storage plants, have brought about the need of large quantities of water for condensing and cooling purposes. The economic advantages of condensing the exhaust steam from the engines in power plants at the lowest possible temperature are too well known. For marine work, wherein condensing was first practiced on a large scale, an unlimited supply of water was readily obtained, while for power plants on land, a sufficiently copious supply of water is in many cases unattainable at any price. In refrigerating plants large quantities of cool water are required for the liquefaction of the refrigerating medium; in addition thereto, water is needed to condense the steam, as this steam is now in most cases used for the manufacture of the ice.

In all places where large quantities of water are needed, the local public water supply must be relied upon, unless a river is near enough to furnish the vast quantities of water required. The local water supply is generally found quite expensive and the river water is frequently impure, or if near the ocean, is affected by the tides and becomes brackish.

The great saving effected by cooling the water and using it over and over again, has been recognized for a considerable time, and means for obtaining this effect have been invented, which finally led to the construction of the modern cooling tower. That the experimental stage has been passed, is evidenced by the fact that numerous steam plants have been located where there is no natural water supply for condensing purposes, and have been equipped with condensing engines and cooling towers. This selection of site has been influenced by better coaling facilities, more favorable distribution of the electric current, the lesser cost of land away from water fronts, and the knowledge that results practically equal to those obtainable with a natural water supply can be had with properly applied cooling towers.

Theory of Cooling Towers.

The principle upon which cooling towers operate is simply the spreading of the water to be cooled in such a way as to bring the greatest surface in contact with the greatest quantity of air, so that evaporation may take place quickly and effectively. In actual operation the water coming from the condenser in a heated condition, when exposed to the air, is enveloped in a coating of vapor which is carried away by the air currents in contact with its surface. This vap is continually replaced and carried away by successive contacts with fresh quantities of air. Each cubic foot of air has a vapor-carrying capacity which is governed by the percentage of moisture already in it, or, as it is called, its relative humidity. When the air is dry, its heat-absorbing efficiency measured by its vapor carrying capacity is high as compared to a similar quantity of air at or near the point of saturation. In other words, the drier the air and the greater the velocity with which it is moved over the surface of the water, the greater will be the vaporization of the water, and consequently the more effective will be the cooling of the water.

The capacity of the air for carrying moisture increases with the rise of temperature. Saturated air, i.e., air which holds all the water in vapor form that it is capable of holding, would at a temperature of 200° F. hold 100 times as much moisture as air in a saturated state at a temperature of 32° F. To vaporize a pound of water at atmospheric pressure requires the absorption of 966 B. T. U., and the heat thus required must be derived from the remaining water, consequently its temperature is lowered unless it receives sufficient heat again from its surrounding air.

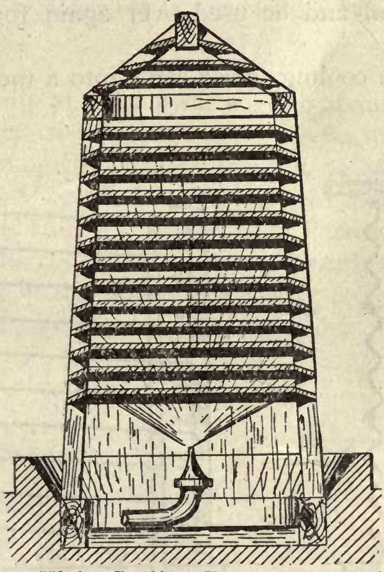


Fig. 1.—Klein Cooling Tower With Injector.

There is a maximum of density for each temperature and hence of pressure which the vapor exerts. The rate of vaporization is proportional to the difference between the elastic force of the vapor at the surface of the liquid and that of the vapor actually present in the surrounding air. From this it follows that the vaporization will be the faster, the greater this difference.

The efficiency of a cooling tower depends therefore greatly on—

1. The amount of water surface.

2. The amount of air brought in contact with that surface.

3. The difference of pressure of the vapors at the water surface and the surrounding air.

These three conditions mainly govern the rate of vaporization. The lowering of temperature of the water depends on the dryness of the air.

History and Development of the Cooling Tower.

The oldest and most simple method of cooling water was to expose the warm water sufficiently long to the atmosphere by running it into large open ponds, and a large number of such ponds can still be seen in European countries, although they take up a considerable ground space and are not really satisfactory.

An improvement on these ponds were spray coolers, that is, an arrangement to throw the warm water in a fountain-like spray into the air. It was soon noticed that the vapor raised in this process caused a considerable nuisance, and these coolers accordingly can only be used in a very open space. Further, with even moderate air currents, a considerable portion of the water is blown beyond the pond.

Klein, in Germany, has tried to overcome these defects by enclosing the cooling towers (Fig. 1). Here the water is drawn from a jet against slabs of wood, and by dropping down the tower amongst the air rushing in between the laths, is so thoroughly cooled that it can be drawn from the tank below the tower perfectly cool and be used over again for the same purpose as before.

Before the modern cooling tower came into a more general use, various

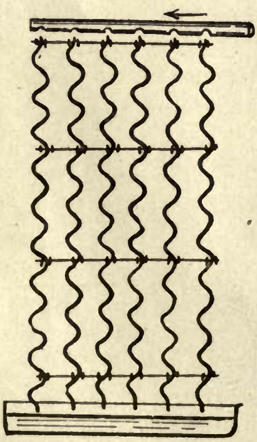


Fig. 2.

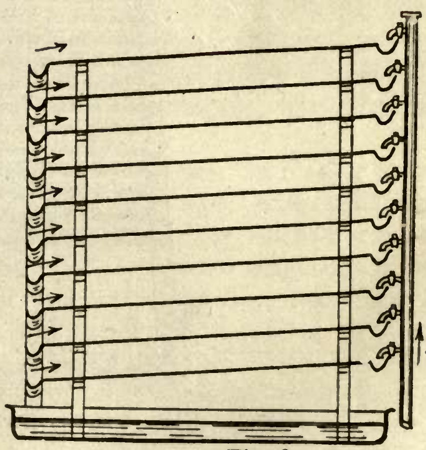


Fig. 3.

Fig. 2.—Cooling Device Having Corrugated Partitions.
Fig. 3.—Cooling Device Having Inclined Metal Sheets.

other devices were employed to cool the water. Fig 2 shows corrugated sheet metal partitions, placed over the water tank. The water trickling down forms a thin film on each side of the partitions, thus offering a large cooling surface to the air passing through between the partitions.

Fig. 3 shows slightly inclined metal sheets, over which the hot water flows in a thin layer and is caught in gutters, while the air is blown in counter currents through the spaces, or forced through them by natural draft by attaching a draft chimney to the other end, a device which is described later on.

One of the earlier apparatus, but which is still used to some extent in European countries on account of its high efficiency, is illustrated in Fig. 4. It is a water cooling device in connection with a submerged ammonia condenser. It consists of a number of sheet metal disks, which are fastened to a

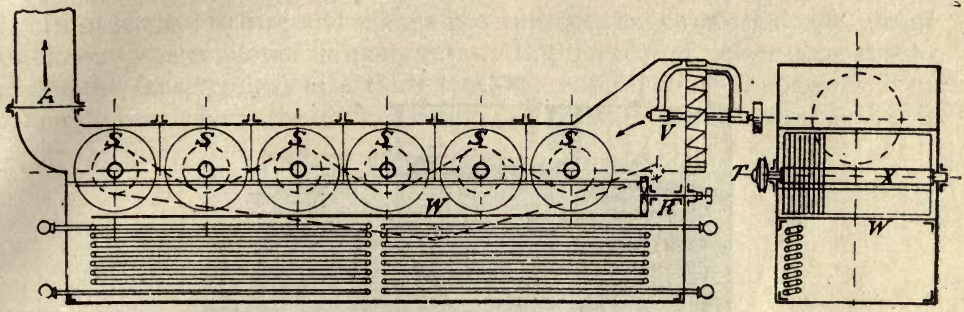


Fig. 4.—Cooling Arrangement in Combination With Ammonia Condenser.

horizontal shaft and dip at their lower edge to about one-third of the diameter into the cooling water of the condenser. These disks have a diameter of 4 to 5 feet, and are arranged in groups from 50 to 80 on one shaft. The disks revolve slowly, 5 to 8 revolutions per minute, and become covered with a thin film of water and thus form a series of narrow channels, through which the air is blown. The condenser coils are directly underneath the system of disks and submerged in the tank. The water is kept in constant circulation around the condenser pipes by a special agitator.

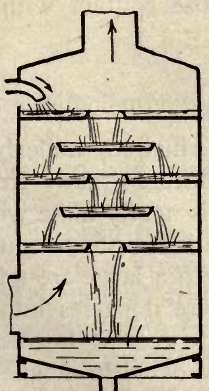


Fig. 5.—Type of Rain Cooler.

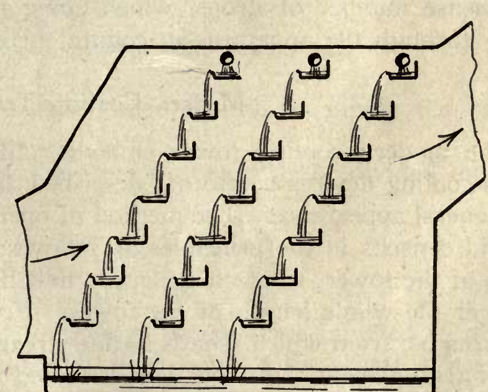


Fig 6.—Type of Rain Cooler.

Figs. 5 and 6 show two types of what is called a rain cooler. These coolers have the advantage that it is easy to produce a counter current between the air and the hot water, which, like cascades, has a downward flow from tray to tray. A cooling effect is also obtained in bringing the air in contact with the dry underside of the trays. Both coolers may be equipped with draft chimneys.

Another type of a rain cooler is illustrated in Fig. 7. The principle is easily understood from the drawing. A cylindrical tank is provided with a

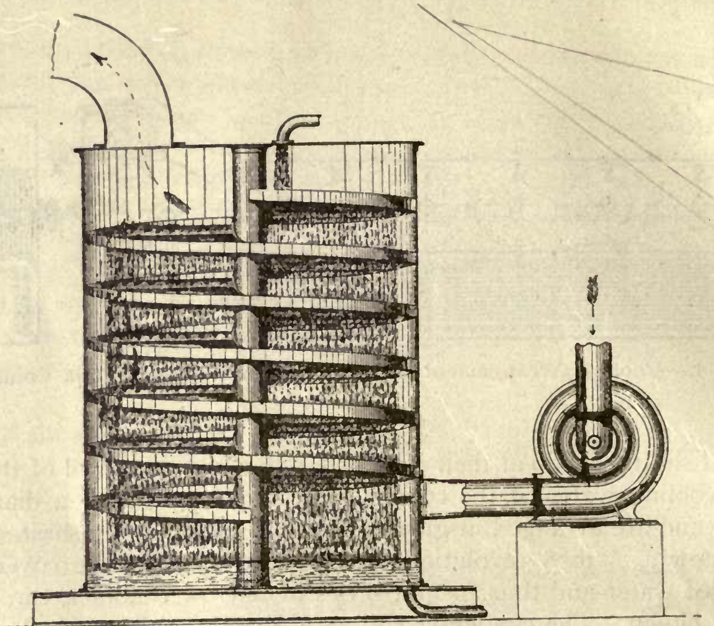


Fig. 7.—Cylindrical Rain Cooler.

perforated partition spirally wound around the axis of the tank. The hot water is showered over the highest part of the partition and is dissolved into an immense number of drops, which come into close contact with the air passing through the apparatus in countercurrent.

Modern Cooling Towers.

The modern cooling tower embodies all the principles underlying the various cooling devices heretofore described, but it differs greatly from them in its general appearance. The method of operation is nearly alike with every type and consists in the principles as follows: The hot water is pumped to the top of the tower, where it generally first flows into a large trough, which runs over the whole length of the tower. From there it passes into smaller cross troughs, from which it falls in fine streams on to cooling hurdles below. By this arrangement the water is distributed equally over the whole area of the tower, which can be controlled and regulated while at work. This distribution is so efficient that with only one water inlet, either in the centre or at one end of the tower, exactly the same quantity of water descends at every point of the tower. The main point is to distribute the water so that the greatest amount of surface is exposed, and to provide the necessary circulation of air. To this end various means have been employed, by letting the water run over cooling hurdles made in different forms. But it appears that the form of these hurdles is not of such great importance as the arrangement to ensure a thoroughly even distribution over the entire cooling area without obstructing the air passage.

At first, all the manufacturers of modern cooling towers relied for air circulation on the natural draft. The tower is built as an open structure with an open space left in the centre, which acts like a flue.

In order to increase and maintain a constant air circulation, the use of fan blowers was employed in many cases. But the cost of power necessary to operate the fans resulted in a third type, the natural draft chimney type of cooling tower, where the tank containing the water-distributing device is

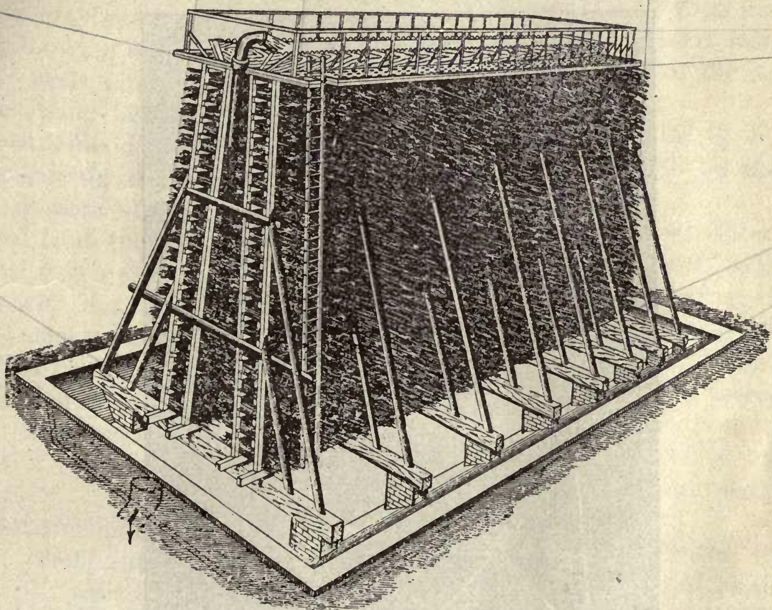


Fig. 8.—Open Cooling Tower With Brushwood.

carried up sufficiently high to induce draft enough to supply the required quantity of air.

Modern cooling towers may therefore conveniently be divided into three distinct groups:

1. The open type.
2. The forced or fan draft type.
3. The natural draft chimney type.

As we have seen from the foregoing, the principle applied in all these three types is virtually the same, that is, to expose the water a maximum length of time to a maximum amount of air. These three types will be discussed at length in the following in their proper order.

Open Air Type.

This type can be well recommended where sufficient ground area is available. It is simple and cheap, as it dispenses not only with the fans, but does away with any enclosure entirely.

In its crudest form it is built up of a frame filled with bundles of brushwood, which offers to the water a very large evaporation surface (Fig. 8).

This form has now almost entirely given way to structures provided with wooden hurdles, the latter being so constructed that the water runs over this surface in thin sheets. On the under side of these hurdles there are numerous projections, which separate the water into drops and pass it on to the next hurdle, and so it is passed on from hurdle to hurdle, until there is a fine artificial rain made, which comes into intimate contact with the outside air, the openings between each hurdle giving ample opportunity for free draughts of air.

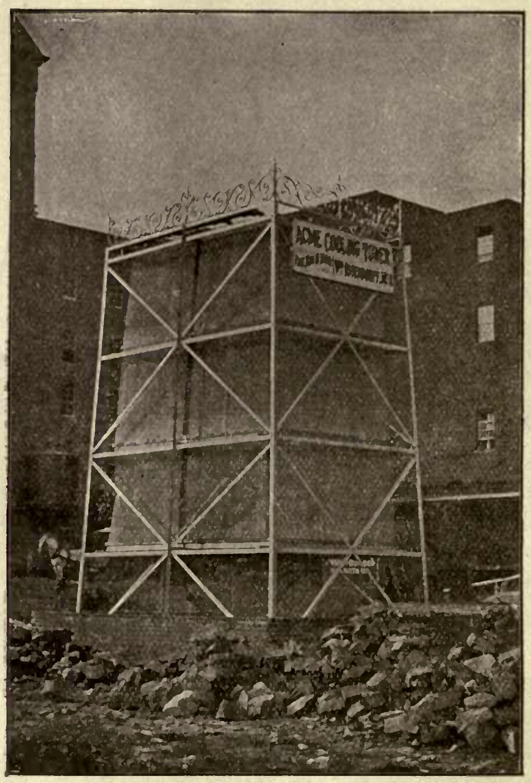


Fig. 9.—"Acme" Cooling Tower.

One trouble with this style of tower lay in the fact that with moderate or high winds, a considerable quantity of water will blow off. This not only is expensive from the standpoint of the cost of water, but it also seriously affects the operation of the machine, besides creating more or less of a nuisance in the immediate vicinity by showering water to the ground.

To decrease this difficulty, some manufacturers provide splash boards, but it seems that their efficiency is not very great and that they also impede the circulation of air. On some of the latest towers erected, this difficulty has been overcome, by making the splash boards movable. One side and one end of the tower are supplied with what are practically a system of Venetian blinds on a large scale. These blinds are placed between the supports of the tower. Each slat is a seven-eighths of an inch board, eight feet long and eight inches wide. These slats or boards have a casting screwed to each end of the board and the casting forms a pin which is inserted into a hole or journal in another casting screwed to the tower supports. A strip is placed vertically on each section of slats running from top to bottom and stapled loosely to each slat. In this way any section of blind can be closed tightly or opened to any degree, just as a Venetian blind is handled. When the wind is light, the slats are set in a horizontal position and absolutely no obstruction to the air is offered. If the wind increases, they can be adjusted accordingly, so that at all times the maximum circulation of air can be realized without losing any water by blowing off. All connections are loosely made, so that the slats may shrink or swell without binding.

The Acme Self-Cooling Water Tower, manufactured by B. F. Hart, New York, embodies some peculiar characteristics, which will be easily detected by looking at the illustration (Fig. 9).

The method of operation is as follows: The hot circulating water, when discharged from the condenser, is pumped to the top of the tower, where it is distributed into a shallow pan. This pan is the upper one of a series that are equipped with the Acme patented spray device. The pans are carried by a structural steel tower strongly braced and gusseted, and open to the air on all sides. The heated water passes by gravity through the pans, where it is divided into minute particles so that a maximum surface is exposed to the evaporative and cooling effect of the surrounding air. The cooled water is caught in a receiving basin under the tower, whence it is returned to the condensers.

Before concluding the chapter on the open type cooling tower, we will not fail to briefly mention the tower built by the Triumph Ice Machine Co., of Cincinnati, which is illustrated in Fig. 10. The principle is the same as employed in every other type, the exposure of the water in a thin sheet to the cooling effect of the atmosphere. This result will be increased by giving the tower a rotary motion against the direction of the air draught.

Forced or Fan Draught Type.

In order to accelerate the evaporation and thus increase the efficiency of the cooling tower, most manufacturers of modern cooling towers obtain the necessarily lighter air circulation by the use of fan blowers. Fan towers are always recommended in cases where the quantity of heat to be removed is great and where the duty is especially severe in the hot summer months. But the cost of power necessary to operate the fans and the wear and tear due to moving parts are disadvantages which have to be taken into consideration in selecting a cooling tower. The fan tower, however, is well suited for ammonia condenser work and for steam condensers where the space available is limited, or where the tower can be placed to advantage upon the roof of the engine or boiler house. While, of couse, the power required to operate the fan is a constant charge, still, by running the fan at a reduced speed when the load is light or the weather is cold, and by returning the heat of the exhaust steam from the fan engine to the boiler by way of the feedwater, the actual charge is reduced to an inconsiderable amount.

As we have seen, the temperature and relative humidity of the atmosphere are the elements which govern the quantity of air necessarily delivered to the towers, and the speed of the fans must be regulated accordingly. A

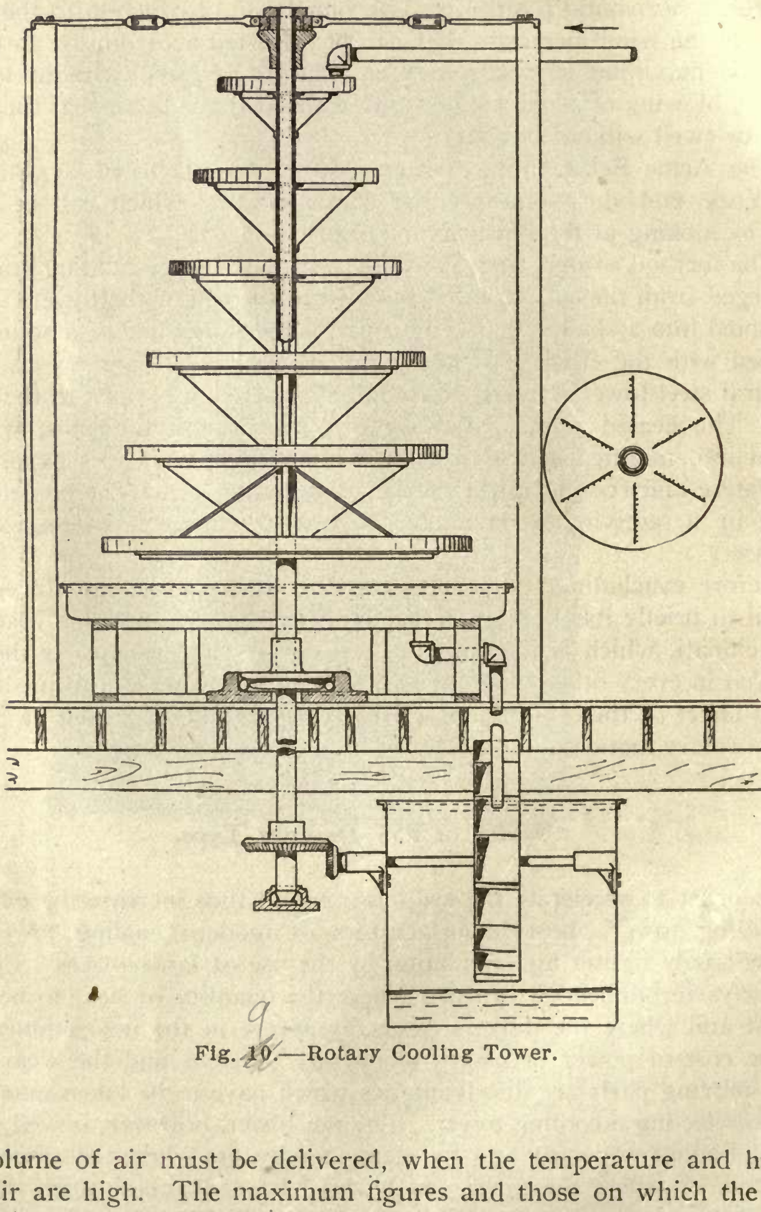


Fig. 10.—Rotary Cooling Tower.

great volume of air must be delivered, when the temperature and humidity of the air are high. The maximum figures and those on which the air delivery is based, are 95° F. in the shade, with 80 per cent. saturation, as we will see from a table given later on. These conditions, being extreme, are seldom met with and are then but of comparatively short duration, but anything approaching this calls for the highest fan speed. This should vary from 25 revolutions per minute in a 10 foot fan to 670 revolutions per minute where a 4 foot fan is used.

Fans are driven most advantageously by an independent steam engine, where the speed may be regulated at will. Motors are used in many installations and make a very compact and economical fan driver where current is plentiful. They should be arranged for changes of speed. Shafting, when located handily, is often used.

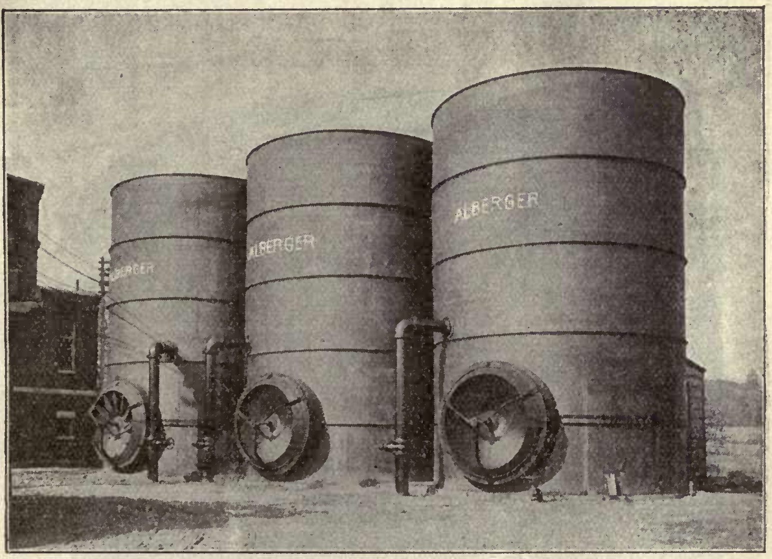


Fig. 11.—Alberger Cooling Towers.

A good example of a fan tower is shown in Fig. 11. This cooling tower is made by the Alberger Condensing Co., of New York. It is cylindrical in shape and constructed of sheet steel. The filling consists of boards of swamp cypress, geometrically arranged in a regular manner, so as to positively determine a complete and ultimate distribution of the water and the air. The fans of the tower are operated by a steam engine which also drives by direct connection a centrifugal circulating pump, that withdraws the hot water from the hot well and discharges it to the distributor of the cooling tower. The distributor is shown in Fig. 12. It will be seen that the water issues from the arms of the distributor through tubes so arranged as to cause the water to retain its jet form until it reaches the filling, upon which it adheres and spreads. As each tube has to supply water for all the filling over which it passes during a revolution, it is of necessity of comparatively large diameter and does not become clogged with leaves or other similar material. The hub of the distributor, which carries the arms, is rotated upon a roller bearing by the reaction of the jets of water, and the small amount of resistance offered permits of a steady and constant rotation with a very small velocity of water in the spouts.

The illustration (Fig 13) shows an Alberger cooling tower as applied to an ice manufacturing plant, where it is not only applied for the liquefaction of the ammonia, but also for the water fore-cooler and the steam condenser. By tracing the course of the water, we see that the cold water is taken by the circulating pump and discharged over the ammonia condenser. After being partially heated, it then passes over the steam condenser and falls into the cooling tower, where it is cooled for re-use. When a water cooler is employed, a portion of the cold water is taken directly from the tower and allowed to pass over the water cooler, while in its coolest condition. As the

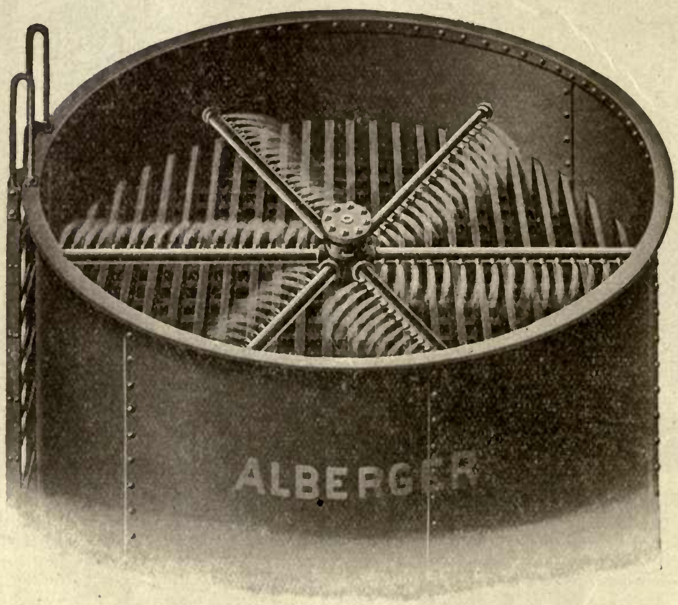


Fig. 12.—View in Top of Alberger Cooling Tower.

circulating water, after passing over the condensers, immediately returns to the tower, it is evident that during a given time any amount of water up to the capacity of the circulating pump can be passed over the condenser. There is practically an unlimited supply available and there is no necessity of trying to cut down to the lowest possible amount, as is the case when it has to be pumped from a deep well or paid for when taken from the city supply. It will be found, therefore, that by circulating an ample amount of water, the final temperature of the ammonia condenser can be lowered, with a corresponding reduction of ammonia pressure and power demanded by the compressor.

Probably one of those most frequently found is the cooling tower manufactured by the Ruemmeli-Dawley Mfg. Co., of St. Louis. This tower is made up entirely of wood. The essential feature of this construction is an

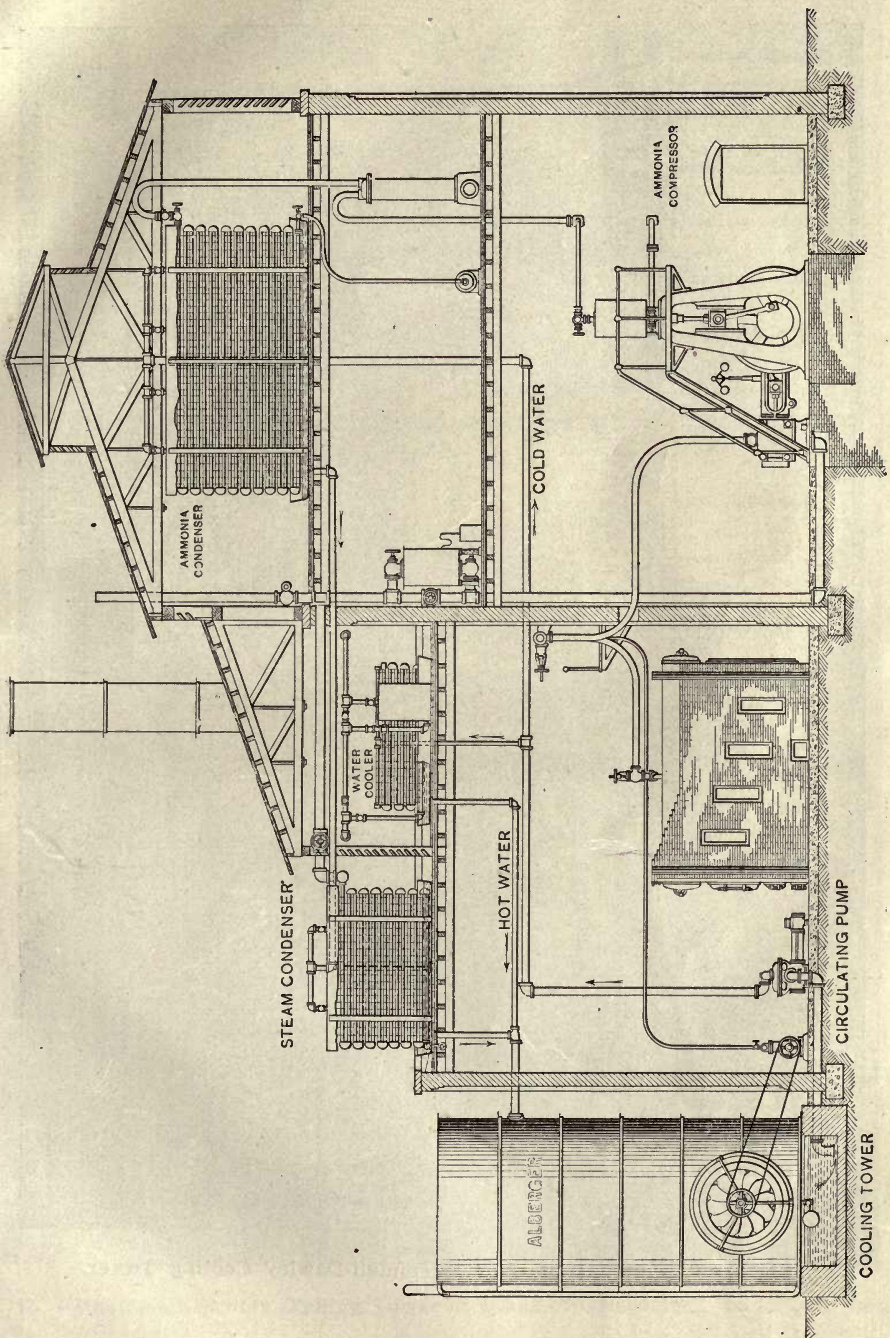


Fig. 13.—Alberger Cooling Tower Installed in Ice Plant.

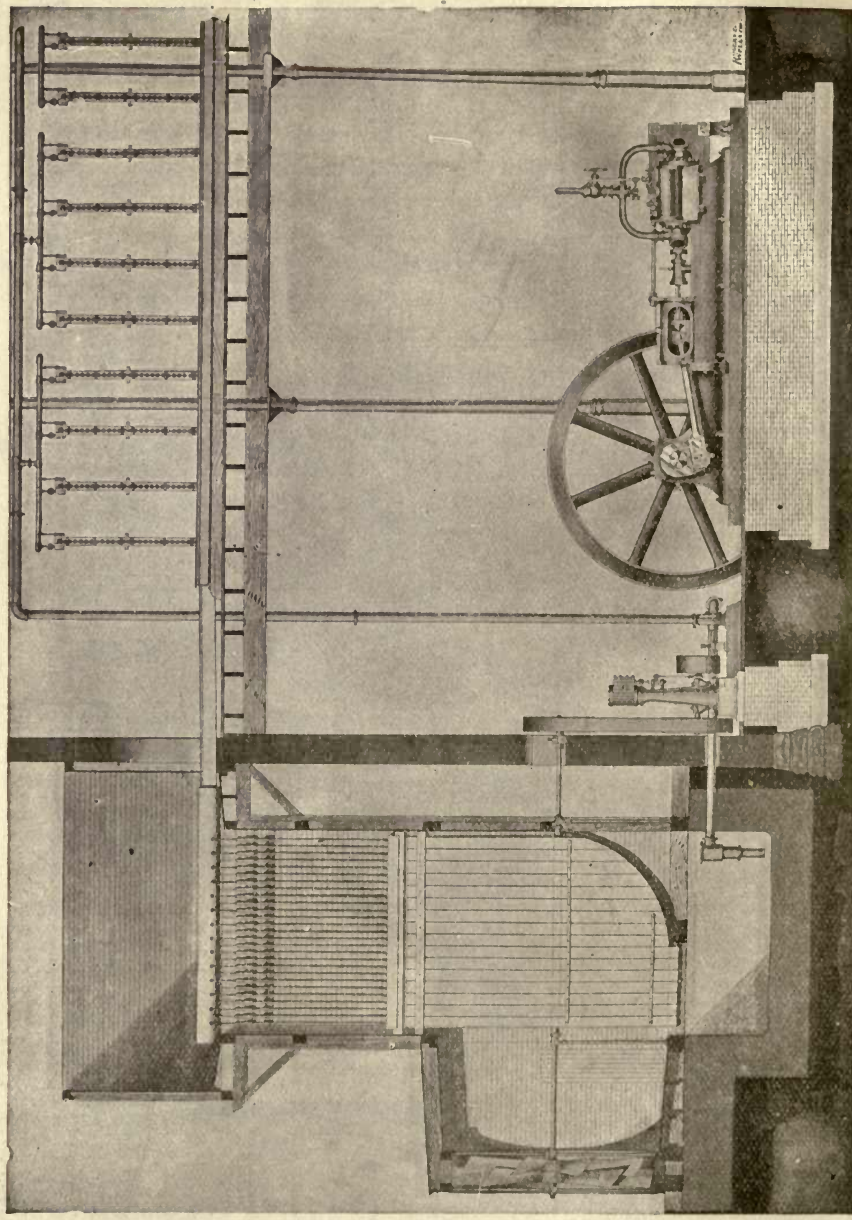


Fig. 14.—Sectional View of Ruemmeli-Dawley Cooling Tower.

even distribution, over flat surfaces, of the water to be re-cooled. It does not run down these surfaces in streaks, but flows in a uniformly thin sheet, over which air is blown by a fan, thus offering a large surface of water to the current of air that blows over it. The air causes part of the warm water to

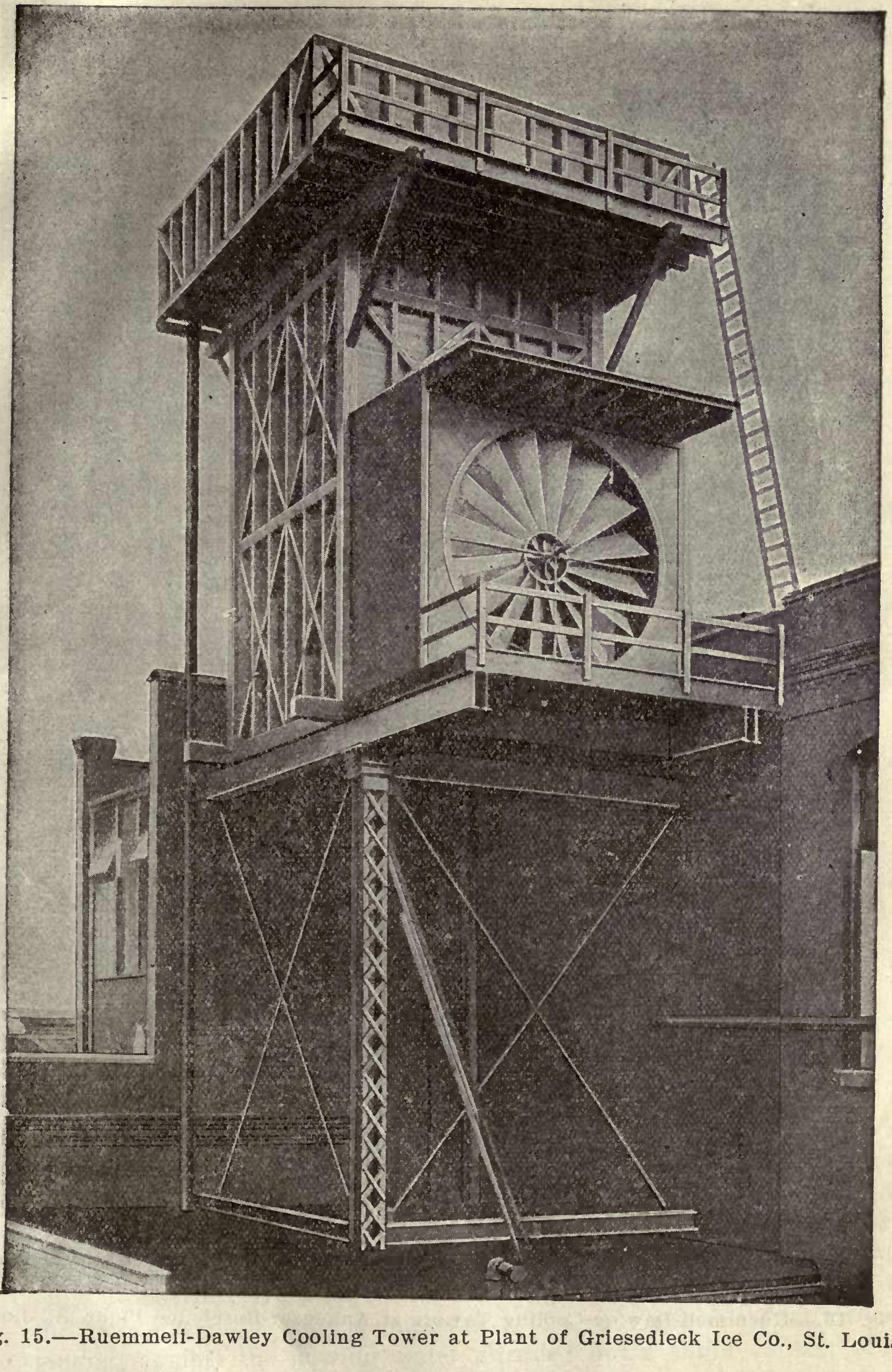


Fig. 15.—Ruemmeli-Dawley Cooling Tower at Plant of Griesedieck Ice Co., St. Louis.

evaporate, and the heat which changes the water into vapor is taken from the remaining body of water which is thus cooled, while the air carries away this heat in the form of vapor.

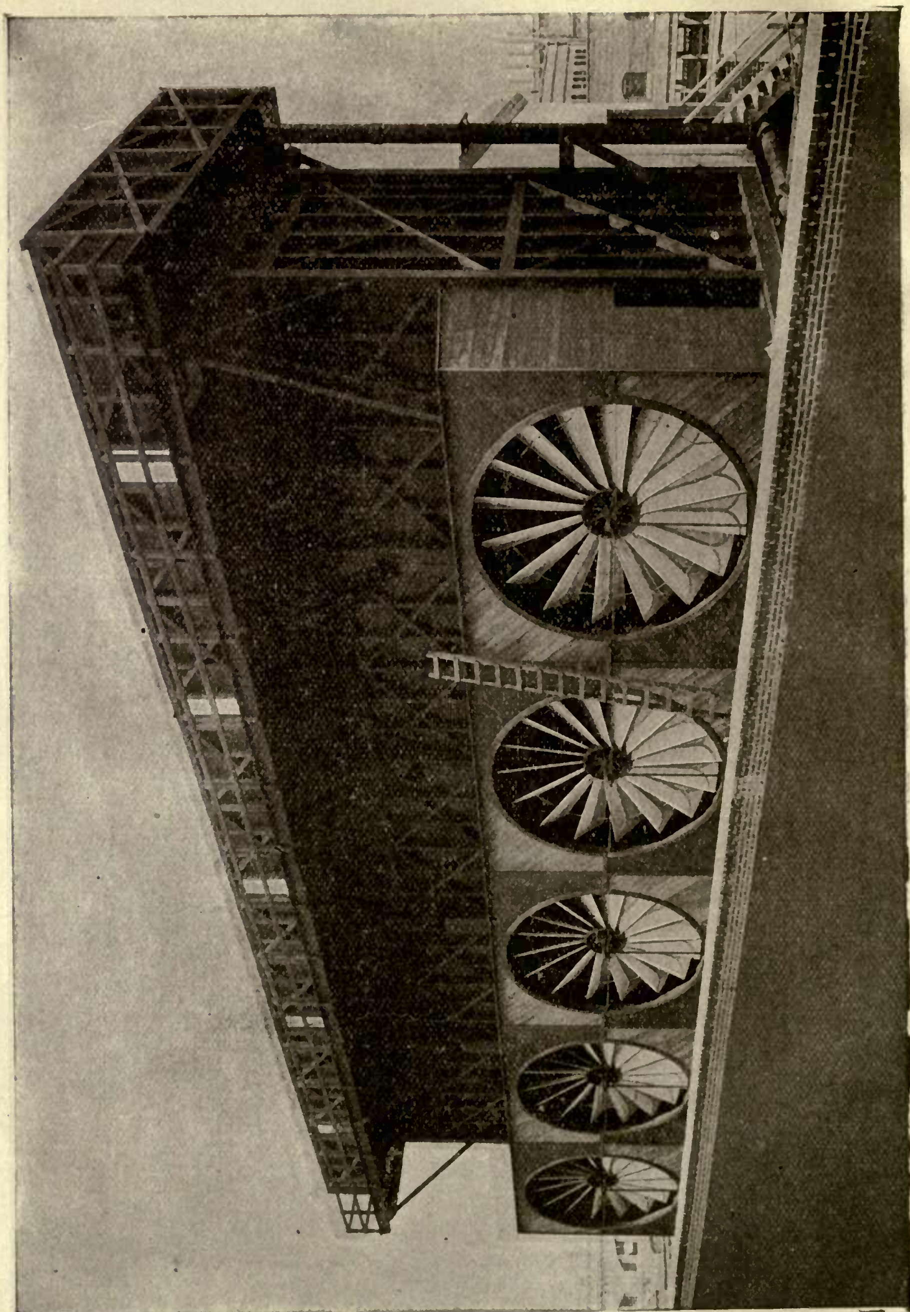


Fig. 16.—Ruemmeli-Dawley Cooling Towers at Anheuser-Busch Ice Plant, St. Louis.

Illustration (Fig. 14) shows a cooling tower cooling the water used over the ammonia condensers. The tower is located in such a manner that the distributing troughs are directly connected with the condenser pan, from which the water runs directly into and over the filling of the tower, gathers in the basin below and is forced from there to the top of the ammonia condensers by a rotary pump driven by the same little engine which drives the air circulating fan of the cooling tower.

A great number of these cooling towers are in operation in all parts of the United States. The tower represented in Fig. 15 is erected at the plant of the Griesedieck Artificial Ice Co., St. Louis, and has a capacity of 1,200,000 gallons daily. The largest cooling tower plant is located in St. Louis, at the plant of the Anheuser-Busch Brewing Ass'n, where with twenty towers 14,000,000 gallons of water are cooled per day. The photo (Fig. 16) has

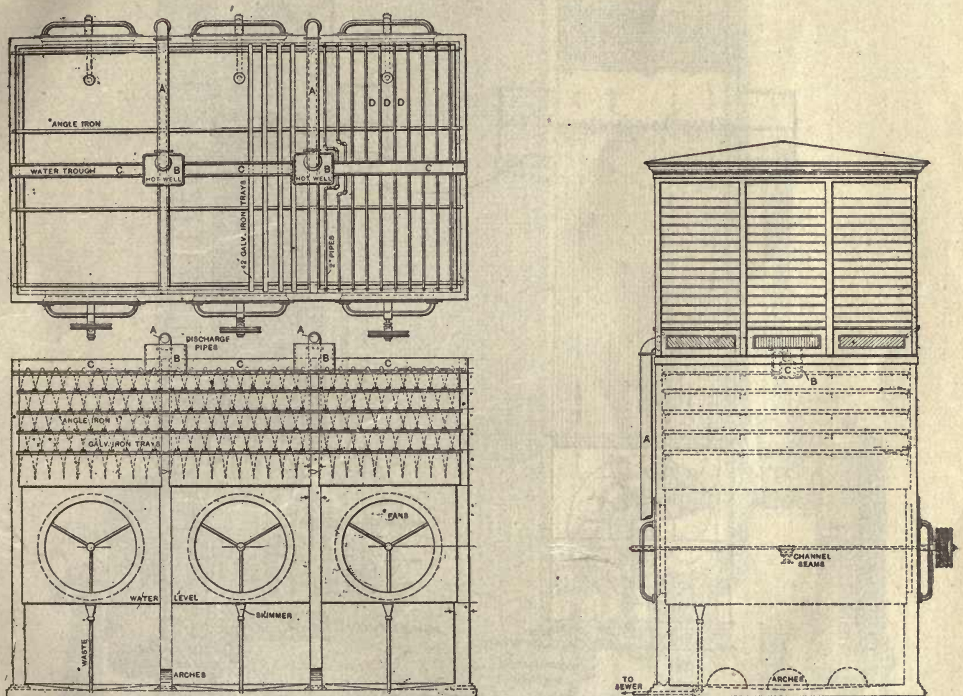


Fig. 17.—Cooling Tower of International Steam Eng'g Co., New York.

been taken at the Anheuser-Busch plant, showing a battery of five cooling towers, with a capacity of 3,500,000 gallons daily.

The International Steam Engineering Co., of New York, has put a cooling tower on the market, in which the system of percolation seems to be quite a departure from the average cooling tower. While in the old method the precipitation of water in sheets or layers with a series of air currents impinging against the flowing water afforded but a slight contact of the air current against the constituent elements of the water to be cooled, the system of percolation adopted by this kind of cooling tower seems to have met with great success, according to its manufacturers. The water is pumped into troughs (see Fig. 17), from which lateral pipes extend, and the water is allowed to fall by gravity from these lateral pipes in drops to the first row of troughs. The area of air contact in a drop of water is immediately seen to be large. On dropping to the first row of troughs the water is disintegrated and again allowed to flow from these troughs, through lateral holes in them, in drops of water presenting an entirely different area of contact for the extraction of heat units contained therein. This procedure is carried on continuously throughout a series of troughs until the water has arrived at the

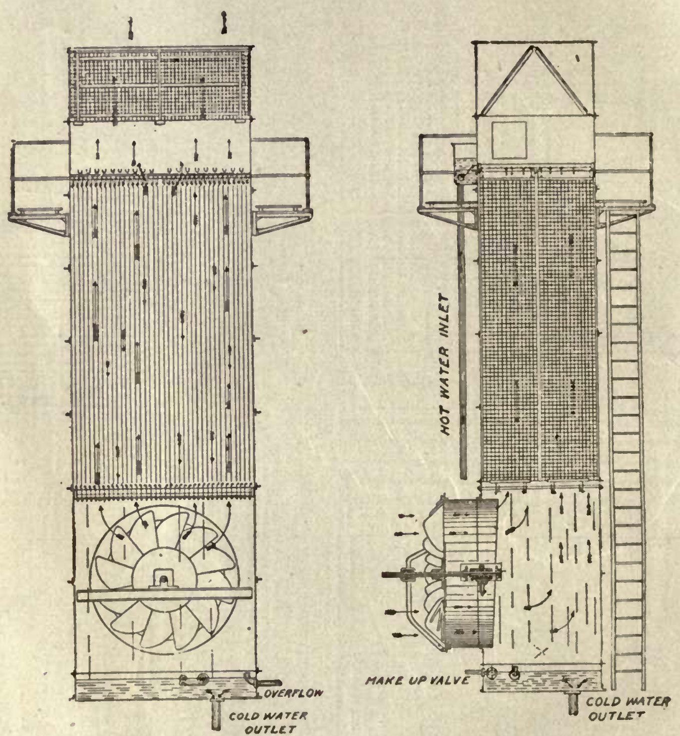


Fig. 18.—Sectional Views of Barnard Wheeler Cooling Tower.

greatest possible coolness obtainable with air currents, and the manufacturers claim to have obtained in practice as low as 15 degrees below atmosphere.

These towers are preferably built of brick, owing to its indestructibility and imperviousness to disintegration. The cupola arrangement is a particular feature, whereby the loss by evaporation is said to be reduced to less than 4 per cent. of the total amount of water cooled, as the cupola retains much of the moisture and evaporation being held in suspension in the cupola by the air currents and slowly projected against the lower boards which drain back to the tower.

One of these cooling towers is built for the U. S. Government at Federal Prison, Atlanta, Ga. It is cooling water to seven degrees F. below surrounding atmosphere with 98 per cent. humidity. The tower has a capacity of about 100 H.P. condensing plant, and is driven by direct slow speed motor, operating on the remarkably small amount of 2.9 H.P. at maximum load.

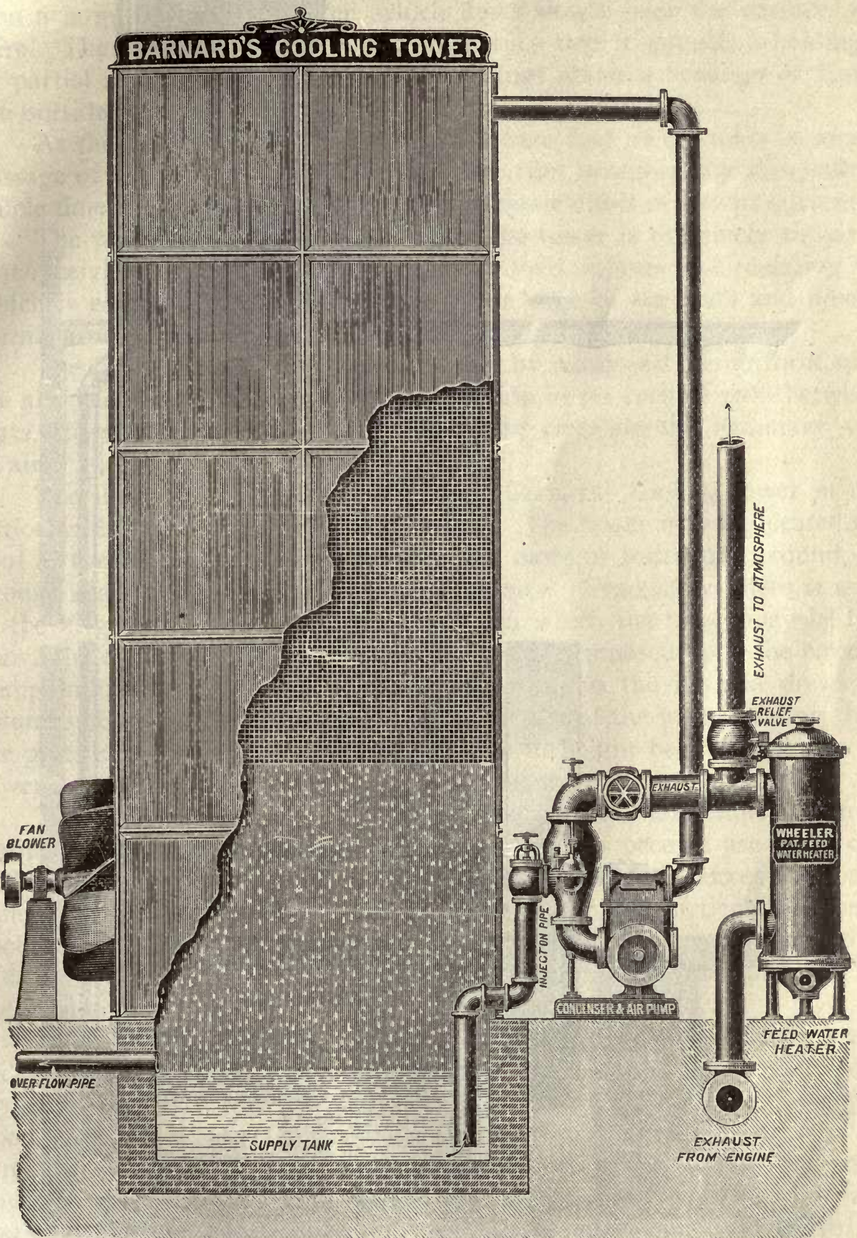


Fig. 20.—Barnard Cooling Tower in Combination with Jet Condenser.

The "Barnard" cooling tower is in a class by itself. It is constructed of steel plate, but may be built of brick or wood, as it is only a receptacle for the "mats" and system of water distribution.

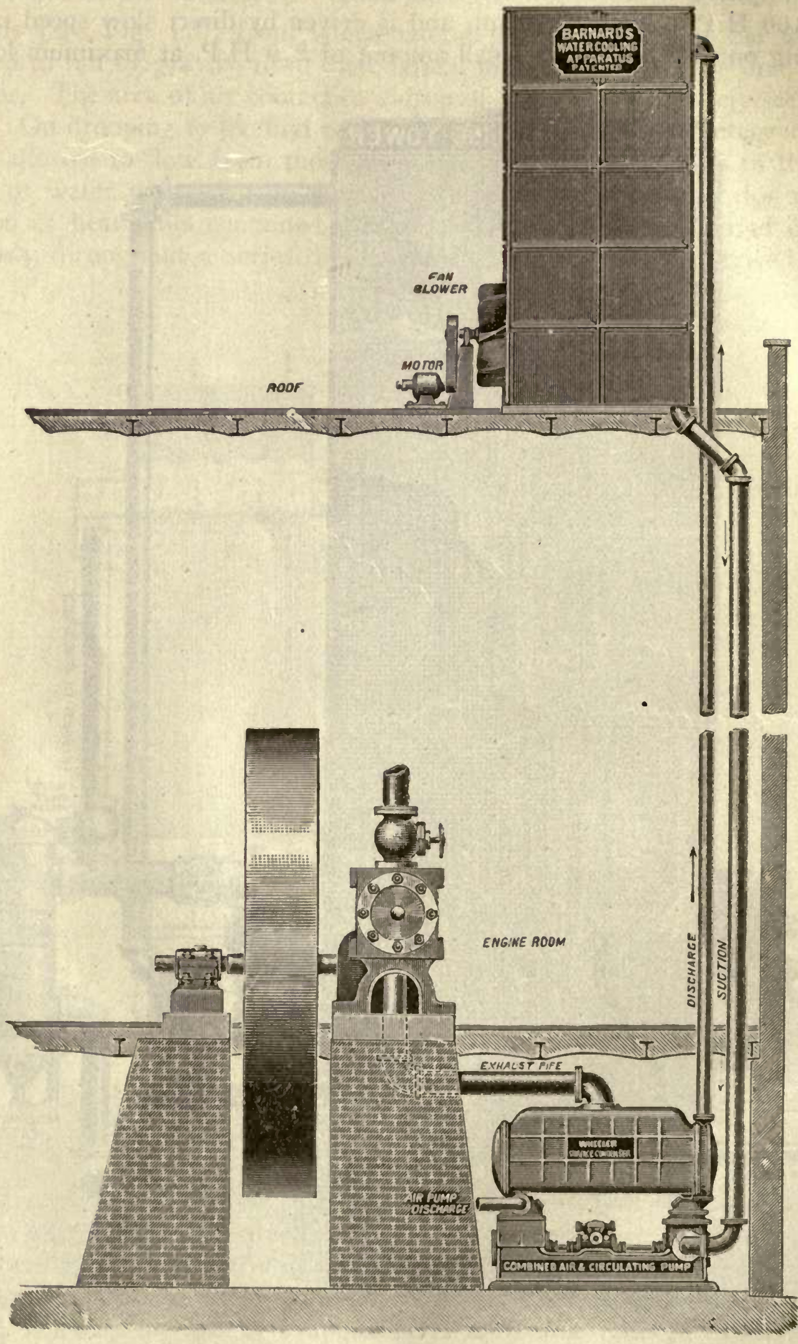


Fig. 19.—Barnard Cooling Tower in Combination With Surface Condenser.

The sectional views (Fig 18) show the rectangular form, within which are suspended vertically, and properly spaced, the required number of mats.

These mats are made of special steel wire cloth, galvanized after weaving. This arrangement is said to have proven in practice to be an ideal one, as the mats are practically a metallic sponge capable of holding in semi-suspension a large quantity of water, which flows slowly over the surfaces of the wire. The formation of the wire cloth is such that it compels a holding back or partial interruption of the flow and brings about a "change of front" to the outside films of water.

As the quantity of water held by a square foot of the mats is small, the passage of the water over and through the mats is necessarily slow, affording ample time for the evaporative and refrigerative effect of the air currents.

The water distribution at the top of the tower is extremely simple, each mat receiving its proper proportion of the total volume of circulating water, which is equally distributed over the upper edge of the mats and flows uniformly from top to bottom.

The fan is placed below the mats, and by reason of the uniform spacing, the air meets with a minimum of obstruction in its vertical path between the mats, thereby requiring but little power to circulate the necessary volume of air.

The illustration (Fig. 19) shows a "Barnard" cooling tower in combination with a Wheeler condensing system. The tower may be located on the roof of the building or other place elevated more or less above ground, where ground space is not available, or too expensive. Practically, there is no limit to the height of a building, or structure, on which the tower may be located above the condenser, as the only additional duty imposed upon the circulating pump in lifting the water to the roof, owing to the up and down water columns being balanced, is caused by the friction of the water passing through the pipes and condenser, and the difference in height between the top of the tower and the reservoir or tank at base of same.

The Wheeler surface condenser, fitted with independent pumps, is claimed to be well adapted for this service and has been in use for a considerable time. The manufacturers are referring to plants in successful operation sufficiently long to demonstrate its unqualified success, particularly where the cooling towers were placed on the top of high buildings, and where there is a difference of fully 90 feet between the Wheeler condenser and the top of the Barnard cooling tower.

In Fig. 20 the Barnard cooling tower is shown in combination with an independent air pump and jet condenser, the tower being located on the ground. In most cases the air pump, under the jet system, can be depended upon to maintain a fairly good vacuum, say from 22 to 24 inches, and at the same time elevate the water to the top of the tower. It is not possible, however, to load the air pump with this double duty and obtain as high vacuum and maximum efficiency as would result if the air pump was confined to its legitimate duty and the work of elevating the water was performed by a water cylinder attached to the air cylinder or by a separate pump. In the interest of higher duty and lower cost of operation, it would seem advisable to use the three-cylinder type of direct-acting pumps, which is employed in combination with the Wheeler surface condenser, previously described. With

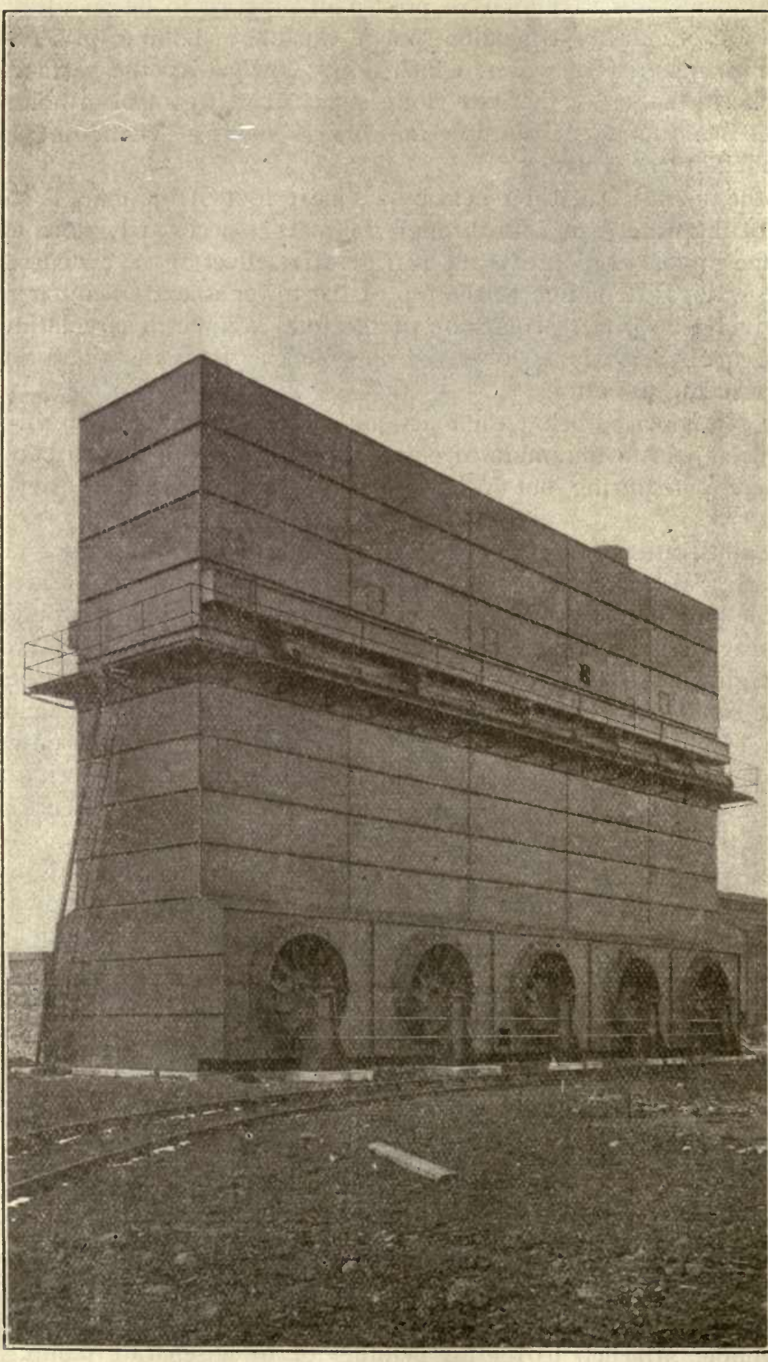


Fig. 21.—Battery of Barnard Cooling Towers at Liverpool, England.

this arrangement a much better vacuum can be maintained and at no extra expense for power. A battery of five of these towers operating at Liverpool, England, is illustrated in Fig. 21.

A novel feature is embodied in the Worthington cooling tower, which deserves careful study. The sectional view (Fig. 22) shows a cylindrical steel

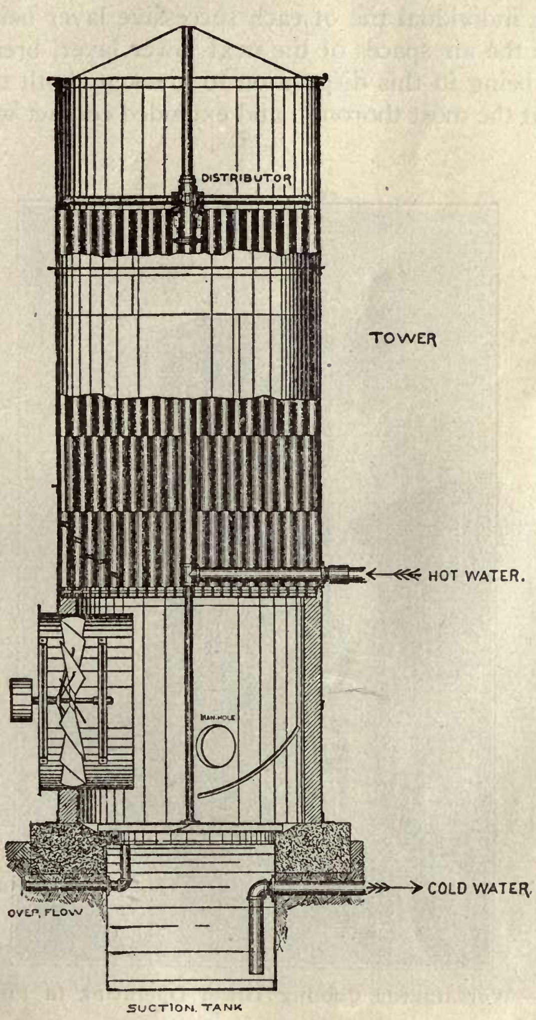


Fig. 22.—Sectional View of Worthington Cooling Tower.

shell open at the top, supported upon a suitable foundation, and having fitted at one side the fan, which circulates the current of air through the tower and its filling. This filling consists of layers of cylindrical tubular tiling, which rests upon a grating supported by a brick wall extending around the circumference of the tower. The heated discharge water from the condenser enters the tower at the side, passes up the central pipe, is delivered on the upper layer of tiling and over the whole cross-section of the tower by a distributing device consisting of four pipes, which are caused to rotate about the central water pipe by the simple reaction of the jets of heated water issuing from one side of each pipe. The water thus delivered spreads over the outside and inside surfaces of the walls of the tiling, and forms a continuous sheet, which is presented to the action of the air. The tiling are placed on end in horizontal layers, one upon the other, and packed as closely as possible, the walls of each individual tile of each successive layer being disposed so as to come opposite the air spaces of the next lower layer, breaking joints, as it were, the object being in this disposition to break up both the currents of air and water, so that the most thorough and extended contact will take place.

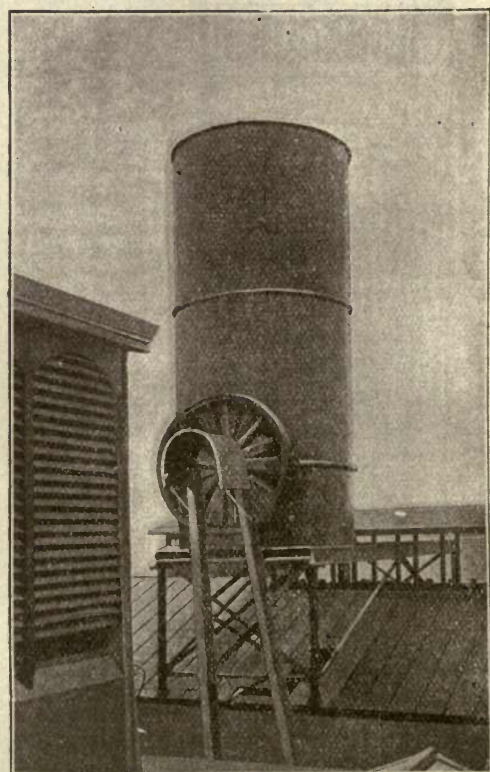


Fig. 23.—Worthington Cooling Tower Operating in Power Plant.

If there are ten layers of tiling in a tower, then there are nine places, in addition to the original spreading at the top, at which there is a complete distribution of the water. It will be seen that each tile must rest on at least two, and possibly three in the next lower layer. Assuming, however, that each tile rests on only two others, a given quantity of water, placed on any one tile in the top layer, will be divided over at least two tiles in the second layer, three in the third, four in the fourth, and so on, until it becomes spread over fifty-four in the lowest layer on the grating.

The air is distributed in an equally good manner, and there is a large, free area with equal facility for its passage upward over the entire cross-section of the tower.

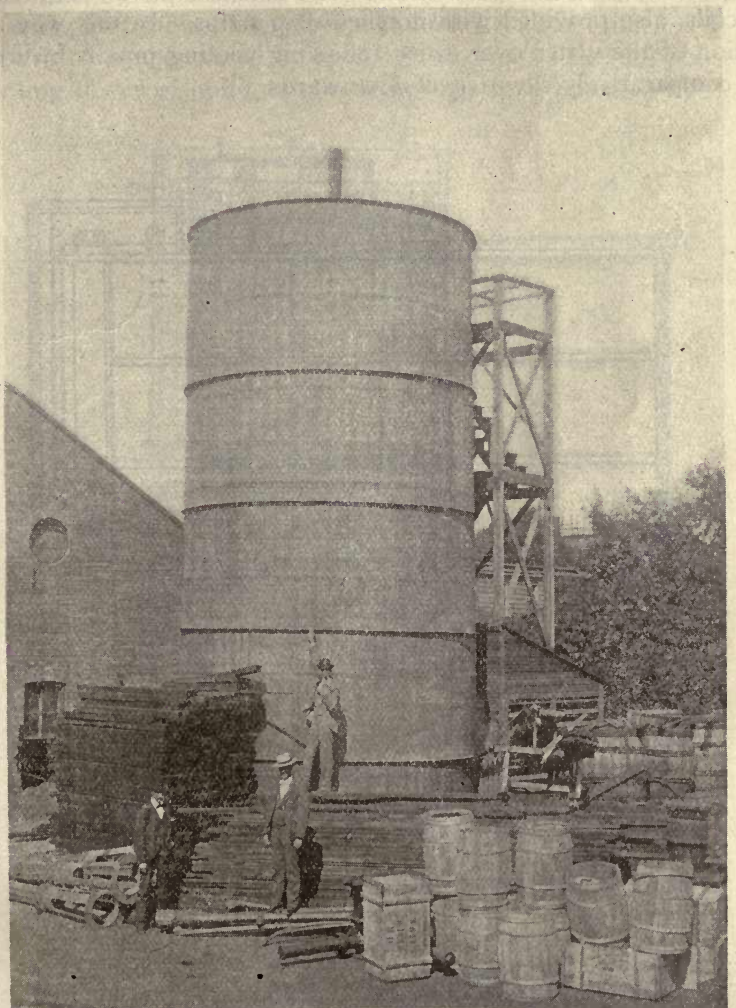


Fig. 24.—Worthington Cooling Tower Operating in Refrigerating Plant.

Figs. 23 and 24 show the Worthington cooling tower as it is connected to a power plant and a refrigerating plant respectively. The same tower in combination with the pumps and engines of a modern office building is illustrated in Fig. 25.

Chas. H. Leinert's "Only" cooling tower (Fig. 26) is, as far as we know this tower, indeed the only one of this particular construction. Whether it is the only efficient one, has to be proven by its maker.

The tower is of the closed type and built entirely of iron, no wood being used. The manufacturers claim that a high efficiency is obtained by a peculiar combination of natural and mechanical draft.

The hot water enters a main trough on top of the tower, from where it is distributed into galvanized iron gutters by means of short vertical pipes. The gutters are provided with notches and are set over a large number of cooling coils, also provided with notched drip strips. In this way a uniform distribution of the water over every following cooling pipe is insured, resulting in a comparatively slow travel downwards.

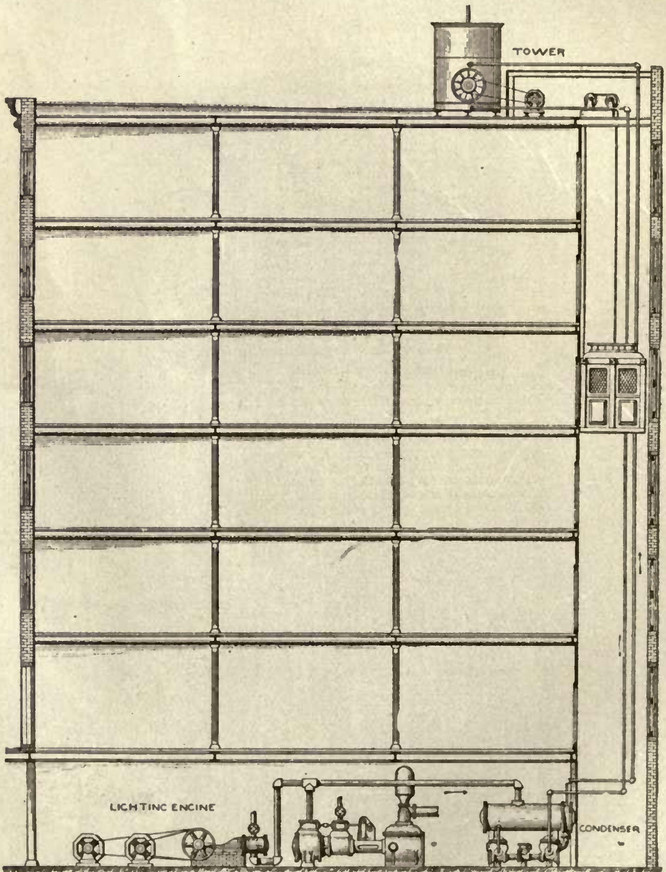


Fig. 25.—Worthington Cooling Tower on Roof of Modern Office Building.

Half way down, the cooling pipes are set at right angles to the upper pipes in order to produce an equal cooling effect of the water in all parts of the tower and to allow the air to absorb all vapor.

The great advantage of this tower is, that the water is not only cooled by the air delivered by the fan but also by the outer air. The galvanized cooling pipes extend through the shell of the tower and a natural flow of air through the pipes takes place on account of the difference in temperature of the outer and inner surface of the cooling pipes. This air partly removes the sensible heat of the hot water flowing over the pipes. This arrangement however, complicates the construction of the tower, as each end of the pipes has to have a stuffing box to avoid leakage.

The manufacturer claims that the fan need only be used during the hot summer months, as experiments have shown that the natural draft through the fan opening and the cooling pipes will cool the water sufficiently, while an additional draft may be caused by opening the door of the fan house.

A cooling tower of quite unique design has been patented by A. Siebert,

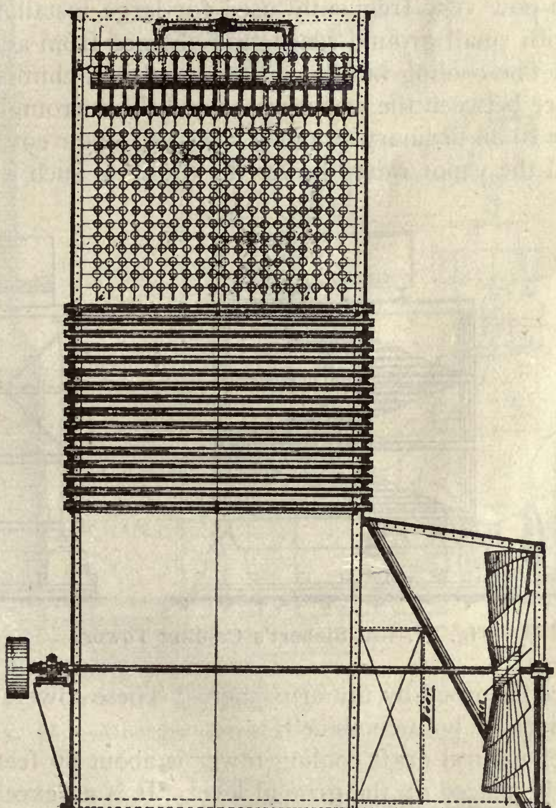


Fig. 26.—The "Only" Cooling Tower.

St. Louis (see Fig. 27). It consists of a framework, with four columns and with channel beams fastened to them on both sides, further securely tied by tie rods on the narrow side and sideplates of cast-iron on the long side. The whole tower is made of iron, no wood being used or soldering done.

The sheets, over which the water is run and air is passed in a thin film and at high pressure, are placed in an angle of 22½°, and are 10 feet long and formed in several zigzags, so as to revert the current of the water just as many times; the sheets are made of galvanized corrugated sheet iron. The angle is so selected that no water is standing in depressions and yet the flow of water retarded very much, as it has to rise and fall 1/8 inch every 1¼ inches. This makes the water flow in the thinnest possible film without sputtering, and induces evaporation without carrying water particles along.

The air is passed over the outer and lower edge of the sheets rapidly and in a thin film, following the corrugations, and therefore can thoroughly and quickly exchange heat with the water. For it is evident that both sides (top and bottom) of the corrugated sheets transmit heat, one from the air through the very thin galvanized iron and finally to the water, and the other being covered with water to it direct.

Natural Draught Chimney Type.

This type is now very frequently used for large installations, as it combines low cost with small ground space, and absence from any nuisance from vapor or spray. The cooling hurdles are enclosed in a chimney, and the temperature difference between the warm water and the surrounding air produces a draught similar to an ordinary chimney stack. The air enters at the bottom of the tower, and the vapor raised leaves the cooler at such a height that it is

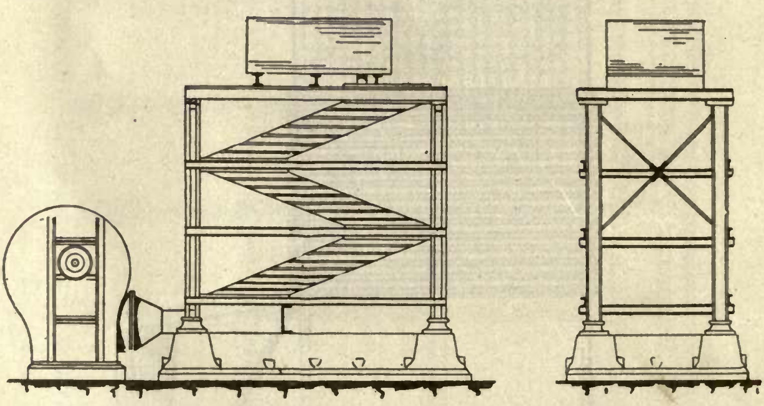


Fig. 27.—A. Siebert's Cooling Tower.

practically at once absorbed by the atfosphere. These towers are built either totally of wood, iron or both combined.

The Alberger natural draft cooling tower is about 80 feet high, and consequently should be placed on the ground level. It is an excellent machine to use when it is desirable to convey the vapor from the tower above adjoining buildings, or where the tower must be at some distance from the engine room and such a location renders inconvenient the transmission of power to the fan of a fan tower. The arrangement of filling is at the extreme bottom of the tower, and air is allowed to enter around the piers that support the structure of the tower. The distributor is the same as that used with the fan towers, and the stack is connected to the top of the tower by means of a conical section, as illustrated in Fig. 28.

It will be seen that the circulating pump comprises hot and cold water pumps, operated by the same steam end. The cold water pump derives its supply of water from the cold well of the cooling tower and discharges into the barometric condenser, being assisted by the vacuum in the latter. The water there condenses the exhaust steam from the engines and falls down the barometric tube against the atmospheric pressure to the hot well; from the latter it is removed by the hot water pump and discharged to the distributor of the cooling tower. After falling through the cooling tower and becoming cooled by the evaporation caused by contact with the ascending air, it finally reaches the cold well cooled for re-use in the condenser.

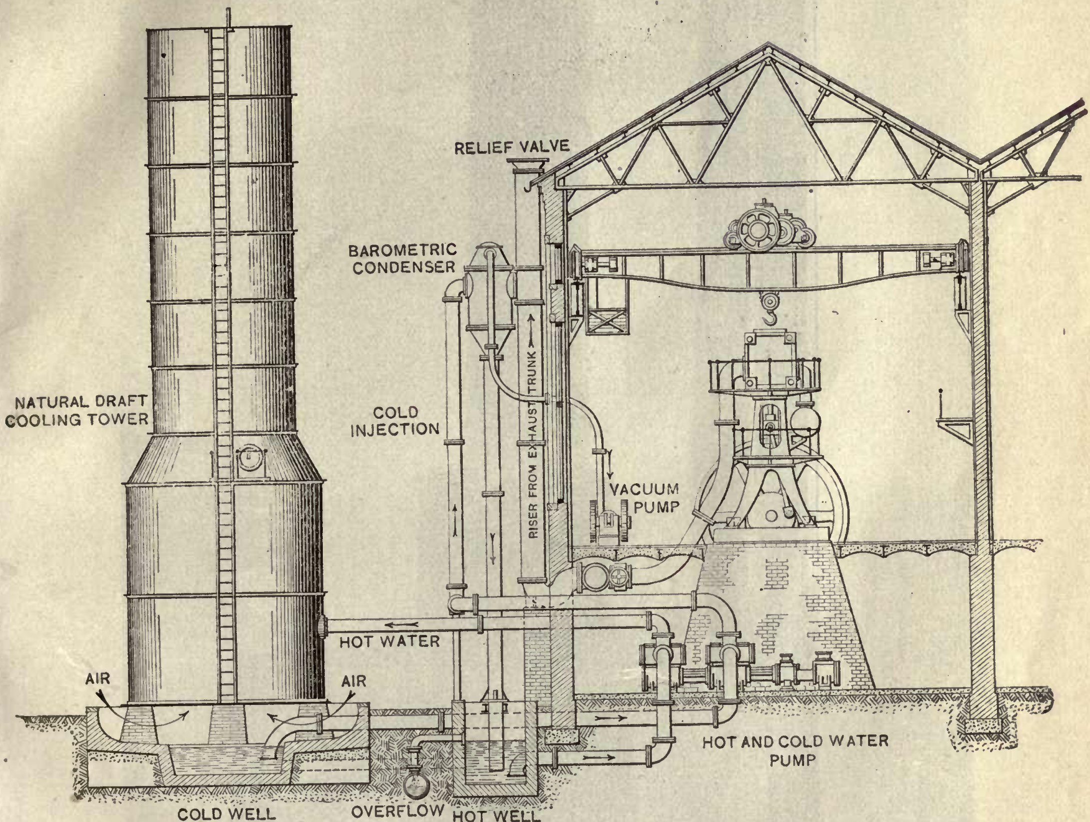


Fig. 28.—Alberger Natural Draft Cooling Tower.

The Barnard-Wheeler water cooling tower is also built as a natural draft chimney type, as will be seen from the illustration (Fig. 29). It differs in its essential features in no respect from the forced draft type, which has been described above, with the exception that the fan has been omitted and a stack attached to the tower, to induce natural draft.

In illustration (Fig. 30) we recognize the old rain cooler, illustrated as Fig. 3. The cooler is operated in combination with a condensing system, and consists of the condenser, the rain cooler, and the draft chimney. This design is a German one, and, characteristic to this nation, combines an efficient cooling arrangements with beauty in design.

The Worthington cooling tower is also built as a natural draft tower, and as such is illustrated in Fig. 31. The construction of the tower is practically the same as the fan tower, except that the circulation of the air is caused by the draught produced by the stack placed above the filling of the tower. The air enters at the bottom around the periphery of the tower, passes up through

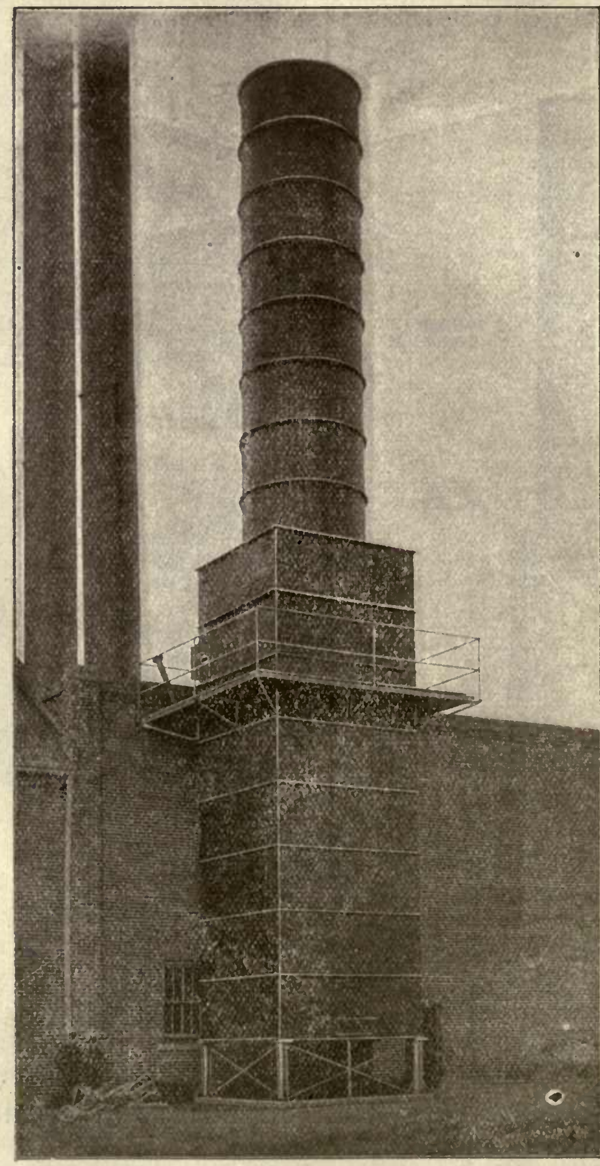


Fig. 29.—Barnard Natural Draft Cooling Tower.

the filling, and there meets and cools the circulating water and passes up and out through the stack. The stack is so proportioned as to give about the same velocity and quantity of air as with the fan tower, and the results are claimed to be equally good as regards the cooling effect.

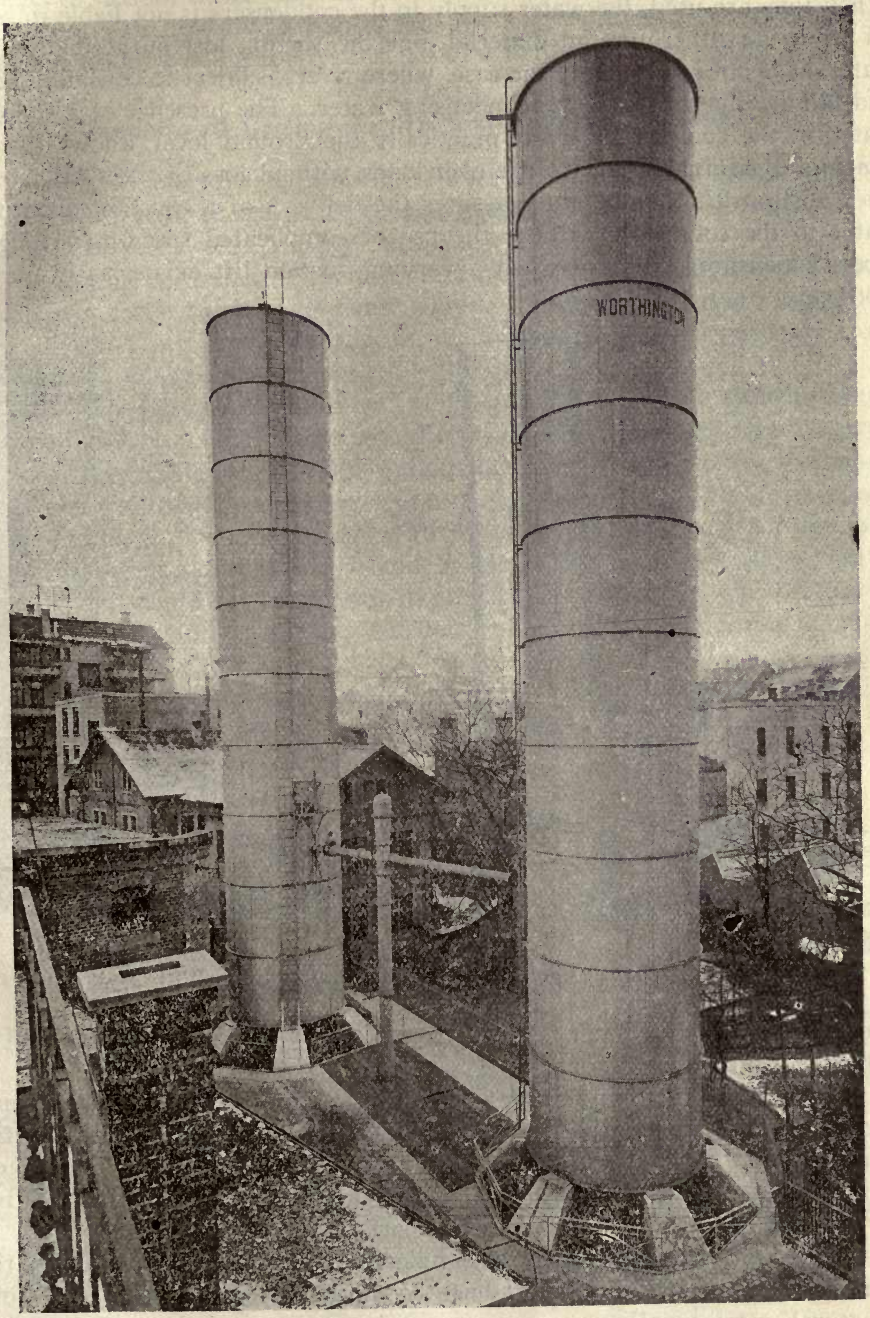


Fig. 31.—Worthington Natural Draft Cooling Tower.

Advantages of a Cooling Tower.

Cooling towers possess operative advantages of considerable importance. When they are used, the water supply to the condensers is not liable to be cut off by ice or other foreign material, nor the suction lost on account of low water, as is not infrequently the case, where rivers, subject to considerable rise and fall are the source of the condensing water. The presence of a supply of water in the cooling tower, at practically the ground level, allows the condensing apparatus to carry large over-loads without loss of the suction. The fixed suction lift thus obtained assures the delivery of a constant quantity of water to the condenser without the use of complicated speed-governing devices, which are necessary when a varying suction lift exists, as is the case

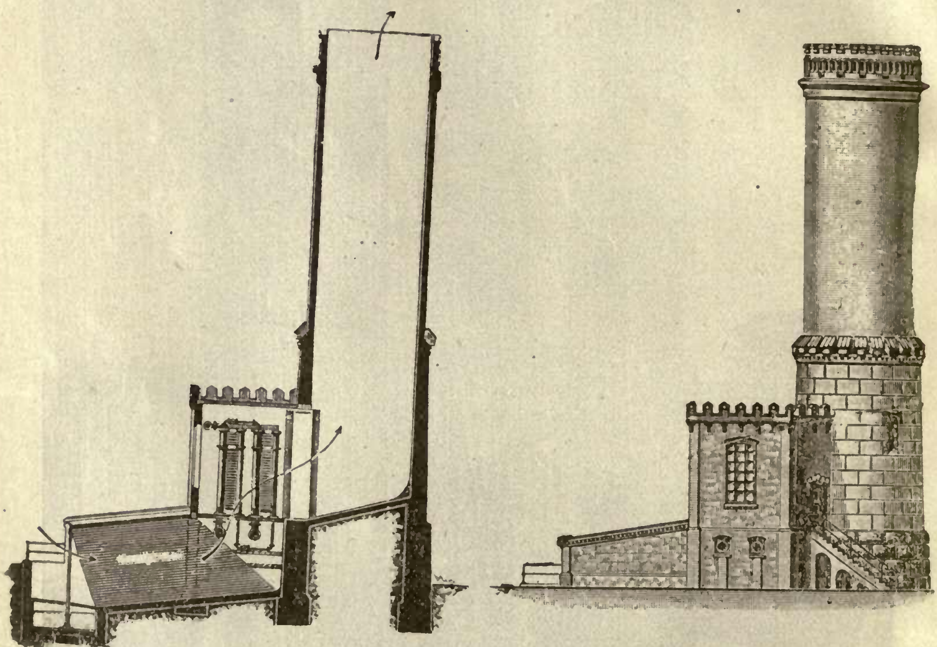


Fig. 30.—Natural Draft Cooling Tower in Combination With Rain Cooler.

where the condensing water is taken from a source subject to rise and fall due to tide or climatic conditions.

Freedom from foreign material permits of the use of a more complete spraying device in the condenser, and a higher efficiency follows; furthermore, the durability of the condenser is enhanced as the water usually contains the oil from the cylinder lubrication of the main engines, and is free from any material that can wear the moving parts.

The use of cooling towers also relieves the condenser and pumps from corrosive action caused by the presence of salt and some chemicals often found in natural water supplies.

It is these and other seemingly small points that when grouped together have proved very valuable to the every-day running of a steam plant. There is nothing so objectionable as the loss of a vacuum through the stoppage of the water supply. Even if the station can carry the load with the engines running non-condensing, they will be at a great disadvantage and will usually show harshness of action, which may result in a serious disarrangement. A single occurrence of this kind more than offsets any slight difference of steam economy by the use of cooling towers instead of a natural water supply.

Economy of Cooling Towers and Results in Cooling.

There is, of course, a certain loss of water by evaporation, but this rarely exceeds ten per cent. of the water cooled, while under favorable conditions of the air it does not exceed five per cent.

The saving of water is, therefore, from ninety to ninety-five per cent., and where a large condensing plant would, for instance, require 1,000,000 gallons of water per day, it will by use of the cooling towers need only from 50,000 to 100,000 gallons per day.

Take city water at 10 cents per 1,000 gallons, 1,000,000 gallons would cost $100, while 100,000 gallons would cost only $10, thus effecting a saving of $90 per day. About 1,000,000 gallons per day are needed for the steam condensers of a 500 horse-power condensing engine. A 500 horse-power non-condensing engine would require about nineteen tons of coal per day, and running condensing the saving would be about five tons of coal, which at $3.50 per ton would be $17.50 per day. Condensing water with the use of cooling towers would cost $10 100,000 gallons), the net saving equaling $7.50 per day, or $2,700 per year.

The following data are supplied by the Ruemmeli-Dawley Mfg. Co., and show the results in cooling obtained by the use of cooling towers:

For ammonia condensers, with the air at 95° F. and 37 per cent. humidity:

Initial temperature of water entering cooling tower	100° F.
Final temperature of water leaving cooling tower	71° F.
Result in cooling	29° F.

For steam condensers, with the air at 95° F. and 44 per cent. humidity:

Initial temperature of water entering cooling tower	160° F.
Final temperature of water leaving cooling tower	81° F.
Result in cooling	79° F.

The tables below give a series of tests at different temperatures and different degrees of humidity of the air.

The International Steam Engineering Co., of New York, has conducted a series of tests on their cooling tower, which has been described above. The table given elsewhere shows the results of these tests, which indicate a remarkably high efficiency.

Capacity and Size of Cooling Towers.

When we consider the requirements in a power plant, we will see that the work of a cooling tower lies in abstracting sufficient heat from the circulating water to reduce its temperature enough to use it again in the condenser.

FOR AMMONIA CONDENSERS.

Temperature of Air in the Shade.	Humidity of the Air.	Temperature of Warm Water.	Temperature of Cooled Water.
95°	37 per cent.	100°	71°
84°	67 per cent.	100°	75°
77°	40 per cent.	100°	61°
70°	48 per cent.	90°	60°
91°	42 per cent.	86°	72°
88°	42 per cent.	86°	68½°
80°	70 per cent.	85°	71°

FOR STEAM CONDENSERS.

Temperature of Air in the Shade.	Humidity of the Air.	Temperature of Warm Water.	Temperature of Cooled Water.
95°	44 per cent.	160°	81°
95°	41 per cent.	140°	79°
94°	43 per cent.	120°	76°

This means a reduction from about 120° F. to 80° F., when a vacuum of about 25 inches is to be maintained. Vacuum results are measured, aside from the air displacement, by the quantity and temperature of the cooling water. When the temperature is low, the quantity required is correspondingly small. The question becomes one of proportion, and the ratio of water to that of exhaust steam to be condensed is determined by the following formula:

$$R = \frac{H - T_1}{T_1 - T_2}$$

Where H = total heat in exhaust steam.
T_1 = temperature of discharge.
T_2 = temperature of suction.
R = ratio.

With conditions mentioned above, this would be—

$$\frac{1150 - 120}{120 - 80} = 25.7.$$

Or, 25.7 lbs. of cooling are required to condense each pound of exhaust steam to maintain a vacuum of 25 inches when the temperature of the circulating water is 80° F.

In order, now, to find the amount of cooling water required per hour per horse-power of engine, we must first determine what kind of engine is to be used, as on this depends the steam consumption.

The following table shows the average operation of a steam engine for one horse-power per hour:

A direct acting steam pump uses 120 lbs. steam per H.P. per hour.

A plain slide valve engine uses 60 to 70 lbs. steam per H.P. per hour.

A high speed automatic engine uses 30 to 50 lbs. steam per H.P. per hour.

A Corliss simple non-cond. engine uses 25 to 28 lbs. steam per H.P. per hour.

A Corliss comp. non-cond. engine uses 23 to 26 lbs. steam per H.P. per hour.

A Corliss simple condensing engine uses 19 to 21 lbs. steam per H.P. per hour.

A Corliss compound condensing engine uses 13 to 15 lbs. steam per H.P. per hour.

When it is taken into consideration that the average boiler will evaporate 8 lbs. of water per lb. of coal, it is very easy to determine how much coal is required and how much can be saved through the operation of the condensing system attached to a simple or compound engine.

Upon the quantity and terminal temperature of the circulating water is based the area of surface necessary in the tower to cool the water. The apparatus will handle to good advantage only that quantity for which it is designed. Greater quantities lessen its efficiency. For best results the attendant should regulate the speed of his pump in order to deliver the proper quantity of water required to meet the varying conditions.

By determining the necessary proportions of a cooling tower installation, the following data may be used to good advantage:

TOWERS WITH INJECTOR.—The pressure required for the jet is from 48 to 66 feet. Two sizes of injectors are commonly employed. The capacity of the smaller one, which is 5/8 inch in diameter, is from 10½ to 12¾ cub. m. per hour, covering a spray surface of from 5 to 7 sq. m., and resulting in lowering the temperature of from 30° to 35° C.

The large injector of ¾-inch diameter will handle from 14½ to 18 cub. m. per hour, covering a spray surface of from 7 to 10 sq. m., and lowering the temperature 30 to 38° C.

The cooling surface may be calculated as follows: About 0.3 sq. m. to cool 20 to 30° C for one H. P. of comp. cond. engine. About 0.1 sq. m. to cool 10 to 15° C. for one H.P. of comp. cond. engine.

Towers with injectors are expensive to operate, as the work of the pump consumes about 3 to 4 per cent. of the engine.

NATURAL DRAFT TOWER.—The cooling of the water depends, as has been outlined before, on atmospheric conditions and amount of water. The required surface may be taken on the same basis as for towers with injectors.

FORCED DRAFT TOWER. The cooling surface may be taken to about 0.035 sq. m. for one H. P. of comp. cond. engine. The suction of the fan is about ¼ inch. For lifting the water and running the fan about 4.5 to 6 per cent. of the engine are consumed, which makes the operation quite an expense when compared with the other systems, but which is greatly counterbalanced by obtaining constant and positive results and saving in the first cost of installation.

The dimensions of a Worthington cooling tower are about as follows: An apparatus suitable for 1,000 horse-power is 17 feet in diameter and 30 feet high. The suction tank, which is placed directly under the tower and in the foundation, is 8 feet in diameter and 7 feet deep, and contains about 2,000 gallons of circulating water, this being a sufficient quantity to fill the condenser pump, pipes and tower on starting up, and to carry on continuously the transfer of heat from the exhaust steam to the atmospheric air.

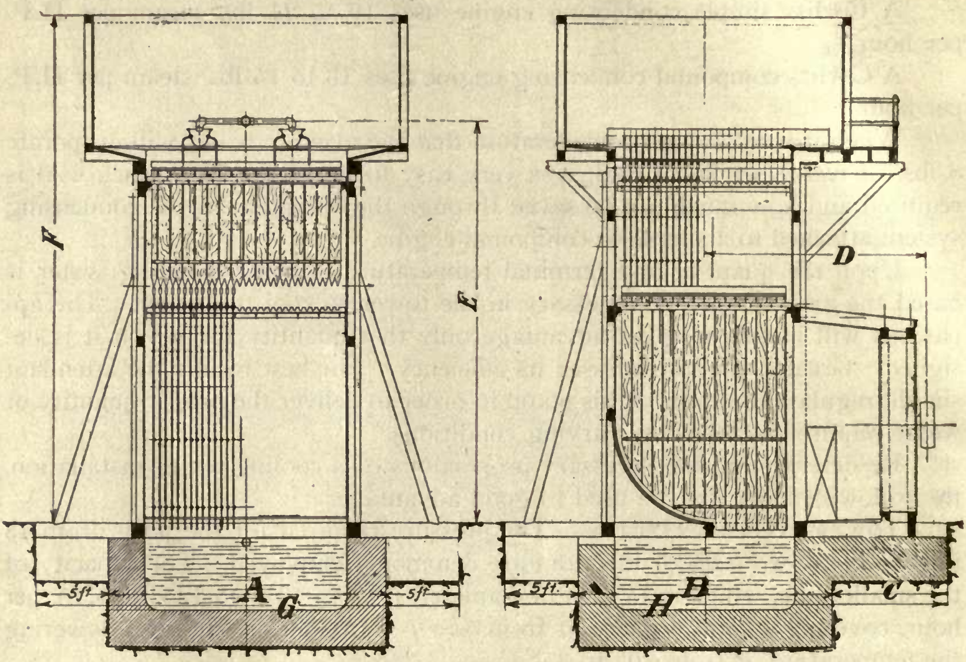


Fig. 32.—Views of Cooling Tower Giving General Dimensions (See Tables.)

As the forced draft tower seems to have met with general favor, it has become desirable, when figuring on installing cooling towers, to have some tables to go by in laying out a plant, and for this reason we will append here a few tables, stating general dimensions, capacity, size of fan, etc., of the fan cooling towers, as manufactured by the Ruemmeli-Dawley Co., of St. Louis, and the De La Vergne Machine Co., of New York.

Size and Weight of Cooling Towers.

No. of Tower.	MAIN DIMENSIONS.								Weight in lbs.
	A	B	C	D	E	F	G	H	
I	8′11½″	8′ 6½″	6 ft.	9′ 1″	24′ 9″	32′	18′11½″	19′ 6½″	25,000
II	9′ 9½″	8′11½″	6 ft.	9′ 3″	24′ 9″	32′	19′ 9½″	19′11½″	28,500
III	10′ 2¾″	9′ 9½″	6 ft.	9′10″	24′ 9″	32′	20′ 2¾″	20′ 9½″	32,000
IV	11′ 5½″	10′ 7½″	7 ft.	10′ 4″	24′ 9″	32′	21′ 5½″	22′ 7½″	39,000
V	13′ 3½″	12′ 5½″	7 ft.	11′ 4″	24, 9″	32′	23′ 3½″	24′ 5½″	46,000
VI	14′ 6¾″	13′ 3½″	7 ft.	12′ 6″	25′ 8″	32′ 9″	24′ 6¾″	25′ 3½″	53,000
VII	16′ 4¾″	15′ 1½″	7 ft.	13′ 4″	25′ 8″	32′ 9″	26′ 4¾″	27′ 1½″	59,000
VIII	17′ 7½″	16′ 4½″	8 ft.	14′ 9″	27′ 4″	34′ 7″	27′ 7½″	29′ 4½″	65,700
IX	18′10¾″	17′ 2½″	8 ft.	15′ 3″	27′ 4″	34′ 7″	28′10¾″	30′ 2½″	71,700

Cooling Capacity of Cooling Towers.

Cooling capacity in gallons in 24 hrs. for:	Cooling Capacity in Gallons in 24 hours for: Ammonia CONDENSERS	Steam	H.P. of comp. cond. engine supplied with condens. water.
I	50,000	100,000	50
II	75,000	150,000	75
III	100,000	200,000	100
IV	150,000	300,000	150
V	200,000	400,000	200
VI	250,000	500,000	250
VII	300,000	600,000	300
VIII	400,000	800,000	400
IX	500,000	1,000,000	500

Size of Fans.

No. of Tower.	Size & Number of Fans.	Size of Pulley.	Revol. of Pulley per minute.	H.P. for Fans.
I	1— 6ft.	15"x 8"	100—125	1 — 1½
II	1— 6ft.	15"x 8"	150—170	1½— 2
III	1— 7ft.	18"x 9"	140—150	2 — 2½
IV	1— 8ft.	24"x 9	140—150	3½— 4
V	1— 9ft.	28"x10"	130—140	5 — 6
VI	1—10ft.	30"x11"	130—140	7 — 9
VII	1—10ft.	30"x11"	145—150	10 —12
VIII	1—12ft.	36"x12"	110—120	13 —15
IX	1—12ft.	36"x12"	140—150	16 —20

LOG READINGS OF "ACME" COOLING TOWER.

By B. F. HART.

From a paper read before the American Society of Refrigerating Engineers.

The readings shown below were taken at the Arnholt & Schaefer Brewing Company's plant, Thirty-first and Thompson streets, Philadelphia, Pa., from an "Acme" self-cooling tower measuring 14′ x 18′ x 35′ high.

There are five (5) decks of spraying pans placed 7′ apart, the pan surface on the top deck being 77 square feet. The tower was designed to cool 250 gallons of water per minute, guarantee being to reduce the water to 80 degrees F. when the temperature of the atmosphere did not exceed 80 degrees F. nor the relative humidity 80 degrees.

These readings show observations taken daily and covering the months of July, August, September and half of October and show that this tower was doing excellent work.

The tower is placed on an exposed corner of the building, directly over the ammonia condensers. The water is caught by a concrete collecting pan lined with asphalt. The discharge water from the condensers drops to a 3″ American Well Works belt-driven centrifugal pump, the pump discharging to the top of the tower, a point 65′ above same. The horse-power necessary to run this pump is 7.8. The cooling tower, therefore, is doing its work and a glance at the results show that the average temperature of the water leaving the tower throughout the month of July was 79.1 degrees F., during August it was 79.4 and during September it was 68.7 degrees, so that this plant produced an ample quantity of cold water throughout the heated season without the use of fans and with the total expense of operation of 7.8 H.P. per hour for driving the centrifugal pump. The pump in this case was placed so far below the condenser for the reason that an engine was available at that point to drive it.

DISCUSSION ON COOLING TOWERS AT THE MEETING OF THE A. S. R. E., 1906.

EDGAR PENNEY: May I ask the capacity of the tower you mention per hour?

B. FRANKLIN HART, JR.: Two hundred and fifty gallons per minute.

EDGAR PENNEY: What is the number of pounds or gallons of water you lost through evaporation, etc.?

B. FRANKLIN HART, JR.: We had no way of measuring that, because we had no meters. They are quite expensive things to put in. We know that the only water lost was from evaporation, and such as might sometimes be blown off the tower in the form of spray.

EDGAR PENNEY: You do not know how much water you handled?

B. FRANKLIN HART, JR.: We know from our figures that we were handling from two hundred to two hundred and fifty gallons per minute.

ALBERT A. CARY: I would like to ask Mr. Hart what form of hygrometer was used in those tests?

B. FRANKLIN HART, JR.: A wet and dry bulb hygrometer. We made the calculations from the table.

ALBERT A. CARY: Were the wet and dry bulbs placed against the wall of the building?

B. FRANKLIN HART, JR.: The readings were taken in the condenser room where it was all open. The condensers were placed on what had formerly been the roof of the building, but the walls had been carried up for an extension and the tower placed on it. The roof was open, except for the tower, and the hygrometer was placed so it was handy for the engineer.

ALBERT A. CARY: I asked the question with the point in view that the water tower depends a great deal upon the humidity in the atmosphere; that is a very important matter in obtaining data concerning efficiencies, and if we wish to use the data for future references, it is very necessary for us to know the true humidity of the air. The ordinary hygrometer screwed against the wall, with no disturbance of air surrounding it, does not give true readings.

The Weather Bureau of the United States Government found that to be true, and they use an instrument which I think they call a psychrometer. It is a wet and dry bulb placed on a board, and when made to revolve rapidly the dead air will not collect around the bulb as of an ordinary thermometer. In reading the hygrometer when placed against the wall, I found that it is well, if you have no better conditions, to take a fan and fan it until your reading becomes stationary. You will then find a change of reading on your wet bulb. If it can be placed in the current of an electric fan, then you get much better and truer results, but the information is so important in the study of cooling towers that this matter must be taken into consideration.

B. FRANKLIN HART: As Mr. Cary says, the relative humidity is the key to the whole situation, and we were as careful as we could be in ordinary practice. Of course, it was simply a commercial hygrometer which was used, and there was no special precaution taken in the way of testing or anything of that kind, but, as he says, the humidity is the main thing.

JOHN E. STARR: Another experience with the water tower is in regard to the precipitation of solids; theoretically, at least, the efficiency of the tower, of course, depends on evaporation. The water so evaporated does not, of course, carry with it any of the solids that may have been in suspension in the water. Hence, the expectation would be that, in course of time, with additions of water, the water being cooled would become rich in solids in suppression. It would seem that the solids could not get away by evaporation, and hence they must either remain in the water or be deposited in the piping of the apparatus. I suppose that in an open condenser this feature may not be a very bad one, but in the enclosed type of condenser, or perhaps in spiral piping, it might be worse, and I would like to know if Mr. Hart has any data on this subject, or whether any of the other members have noted any bad effects in this direction.

B. FRANKLIN HART, JR.: Of course, as Mr. Starr says, the deposits would precipitate. All that would come down at the temperature of the water, and I have come in contact with cases where the water used was very heavily laden with carbonates of lime and magnesia, so much so that when the water was used solely as a cooling medium the precipitation was so great that in a few months it filled up all the outlets and passages, and filled up the sewers so that the city officials complained. The tower was put in to help this. In this case the condenser was submerged, so that the only annoyance they had after the tower was in use, that they had to sweep the tower quite often to get rid of the small accumulation which would deposit in the pans, which would be due to the make-up water, which was in the neighborhood of five per cent.; but the deposit on the pipes in the submerged condensers was very great, and it had to be pounded off every once in a while to keep the system going. I think the same people who did that will, in another installation, have to cut out the use of well water entirely and get necessary make-up from the city main.

HENRY W. MAURER: The instrument that Mr. Cary described is quite familiar to refrigerating men, and you will probably recognize what Mr. Cary is driving at. Possibly in ice making plants no occasion is had to use a psychrometer, nevertheless, the device has been on the market a good many years, and has been found very efficient for exceedingly close determinations of moisture, which you are aware, of course, exists.

THE PRESIDENT: Perhaps Mr. Burhorn will give us a word or two on cooling towers.

EDWIN BURHORN: I have not as good a test plant as Mr. Shipley speaks about, and I have not experimented long enough to be able to present anything that I think would be interesting to the society, but I might state that in one of the tests we are making we are using recording thermometers, which record the temperature of the water going through the tower, and coming from the tower every minute of the twenty-four hours. Now, in Mr. Hart's tests I do not know how often he took his readings, but the conditions vary so much during the day that it is quite important to know whether the readings were taken at the most favorable or unfavorable time in order to get a fair average determination. We also find that we can cool the water from a high temperature, say one hundred and thirty or one hundred and forty degrees, down to atmospheric temperature, and the thermometric cooling depends also on the way the tower is designed to a great extent; that is, the amount of water distributed per square foot of tower. The efficiency also varies with the capacity of the tower. A small tower is more efficient per square foot than a large tower, and all those points cannot very well be determined theoretically. It is a matter of practice, and we are trying to find out those things, and as soon as we get it in shape we exject to present it to the society, and we hope it will be of interest.

E. N. FRIEDMANN: I would like to ask a question. How would he arrange a cooling tower in the case where an ammonia condenser is used, and a steam or surface condenser, where the temperature would be one hundred and thirty or one hundred and forty degrees? Would he use one or two cooling towers; one for the ammonia and one for the steam condenser?

B FRANKLIN HART, JR.: In answering Mr. Friedmann's question I would state that we have found that the results are better in each case if a separate tower is used for each function. The fact is, the water for the ammonia condenser, when it gets much above eighty degrees, not exceeding eighty-five, the efficiency of the tower goes backward very fast, whereas for steam condensing, under known vacuum conditions, if the water be reduced to one hundred degrees, it will be fairly efficient. The conditions of temperature are so different that it has been our advice to buyers to use two towers, one tower for each part of the work.

DEEP WELL VERSUS COOLING TOWER.

This question was discussed by Alfred Siebert in *Ice & Refr.* as follows:

Two very important questions must be discussed before we can decide the relative advantages of deep wells and cooling towers. They are: First, cost or amount of interest and deterioration on investment, 6 per cent. + 7 per cent. = 13 per cent. Second, Economy in coal used. I give herewith a table obtained from the United States Department of Agriculture, Weather Bureau, St. Louis, Mo., which will show average amount of humidity and average temperature during the hottest months of 1903 and 1904:

Date.	Av. Temperature. Degrees.	Av. Humidity. Per cent.
July, 1903	80.8	60.7
Aug., 1903	76.4	70.7
Sept., 1903	69.6	76.0
July, 1904	76.0	69.9
Aug., 1904	74.4	69.6
Sept., 1904	71.0	75.2
Average	74.7	70.3

Temperature of well water is seldom below 62°, and since average temperature of air in hot weather is 74.7°, we can surely cool the water 15°, or to 59.7° or 60°, or even below the temperature of the well water on the average. But of course in rainy and warm weather we can not cool water below temperature of the air in the shade, but such days are rare, and we can get two or three times the amount of water by furnishing a larger tower, while well capacity is generally limited. Using twice the amount of water, the water will be heated only 7½° instead of 15°, and temperature of liquid and condensing pressure considerably lower, liquid temperature 7½° lower, and condensing pressure as many pounds as correspond to the condensing pressure then prevailing. Since a 75-ton ice plant requires 300,000 gallons of water per day, it would require an addition of 8 per cent. of 300,000 = 24,000 gallons per day from either city or well to make up for evaporation.

As to first expense, 300,000 gallons capacity per minute, including water distributing device, costs about $1,500; 300,000 centrifugal pump lifting water forty-five feet high, $45; water connections about $200; foundation about $300; or a total of $2,045.

The cost of well and pump, capacity 300,000 gallons, is for drilling 10-inch tubular wells, including black pipe casing, lumber for derrick, labor, freight, etc., $5.25 per foot, per well, or $525; deep well pumps, 12 x 36, with steam end fitted for ten-inch well and six-inch discharge pipe, one 10x66-inch plain brass working barrel and valves complete, thirty-six inch stroke, one ten-inch gum packer with brass attached for fastening working barrel in position; 100 feet 3½-inch ash wood pump rod. complete with 1¾-inch straight pin and box; one No. 3 air chamber with six-inch discharge, check valve combined; one ten-inch patent brass tube well strainer twenty feet long—total cost for all these, $695; cost of connections about $200, and for steam and exhaust connections, $300, or a grand total of $1,720.

Now as to consumption of coal for operation: Blower of cooling tower requires, with three-inch water pressure, twelve-horse power; centrifugal pumps, 208 gallons per minute, 3.8 horse-power; a total of 15.8 horse-power.

The deep well has to lift the water 100 feet, and to discharge it forty-five feet high, water needs to be raised only from ground floor to top of ammonia condenser in a cooling tower plant, then it is raised from condenser pan to top of cooling tower tank, in all only forty-five feet. The power required for this, including friction in pipes, is 7.62 horse-power; by figuring a loss of 15 per cent. in loss of efficiency, from dynamo to motor, we have, in round figures, nine horse-power. However, if direct acting steam pumps are used, water rate per horse power is increased as 32 is to 125, or about four times, therefore power would cost $4 \times 9 = 36$ horse-power, considering the boiler horse-power, and therefore coal consumption for deep well pump would be twice as much as that for cooling tower.

This shows, in my opinion conclusively, that considering the risk we take in drilling wells, and that we may perhaps get no water at all, or bad water, or not enough, it is well to dig just one well, because in ice plants, well water at, say, 62°, effects a great saving in capacity, and ice making capacity, especially in rainy, warm weather when using cooling tower. We have two items of saving: First, the cooling of the liquid after it leaves ammonia condensers, and before it evaporates; second, the cooling of the condensed water before it enters cans. Three hundred thousand gallons of water are sufficient for a seventy-five ton ice plant. This means that $80 \times 2,000 = 160,000$ pounds of condensed water must be cooled, say, from 90° to 65°; 90° being temperature of water coming from cooling tower in rainy weather, 90° temperature of air, and 62° being temperature of well water, therefore 28° can be taken out by well water if proper heat exchange is used. This will require only about 10 per cent. more well water than condensed water to be cooled, or 16,000 + 10 per cent. = 2,000 gallons per day. Each ton of ice made requires about 1,200 pounds of liquid to be cooled, therefore a seventy-five ton plant requires 90,000 pounds; this again being cooled under the same condition as above, requires 10 per cent. more well water than liquid circulated, or 90,000 + 10 per cent. = 99,000 pounds = 12,000 gallons per day.

Boiler would require, if highest economic plant is used, just as much steam as there is ice made plus 10 per cent. allowance for waste, or $75 \times 2,000$ + 10 per cent., or same as condensed water. Two thousand gallons evaporation on tower is about 8 per cent; eight-hundredths of 300,000 = 24,000 gallons, must be furnished by the pump, or the total of 2,000 + 12,000 + 2,000 + 24,000, or 40,000 gallons. He said it would be advisable to dig at least one well and to take the risk of throwing money away, and then when assured that sufficient water, and of the proper purity and temperature can be had, to use deep well pumps, operated by electric motors and dynamos. Of course, if this extra quantity of 40,000 gallons could be bought cheaper from a neighbor or the city, then no deep well pumps would be required.

The increase in capacity of this plant in using well water for the above mentioned use of well water can be ascertained. Latent heat is 488 th.u. at 218 pounds condensing pressure, which pressure will be obtained when water enters condenser gutter, at 90° liquid leaves, then at 105° (15° taken up), while if liquid is cooled to 65° the amount of heat needed to cool the liquid itself is reduced. Assuming twenty-seven pounds suction pressure and 14° temperature of evaporation, then $105 - 65 = 40$ th.u. is abstracted, and the amount of work of each pound of liquid is increased in proportion, as $488 - 105 : 488 - 65 = 383 : 423$, or $383 \times 423 = 100 \times X$; $X = 423 \times 100 + 383 = 11$ per cent.

Now as to the cooling of the condensed water, we cooled this from 90° to 65°. Heat required to make one pound of ice is 284 th.u. Therefore 90 —

65 = 25°; or 25 ÷ 284 = 1-11th, or 9 per cent. saving in heat absorbing capacity of freezing coils.

ATMOSPHERIC CONDENSATION VERSUS COOLING TOWER.

At the Southwestern Ice Manufacturers' Convention at Houston, Tex., 1905, Mr. M. F. Smith read a paper as follows:

In refrigerating plants it is the duty of the condensers to dispel the latent heat taken up by the ammonia in the cooling rooms or ice freezing tanks. The customary vehicle used to carry off this heat is water. In localities where a copious supply of water is obtainable it may be passed over the condensers, where it absorbs the heat and passes off to the sewer.

Since the introduction of cooling towers to relieve this circulating water of the latent heat which it carries, many plants have been installed where the water supply is limited, the customary plan being to pass the water first over the ammonia condenser, then over the steam condenser, after which it is carried to the cooling tower to dispel the heat emitted by both condensers.

We have on exhibition in this city a small working model of a new steam condenser, which utilizes the cooling properties of saturating air instead of a large volume of cool water as a cooling agent.

The condenser proper consists of a series of galvanized steel flasks, mounted in a housing which acts as a flue, being without roof or floor. The flasks are made in such size as the capacity and conditions of the plant may require and are constructed with internal horizontal partitions, which bound a continual fore and aft course for the steam from the inlet at a lower corner to the outlet at an upper corner. Each flask is equipped with a gutter at the top, which is accurately adjustable and may be set perfectly level to overflow in a thin film over both sides of the flask the entire length of the gutter.

The circulating water is fed into this gutter and passes in a thin sheet over the outer surface of the flask, keeping its entire outer surface thoroughly wetted down, dropping from its lower edges into a catch-basin, from which it is returned to the supply tank, to be again pumped over the flasks. Thus this water is used over again and again, the only loss being that which vaporizes from the wet flasks and passes into the atmosphere, carrying off the heat. never exceeding 50 per cent. of the weight of the steam condensed.

The condensing steam is inside the flasks. Entering at a lower corner, it travels in a winding course from bottom to top, pushing the non-condensable gases before it to an upper corner, where they issue into the atmosphere. The condensation water, freed of these gases, passes off from an outlet at the bottom.

The advantages to be gained by this atmospheric system of steam condensation are: Reduced water consumption, as there is no loss of circulating water, except that which vaporizes from the wet flasks, carrying off the heat. Reduced ammonia pressure, as this condenser relieves the cooling tower of the duty of dispelling the heat from the condensing steam, which is four-times greater than that from the condensing ammonia, so that the cooling tower is able to perform its greatly reduced duty at a much lower temperature, reducing the ammonia pressume correspondingly and resulting in a gratifying effect upon the coal consumption, a better and more marketable cake of ice, as by this system the gases which form the core in the ice cake are entirely expelled from the condensation water which passes from the condensing flask absolutely free of gas, practically eliminating the core in the ice.

The circulating water passing over the flasks deposits its scale upon their outer surfaces, from which it can easily be removed without loss of time, and becomes a most desirable boiler feed, dispensing with the expense and trouble of frequently cleaning the boilers.

Each flask acts independently of the others, and when it is desirable to remove the scale from the surface each can in turn be shut out of service, when the scale immediataely dries out, cracks, and the edges of the pieces curl so that a light tap of a mallet brings it down in a shower.

We also have an ammonia condenser which utilizes the cooling properties of saturating air. This consists of a housing built over and about an ordinary pipe ammonia condenser, which, by virtue of construction and position, takes advantage of the prevailing winds. In the top of the housing there are openings over each coil, in which are set gutters, accurately adjustable, that may be leveled to overflow evenly over the entire length of the coil.

For emergency purposes a disk fan is mounted in the north end. On each side of this fan, also in the north end, are doors, which are regulated to stand at any angle desired. The south end consists of doors similarly regulated.

When the wind is in the south the south doors are opened wide and the north doors just enough to allow a draft of about 150 feet per minute to pass through, making a breeze which is a little more than perceptible, but not sufficient to blow the circulating water away from the coils. With a north wind the north doors are opened wide and the south doors adjusted with discretion. In case of a calm or an east or west wind the fan is brought into action. This will probably be less than half the time and will require about 1-10 horsepower per ton of refrigeration.

The other current expense would be:

Water from some outside source to make good the atmospheric vaporization, amounting to less than fifty gallons per daily T. R., and the power required to run the circulating pump, raising less than three-fourths gallon per minute per T. R. from the catch-tank to the gutters above the flasks. The installation of this condenser does away with the necessity of a cooling tower, as the circulating water is pumped directly from the catch-tank to the gutters, to again pass over the condensing coils.

We also have a power and pressure regulator, to be attached to the engine driving the compressor, by means of which the speed of the engine is governed automatically by the increased or decreased demands of the plant.

Under conditions now in common use the speed of the engine is constant, while the temperature and pressure in the expansion coils varies with the changing demands of the plant for refrigerative duty.

For instance, in case, in a cold storage plant, one chamber is emptied of cool goods and at once refilled with goods at normal summer temperature, the temperature surrounding the coils immediately rises, resulting in increased temperature and pressure in the expansion coils. When the engineer notes on his gauge this increased demand he speeds up his engine to such an extent as he thinks sufficient to take up the increased volume of vaporization thus forming. He can not be sure that he is getting just enough speed for this purpose without wasting power, and his action is likely to be tardy. Meantime the temperature has gone up, not only in the chamber undergoing changed conditions, but in all the other chambers in the house. In the case of delicate articles this might result in serious deterioration.

The construction of this power and pressure regulator is such that the moment there is an increase in demand for refrigerative duty the balancing lever is at once affected, which in turn acts on the governor of the engine, increasing the speed just sufficient to take up the increased vaporization without loss of power. In the meantime the pressure in the expansion coils has not been increased more than one-half of a pound and the temperature has been maintained within three-quarters of one degree.

UNDER WHAT CONDITIONS DOES IT PAY TO USE A COOLING TOWER?

This topic was discussed at the meeting of the A. S. R. E., 1905, and opened by Mr. Morris, as follows:

I did not come here for the purpose of having anything to say in this meeting, but more for the purpose of listening and possibly learning. The subject of cooling towers, however, is a most important one in my section of the country, because the temperature of the atmosphere is high, much hotter than it is through this section of the country, and water, especially good water, is hard to get. So the question of cooling the water and using it over again becomes a very serious and a very important one in the refrigerating line, and we have had to use cooling towers in many sections.

The most of the ice plants in Mississippi, Missouri, Arkansas and Texas, especially in Texas and Mexico, are compelled, owing to the scarcity of water, to use cooling towers of some sort. There are hardly any places in our section of the country—hardly any localities—where it would not pay to put in cooling towers, in fact, cooling towers ought to be used throughout that country almost universally, and my own experience is that it is a good plan to use two cooling towers, taking the hot water from the steam condenser and cooling it, and have a separate tower for cooling the water from the ammonia condensers. By doing this we get colder water for the ammonia condensers and get it with a smaller power, it requires less power for forcing the air through it.

As a rule, we use cooling towers in that section with fans. Take, for instance, a 50-ton plant and we use a cooling tower that will require possibly six horsepower to operate the fans. In some cases two towers are built side by side with an engine directly connected to line shaft, with a fan on each end of the shaft—center crank engine with a fan on each end of the shaft—one fan for the hot water tower from the steam condensers and the other for the cool water from the ammonia condensers.

To show you the value of cooling towers, especially of one such as I have just mentioned, I know of a 30-ton plant in Texas where the great trouble was to get sufficient cooling water. They had to depend on an artesian well about 700 feet deep. It was pumped by an air compressor and it was hard to get sufficient water from this well to operate the plant. Finally they put in cooling towers, taking the hot water from the steam condenser through one tower and the cooler water from the ammonia condenser through the other. They have since increased the capacity of the plant by putting in another 60-ton machine, and since putting in these towers they have sufficient water to run the increased plant, whereas before they hardly had enough to get along with a 35-ton capacity.

In many places in Texas we have to go from 1,000 to 3,000 feet deep to get water, and where it is a question of spending $5,000, say, on a deep well, the cooling tower comes in, and often it is good business to put in a cooling tower rather than bore additional expensive wells. I do not know what value the cooling tower would have in this section, I do know that we can not get along without it in the Southwest.

THE PRESIDENT: Is it not true that in Texas, as a rule, the air is much drier than in sections perhaps further north and east, and that a tower for that reason is more effective in your climate?

MR. MORRIS: That may possibly be. I can only speak of the efficiency of the cooling tower in my own section, and I say again that we could not get along without them in the Southwest.

MR. CARY: I think with respect to these cooling towers that they are most successful and generally in use in sections where they have a great scarcity of water, or where water has to be purchased for cooling the condenser, or where water is so bad as to pile up a deposit so as almost to insulate the condensers from the cooling effects of the water. I think under those three heads the cooling tower would be a good investment.

THE PRESIDENT: I would like to hear from some gentleman on the question of the concentration of a solid in the water. Possibly Mr. Burhorn might throw some light on that subject.

Mr. Burhorn replied as follows:

It is like using water in a boiler. The evaporation leaves a certain percentage of solids, and that has to be blown out at intervals. In the cooling tower it is practically the same thing. We might sum up the whole matter more as a financial proposition than anything else. In this part of the country water is expensive, in large plants especially. I know of one case in Washington where the cost of the water is about $5,000 a year. With a cooling tower we can save about 90 per cent. of that cost; and that will soon pay the total cost of the tower. We have a tower put up in New York City that paid the first cost in the first year. It seems to me that it is better than a gold min-ing proposition in a great many cases. The returns certainly pay more for the investment.

The idea of using two towers I think is a good one, the difficulty in a good many cases being that where the water is used on steam condensers, the temperature is so high that it can not be used in one tower to sufficient advantage. In Philadelphia where we use two towers, the conditions are favorable for this particular installation. The water runs from the condensers into one tower, which reduces the temperature to below 100, and then it is pumped to another tower placed directly over the condensers. This tower reduces the temperature so that it is practically the same as city water for the use of the ammonia condenser.

MR. VOORHEES: I think the question of cool water is most important. On any ice plant or for refrigerating or cold storage purposes I think it should be given first consideration. The question of whether you should use a cooling tower on the water at your command is one of the very first questions that should be passed on before you go to the expense of erecting your plant. I think this is the cause of more plants falling down than any other.

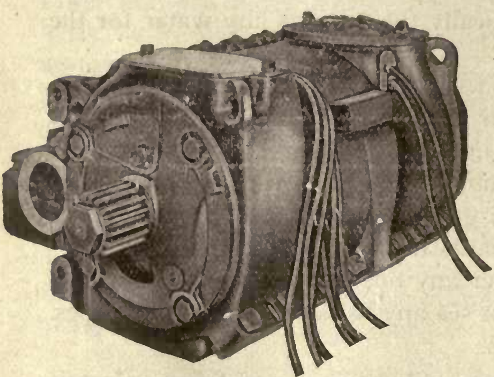
MR. HAVEN: I want to know whether any one has observed bad results from the oxidization of pipes? We do not see any bad effects upon our pipes. They are practically as good as ever then.

MR. CARY: The only time when water will have an oxidizing effect is when heat is applied to drive the air out. Take a glass of water and set it in the sun, and very soon the sides of that glass will be coated with little bubbles of air. That is quite different from atmospheric air. I find from investigating work that the air, when it dissolves on account of the greater solubility of the oxygen, becomes about one part of oxygen to 1.87 parts of nitrogen. The consequence is that the oxygen is much more active and much stronger than it is under atmospheric conditions. Temperature has a considerable influence. At a proper temperature it will act very rapidly and oxidize. A slight heating is necessary, and where a large volume of water is collected and held, the air will separate out and concentrate on different points and pitting will take place. If the water is in motion there is much less danger of that effect than with water standing comparatively stationary.

MR. MATTHEWS: I would like to ask whether this oxidization is centered or over the entire surface.

MR. CARY: The oxidization occurs by the little molecules collecting on one point and remaining there. If the water is in motion it sweeps them away. In a boiler you will find pitting occurs where the water collects and in pipes where the water remains quiet; but where the steam is rapidly sweeping these bubbles away on the metallic surface, you will find little trouble from pitting.

THE WATTMETER.—The wattmeter is generally a small motor which is connected to gears and on the gears are hands which indicate on dials the number of watt-hours of current passing through the circuit. The field magnetism is supplied by two coils of wire enclosing the armature.



The Continuous Use of Condensing Water.

Kent quotes as follows from a series of articles published in *Power*:

In San Francisco, J. N. Stub cools the water after it has left the hot well by means of a system of pans upon the roof. These pans are shallow troughs of galvanized iron arranged in tiers, on a slight incline, so that the water flows back and forth for 1,500 or 2,000 feet cooling by evaporation and radiation as it flows. The fans are about 5 feet in width, and the water as it flows has a depth of about half an inch, the temperature being reduced from about 140° to 90°. The water from the hot well is pumped up to the highest point of the cooling system and allowed to flow as above described, discharging finally into the main tank or reservoir, whence it again flows to the condenser as required. As the water in the reservoir lowers from evaporation, an auxiliary feed from the city mains to the condenser is operated, thereby keeping the amount of water in circulation practically constant. An accumulation of oil from the engines, with dust from the surrounding streets makes a cleaning necessary about once in six weeks or two months. It is found by comparative trials, running condensing and non-condensing, that about 50 per cent. less water is taken from the city mains when the whole apparatus is in use than when the engine is run non-condensing. 22 to 23 in. of vacuum are maintained. A better vacuum is obtained on a warm day with a brisk breeze blowing than on a cold day with but a slight movement of the air.

In another plant the water from the hot well is sprayed from a number of fountains, and also from a pipe extending around its border, into a large pond, the exposure cooling it sufficiently for the obtaining of a good vacuum by its continuous use.

In the system patented by Messrs. See, of Tulle, France, the water is discharged from a pipe laid in the form of a rectangle and elevated above a pond through a series of special nozzles, by which it is projected into a fine spray. On coming into contact with the air in this state of extreme division the water is cooled 40° or 50°, with a loss of evaporation of only one-tenth of its mass, and produces an excellent vacuum. A 3,000 H.P. cooler upon this system has been erected at Lannoy, one of 2,500 H.P. at Madrid and one of 1,200 H.P. at Liege, as well as others at Roubaix and Tourcoing. The system could be used upon a roof if ground space were limited. In the evaporative condenser of T. Ledwards Co., of Brockley, London, the water trickles over the pipes of the large condenser or radiator, and by evaporation carries away the heat necessary to be abstracted to condense the steam inside. The condensing pipes are fitted with corrugations mounted with circular ribs, whereby the radiating or cooling surface is largely increased. The pipes which are cast in sections about 76 in. long by 3½ in. bore, have a cooling surface of 26 sq. ft., which is found sufficient under favorable conditions to permit of

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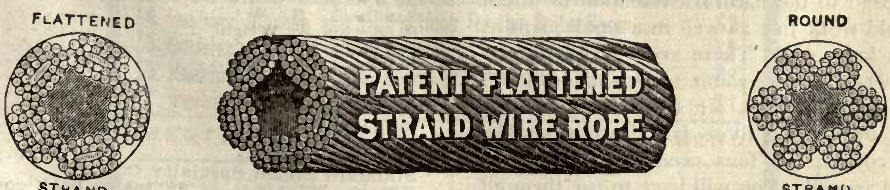

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condensation of 20 to 30 lbs. of steam per hour when producing a vacuum of 13 lbs. per sq. in. In a condenser of this type at Rixdorf, near Berlin, a vacuum ranging from 24 to 26 in. of mercury was constantly maintained during the hottest weather of August. The initial temperature of cooling water used in the apparatus under notice ranged 80° to 85° F., and the temperature in the sun, to which the condenser was exposed, varied each day from 100° to 115° F.

During the experiments it was found that it was possible to run one engine under a load of 100 horse power and maintain the full vacuum without the use of any cooling water at all on the pipes, radiation afforded by the pipes alone sufficing to condense the steam for this power.

Does It Pay to Install Cooling Towers in Small Plants?

This question came up at the American Warehousemen's Convention, 1905, as follows:

MR. READ: In regard to water towers, is it true that water towers can only be used economically by plants of considerable size? We have a small plant and have trouble with water. Our water here in the city of Washington in the summer time is at a temperature of from 85° to 90° F., and we have been advised by engineers that we could not use a water tower with our small plant.

MR. STARR: It seems to me that if you could find room on the roof, where you can get plenty of atmospheric power over a large area of surface, that is at all times exposed to the natural circulation of air, it would work just as well in a small plant as in a large one. There are a large number of very effective water towers made which are supplied with air from fans and the cost of running those fans is considerable. Of course, the fans need not be run the year around. You will have to use them all through the summer. The cost of handling large quantities of air is quite considerable, but at the same time I should say that any good type of water tower could be used, either in a large plant or in a small one. In a small plant there is a smaller amount of water and a smaller amount of air required, and I can not see any objec-

Index to Advertisers.

tion to using one, unless it was in an extremely small plant.

Cooling Ponds.

Of the same nature and use as the cooling tower is the cooling pond, which has been used to some extent in England. Such an equivalent for the cooling tower is not practical in many places. To be successful, a pond area must be supplied of sufficient size to prevent an undue rise in temperature and if the object is as in the case of cooling towers to save water, an undue rise in temperature would cause more or less evaporation from the pond. The heat would be abstracted from the water in the pond by radiation, by conduction into the air, and by evaporation. The dispersion of heat in these ways involves no loss of water except by the last—evaporation. The method of returning the hot condensing water to the pond as usually observed, is to let fall from some distance on a wooden or stone apron, so as to not disturb materially the water in the pond. This also tends to keep the hot water on the surface, which promotes cooling. On the other hand, the water for the engine is withdrawn from beneath the surface, where it is the coolest. The supply of fresh water is carefully strained in order to prevent the influx of mud. A drainage pipe is provided for carrying off all the water, so that the pond can be cleaned at times. It has been found advantageous when possible to use two ponds, alternately. It is estimated that on an average a pond should disperse 600 heat units per square foot of surface, and on this basis the required area can be calculated from the temperature of the return water. The depth is four or five feet. The cooling effect can be increased by carrying the water through shallow open troughs.

Cooling Tower in a Gas Engine Plant.

The *American Electrician* gave an account some time ago of a cooling tower used in connection with a gas engine. It says that the cooling water for the jackets is obtained from a 12 ft. cistern located between the floor of the repair shop in the front of the building, although city water may be used if desired. The water is heated to about 180 degrees F. in passing through the jackets and is cooled by evaporation in air currents as it passes down through a series of drain tiles placed in a cooling tower. There is a marked advantage in using the same water continuously, since incrustation in the jackets and pipes is thereby reduced to a minimum. Where water is used containing much carbonate of lime in solution, the temperature of the jackets will have to be reduced unless the lime is precipitated or neutralized with soda or other agent; even then much trouble may be experienced. In this case, it says, only a small amount of scale is formed and this is largely produced by the use of city water, which is necessary to supply the loss due to exaporation. A three-throw water circulating pump is belted either directly from one engine, or from an underground shaft driven from the other engine. The quantity of cooling water used by each engine varies from 4 to 5 gallons per horsepower hour.

COOLING TOWERS.

Points to Be Considered in Designing Towers.

If an engineer has at hand an unlimited supply of cold water than can be had without prohibitive cost, there is little excuse for not running an engine condensing; but, in the face of this fact, it is estimated that about nine-tenths of the engines in this country are run non-condensing. The reason being that the cost of cooling water more than balances the economy of from 20 to 30 per cent. that would result from having a lower pressure and temperature on the exhaust side of the steam cylinder. This is the field of the cooling tower—to effectively cool large quantities of water at a moderate initial and low running cost. The temperature reduction is accomplished by radiation, contact of cold air, and evaporation, the latter being by far the most effective agent in securing the desired end, while with every pound of water evaporated or converted into vapor, 955.7 or practically 1,000 b.t.u. are absorbed from the remaining body of water. Since evaporation takes place only on the surface of fluids, it is accelerated by the removal of the air next to the water surface, as soon as this air has become saturated with vapor.

To meet these conditions, cooling towers

must provide a method of spreading the water over an area large enough to expose it as long as necessary for reducing the temperature, and must supply a draft of air by means of a fan or otherwise, the fan when used being placed at the bottom of the tower. Running expenses connected with the operation of the tower are the power consumed in raising the water to the top of tower, and that for running the fan as well as the cost of the makeup water required to supply the place of that evaporated. The cost of the first item depends largely upon the location selected for the tower. For good operation, it must be placed near the condenser, as otherwise the temperature of the water will rise during its passage from the tower to the condenser. Generally speaking, less than 10 per cent. of the water is lost, but this loss depends on the temperature, the humidity of the atmosphere, etc. The expense of oprating the fan depends largely on the type of fan selected and the construction of the tower and the resulting air resistance, the amount of which depends upon the plan selected for distributing the water.

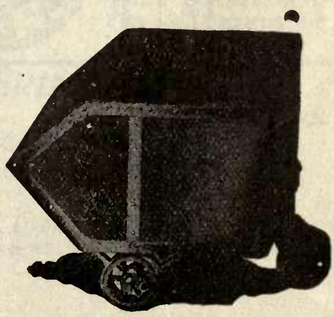
Only particular designs of disk wheels are used in connection with cooling towers, these types having been tested and found to be most efficient. Many engineers construct their own cooling tower, purchasing merely the fans and some means of driving them, either a small vertical engine or electric drive as may be preferred.—From *The Engineer.*

Motor Driven Fans.

Dia. of Fan in Ins.	Medium Speed				Maximum Speed			
	Approx. Speed	Motor Size Number	Wt. Not Pkd.	Price	Approx. Speed	Motor Size Number	Wt. Not Pkd.	Price
18	800	¼ E.B.	115	$170	1,000	¼ E.B.	115	$170
24	600	¼ E.B.	165	180	800	½ E.B.	255	220
30	500	½ E.B.	280	230	675	1 E.B.	330	260
36	425	1 E.B.	380	280	550	2 E.B.	440	370
42	350	2 E.B.	575	400	470	3 E.B.	760	500
48	300	3 E.B.	825	500	410	5 E.B.	925	600
54	260	5 E.B.	1,025	600	365	1-100 M.P. 8	1,075	700
60	235	1-100 M.P. 8	1,050	725	325	1-100 M.P. 8	1,000	850
66	210	1-100 M.P. 8	1,150	On application	300	1½-100 M.P. 8	1,275	On application
72	195	1-100 M.P. 8	1,375		275	2-100 M.P. 8	1,750	
84	165	1½-100 M.P. 8	1,675		235	4-100 M.P. 8	2,325	
96	145	2-100 M.P. 8	2,175		200	4-100 M.P. 8	2,575	
108	130	4-100 M.P. 8	2,900		185	6-100 M.P. 8	3,200	
120	115	4-100 M.P. 8	3,200		165	10-100 M.P. 8	4,200	

Belt Driven Fans.

Dia. of Fan in Ins.	Med'm Speed	Disc Fan			Propeller Fan		
		Size Pulley	Weight Not Packed	Price	Size Pulley	Weight Not Packed	Price
18	800	4x 2½	100	$30	4x2½	60	$40
24	600	5x 2½	132	40	5x2½	125	50
30	500	6x 3½	166	50	6x3½	160	65
36	425	7x 4½	190	60	7x4½	225	80
42	350	8x 5½	290	80	8x5½	400	100
48	300	8x 5½	350	100	8x5½	465	120
54	260	9x 5½	425	120	9x5½	600	150
60	235	10x 6½	535	150	10x6½	575	185
66	210	10x 6½	665	175	10x6½	720	220
72	195	12x 7½	875	200	12x7½	950	250
78	180	14x 8½	1,000	225	14x8½	1,050	275
84	165	14x 8½	1,025	250	14x8½	1,125	300
96	145	16x10½	1,175	300	16x8½	1,375	350
102	130	18x12½	1,470	350	18x8½	1,700	400
120	115	20x12½	1,800	400	20x8½	2,000	500



TESTS OF COOLING TOWER, FEDERAL PRISON, ATLANTA, GA.

Time	Humidity	Tank Temp.	Pump Temp.	Reduction Temp.	Difference.	Temp in Sun.	Temp in Shade.	Weather.
6.00	98	100	77	23	+ 6		71	Cloudy
6.30	98	100	77	23	+ 4		73	"
7.00	98	100	76	24	+ 1	76	75	"
7.30	98	100	77	23	+ 1	77	77	"
8.00	98	100	78	22	+ 1	79	77	"
8.30	98	100	78	22	+ 1	81	77	"
9.00	90	100	78	22	— 1	87	79	Part cloudy
9.30	90	100	78	22	— 2	85	80	"
10.00	90	100	79	21	— 1	91	80	"
10.30	97	101	80	21	— 1	90	81	"
11.00	95	101	81	21	— 2	91	83	"
11.30	97	102	81	21	— 4	91	85	"
12.00	97	102	81	21	— 7	. .	88	"
12.30	97	104	81	23	— 4	. .	85	Cloudy
1.00	98	104	81	23	— 3	. .	84	"
1.30	98	103	81	22	— 3	. .	84	"
2.00	98	103	81	22	— 2	. .	83	"
2.30	98	103	81	22	0	. .	81	"
3.00	99	100	81	19	+ 1	. .	80	"
3.30	99	100	81	19	+ 2	. .	79	Part cloudy.
4.00	99	100	80 5/10	19 5/10	+ 1 5/10	. .	79	"
4.30	99	100	80	20	+ 2	. .	78	"
5.00	99	100	80	20	+ 2	. .	78	Clearing.
5.30	99	100	80	20	+ 3	. .	77	
6.00	99	100	80	20	+ 3	. .	77	
7.00	82	102	79	23	+ 2	82	77	Clear.
7.30	80	102	79	23	+ 1	84	78	"
8.00	78	102	80	22	+ 1	86	79	"
8.30	68	101	80	21	0	88	80	"
9.00	65	102	80	22	— 1	90	81	"
9.30	62	102	80	22	— 3	91	83	"
10.00	50	102	80	22	— 4	92	84	"
10.30	54	102	80	22	— 4	93	84	"
11.00	55	102	80	22	— 4	94	84	"
11.30	56	102	80	22	— 5	94	85	"
12.00	57	101	80	21	— 5	94	85	"
12.30	55	102	80	22	— 6	97	86	"
1.00	50	101	80	21	— 7	100	87	"
1.30	52	101	80	21	— 7	102	87	"
2.00	53	101	80 5/10	20 5/10	— 7	103	87	"
2.30	55	102	80	22	— 7	100	87	"
3.00	54	101	80	21	— 7	98	87	"
3.30	55	100	80	20	— 7	96	87	"
4.00	54	100	80	20	— 6	91	86	"
4.30	54	101	80	21	— 6	92	86	"

Engineers' Exchange.

Advertisements will be inserted under this head for engineers and firemen wanting positions, free of charge. Answers may be sent in our care. Advertisements of owners of steam power or electric plants wanting help in every case will be charged twenty-five cents per line, each insertion. This department is for the exclusive use of engineers and firemen wanting positions, and employers wishing help.

In connection with our engineers' exchange we have established a free Bureau of Information for the benefit of engineers and firemen out of employment and employers wanting help. Applications for help will have prompt attention, and those wishing employment should file at this office their names and addresses, together with a record of experience and reference.

ENGINEERS.—Wanted to sell or furnish information leading to the sale of the improved Berryman Feed Water Heater. See our advertisement, page 73. Write for particulars. BENJ. F. KELLEY & SON, 91 Liberty Street, New York City.

TWO AMERICAN YOUNG MEN, 22 years of age, students of mechanical and electrical engineering, with knowledge of engines and electric wiring, desire positions as assistant engineers in this country or abroad. L. W. H., care ENGINEERS' LIST.

POSITION WANTED by an engineer with 15 years experience; has a second-class license and the best of reference. Understands all kinds of engines and boilers. F. B., care ENGINEERS' LIST.

YOUNG MAN, 23, technical school graduate, three years experience electrical work at switch and panel board and switch making; also machinist work, wishes a position as electrician's helper or to learn to be engineer. Alfred Viren, 352 W. 37th St., N. Y. City.

POSITION WANTED. By young man with nine years' experience as stationary engineer and electrician; desires position as draftsman or tracer. Will start low if position offers good opportunity. California, New Mexico or Mexico preferred. Address care ENGINEERS' LIST.

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Advertisements inserted under this heading, without display, for 25 cents per line each insertion.

FOR SALE.—Blake Pump, 2½x2¾x4 with receiver and tank. Inquire of Mr. Armstrong, Hotel Leonore.

FOR SALE CHEAP.—An almost new galvanized iron vapor tank, 3½ feet by 3 feet, for 6 in. exhaust. Engineer, 92 4th Ave.

WANTED.—Scranton school and other second hand engineering books. State price. J. C., care ENGINEERS' LIST.

Volume, Density, and Pressure of Air at Various Temperatures. (D. K. Clark.)

Fahr.	Volume at Atmos. Pressure.		Density. lbs. per Cubic Foot at Atmos. Pressure.	Pressure at Constant Volume.	
	Cubic Feet in 1 lb.	Compara-tive Vol.		Lbs. per Sq. In.	Compara-tive Pres.
0	11.583	.881	.086331	12.96	.881
32	12.387	.943	.080728	13.86	.943
40	12.586	.958	.079439	14.08	.958
50	12.840	.977	.077884	14.36	.977
62	13.141	1.000	.076097	14.70	1.000
70	13.342	1.015	.074950	14.92	1.015
80	13.593	1.034	.073565	15.21	1.034
90	13.845	1.054	.072230	15.49	1.054
100	14.096	1.073	.070942	15.77	1.073
110	14.344	1.092	.069721	16.05	1.092
120	14.592	1.111	.068500	16.33	1.111
130	14.846	1.130	.067361	16.61	1.130
140	15.100	1.149	.066221	16.89	1.149
150	15.351	1.168	.065155	17.19	1.168
160	15.603	1.187	.064088	17.50	1.187
170	15.854	1.206	.063089	17.76	1.206
180	16.106	1.226	.062090	18.02	1.226
200	16.606	1.264	.060210	18.58	1.264
210	16.860	1.283	.059313	18.86	1.283
212	16.910	1.287	.059135	18.92	1.287

Weights of Air, Vapor of Water, and Saturated Mixtures of Air and Vapor at Different Temperatures, under the Ordinary Atmospheric Pressure of 29.921 inches of Mercury.

Temperature, Fahrenheit.	Weight of a Cubic Ft. of Dry Air at Different Temperatures, lbs.	Elastic Force of Vapor, Inches of Mercury.	MIXTURES OF AIR SATURATED WITH VAPOR.				
			Elastic Force of the Air in Mixture of Air and Vapor, Inches of Mercury.	Weight of Cubic Foot of the Mixture of Air and Vapor.			Weight of Vapor mixed with 1 lb. of Air, pounds.
				Weight of the Air, lbs.	Weight of the Vapor, pounds.	Total W'ght of Mixture, pounds.	
0°	.0864	.044	29.877	.0863	.000079	.086379	.00092
12	.0842	.074	29.849	.0840	.000130	.084130	.00155
22	.0824	.118	29.803	.0821	.000202	.082302	.00245
32	.0807	.181	29.740	.0802	.000304	.080504	.00379
42	.0791	.267	29.654	.0784	.000440	.078840	.00561
52	.0776	.388	29.533	.0766	.000627	.077227	.00819
62	.0761	.556	29.365	.0747	.000881	.075581	.01179
72	.0747	.785	29.136	.0727	.001221	.073921	.01680
82	.0733	1.092	28.829	.0706	.001667	.072267	.02361
92	.0720	1.501	28.420	.0684	.002250	.070717	.03289
102	.0707	2.036	27.885	.0659	.002997	.068897	.04547
112	.0694	2.731	27.190	.0631	.003946	.067046	.06253
122	.0682	3.621	26.300	.0599	.005142	.065042	.08584
132	.0671	4.752	25.169	.0564	.006639	.063039	.1177[illegible]
142	.0660	6.165	23.756	.0524	.008473	.060873	.16170
152	.0649	7.930	21.991	.0477	.010716	.058416	.22465
162	.0638	10.099	19.822	.0423	.013415	.055715	.31713
172	.0628	12.758	17.163	.0360	.016682	.052682	.46338
182	.0618	15.960	13.961	.0288	.020536	.049336	.71300
192	[illegible]	19.828	10.093	.0205	.025142	.045642	1.22643
202	.06[illegible]	24.450	5.471	.0109	.030545	.041445	2.80230
212	.0591	29 921	0.000	.0000	.036820	.036820	Infinite.

Log Readings on Acme Cooling Towers.

1906.	Atmosphere.			Water.			Reduction as compared with atmosphere	
Date. Time.	Degrees wet bulb	Degrees dry bulb	Rel. hum. per cent.	Entering tower, degrees.	Leaving tower, degrees.	Reduction in tower, degrees.	Degrees below	Degrees above
July 16, 3 P. M.	84	75	60	88	82	6	2	—
" 16, 6 P. M.	79	76	85	90	83	7	4	—
" 17, 8 A. M.	82	75	68	93	84	9	—	2
" 18, 4 P. M.	92	72	34	90	77	13	15	—
" 19, 10 A. M.	82	72	57	90	80	10	2	—
" 20, 4 P. M.	94	77	41	90	82	8	12	—
" 21, 11 A. M.	87	75	52	90	81	9	6	—
" 22, 1 P. M.	91	75	42	89	81	8	10	—
" 23, 10 A. M.	84	75	60	84	78	6	6	—
" 24, 8 A. M.	73	67	70	82	72	10	1	—
" 25, 1 P. M.	80	67	47	79	71	8	9	—
" 26, 1 P. M.	79	67	50	82	74	8	5	—
" 27, 8 A. M.	70	66	78	83	77	6	—	7
" 28, 11 A. M.	80	71	59	94	85	9	—	5
" 28, 1 P. M.	86	72	46	87	79	8	7	—
" 29, 1 P. M.	84	74	57	86	78	8	6	—
" 30, 11 A. M.	84	76	64	86	70	7	5	—
" 31, 11 A. M.	82	72	57	88	81	7	4	—
Mean results for month.	82.4	72.4	57	87.3	79.1	8.2	4.3	
Aug. 1, 7 A. M.	79	72	67	86	79	7	—	—
" 4, 4 P. M.	92	78	47	88	82	6	10	—
" 5, 11 A. M.	88	78	58	93	86	7	2	—
" 6, 11 A. M.	89	77	52	88	84	4	5	—
" 6, 2 P. M.	94	76	39	88	82	6	12	—
" 7, 8 A. M.	80	74	71	92	84	8	—	4
" 8, 1 P. M.	83	75	64	89	82	7	1	—
" 9, 1 P. M.	84	71	48	84	77	7	7	—
" 10, 1 P. M.	82	73	60	86	80	6	2	—
" 11, 2 P. M.	90	78	53	89	83	6	7	—
" 12, 10 A. M.	84	74	57	84	79	5	5	—
" 13, 1 P. M.	74	66	62	76	72	4	2	—
" 14, 1 P. M.	85	69	40	85	76	9	9	—
" 15, 1 P. M.	82	61	30	84	76	8	6	—
" 18, 1 P. M.	80	74	71	84	78	8	2	—
" 19, 1 P. M.	84	74	57	88	81	7	3	—
" 20, 2 P. M.	85	76	61	89	81	8	4	—
" 21, 1 P. M.	88	77	55	93	84	9	4	—
" 22, 1 P. M.	86	77	61	89	82	7	4	—
" 23, 1 P. M.	84	79	76	92	83	9	1	—
" 24, 9 A. M.	74	70	79	82	74	8	—	—
" 25, 1 P. M.	68	66	88	76	70	6	—	2
" 26, 1 P. M.	82	78	80	84	78	6	4	—
" 27, 1 P. M.	84	77	76	89	82	7	2	—
" 28, 1 P. M.	77	68	59	81	73	8	4	—
" 29, 11 A. M.	75	69	70	83	76	7	—	1
" 30, 2 P. M.	87	77	58	91	82	9	5	—
Mean results for month.	82.9	73.4	60.7	86.4	79.4	6.9	3.3	—
Sept. 1, 6 P. M.	78	60	35	82	77	5	1	—
" 2, 1 P. M.	76	67	59	75	69	6	7	—
" 3, 2 P. M.	85	72	49	77	71	6	14	—
" 4, 2 P. M.	73	58	40	69	60	9	13	—
" 5, 1 P. M.	78	67	53	66	62	4	6	—
" 6, 1 P. M.	82	70	51	77	71	6	11	—
" 23, 1 P. M.	80	67	47	80	71	9	9	—
" 24, 1 P. M.	69	55	45	70	63	7	6	—
" 25, 1 P. M.	70	57	45	73	65	8	5	—
" 26, 1 P. M.	74	65	58	79	71	8	3	—
" 27, 1 P. M.	76	70	71	83	76	7	—	—
" 28, 1 P. M.	75	63	49	74	68	6	7	—
" 29, 1 P. M.	78	70	63	82	74	8	4	—
" 30, 3 P. M.	68	60	60	71	65	6	3	—
Mean results for month.	75.8	64.3	51.7	75.5	68.7	6.7	6.3	—
Oct. 1, 1 P. M.	60	54	66	64	58	6	2	—
" 2, 1 P. M.	70	61	57	72	66	6	4	—
" 3, 1 P. M.	72	62	54	74	67	7	5	—
" 4, 1 P. M.	64	63	94	73	68	5	—	6
" 5, 1 P. M.	72	65	65	82	72	10	—	—
" 6, 1 P. M.	70	67	83	82	74	8	—	2

RELATIVE HUMIDITY, PER CENT.

Difference between the Dry and Wet Thermometers, Deg. F. — Relative Humidity, Saturation being 100.

Dry Thermometer, Deg. F.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26	28	30
32	90	79	69	59	50	40	31	21	12	3																	
40	92	84	76	68	60	53	45	38	30	22	16	8	1														
50	93	87	80	74	67	61	55	50	44	38	33	27	22	16	11	6	1										
60	94	89	84	78	73	68	63	58	53	48	44	39	34	30	26	22	18	14	10	6	2						
70	95	90	86	81	77	72	68	64	60	55	52	48	44	40	36	33	29	26	23	19	16	13	10	7	1		
80	96	92	87	83	79	75	72	68	64	61	57	54	51	47	44	41	38	35	32	29	26	23	20	18	13	8	3
90	96	92	88	85	81	78	75	71	68	65	62	59	56	53	50	47	44	41	39	36	34	32	29	26	22	17	13
100	97	93	90	86	83	80	77	74	71	68	65	62	59	57	54	51	49	47	44	42	39	37	35	33	29	25	21
110	97	94	90	87	84	81	78	76	73	70	67	65	62	60	57	55	53	50	48	46	44	42	40	38	34	30	27
120	97	94	91	88	85	83	80	77	75	72	70	67	65	62	60	58	56	54	51	49	47	45	44	42	38	35	31
140	97	95	92	89	87	84	82	79	77	75	73	71	68	66	64	62	60	58	56	55	53	51	49	48	44	41	38

CENTRIFUGAL FANS.

Flow of Air through an Orifice.

VELOCITY, VOLUME, AND H.P. REQUIRED WHEN AIR UNDER GIVEN PRESSURE IN OUNCES PER SQ. IN. IS ALLOWED TO ESCAPE INTO THE ATMOSPHERE.

(B. F. Sturtevant Co.)

Pressure in ounces per sq in.	Velocity, ft. per min.	Volume through 1 sq. in. Effective Area, cu. ft. per min.	Horse-power to move the Given Volume of Air.	Horse-power per 1000 cu. ft. per min.	Pressure in ounces per sq. in.	Velocity, ft. per min.	Volume through 1 sq. in. Effective Area, cu. ft. per min.	Horse-power to move the Given Volume of Air.	Horse-power per 1000 cu. ft. per min.
⅛	1,828	12.69	.00043	.0340	2	7,284	50.59	.02759	.5454
¼	2,585	17.95	.00122	.0680	2⅛	7,507	52.13	.03021	.5795
⅜	3,165	21.98	.00225	.1022	2¼	7,722	53.63	.03291	.6136
½	3,654	25.37	.00346	.1363	2⅜	7,932	55.08	.03568	.6476
⅝	4,084	28.36	.00483	.1703	2½	8,136	56.50	.03852	.6818
¾	4,473	81.06	.00635	.2044	2⅝	8,334	57.88	.04144	.7160
⅞	4,830	33.54	.00800	.2385	2¾	8,528	59.22	.04442	.7500
1	5,162	35.85	.00978	.2728	2⅞	8,718	60.54	.04747	.7841
1⅛	5,473	38.01	.01166	.3068	3	8,903	61.83	.05058	.8180
1¼	5,768	40.06	.01366	.3410	3⅛	9,084	63.08	.05376	.8522
1⅜	6,048	42.00	.01575	.3750	3¼	9,262	64.32	.05701	.8863
1½	6,315	43.86	.01794	.4090	3⅜	9,435	65.52	.06031	.9205
1⅝	6,571	45.63	.02022	.4431	3½	9,606	66.71	.06368	.9546
1¾	6,818	47.34	.02260	.4772	3⅝	9,773	67.87	.06710	.9887
1⅞	7,055	49.00	.02505	.5112	3¾	9,938	69.01	.07058	1.0227
					3⅞	10,100	70.14	.07412	1.0567

Amount of Water for Surface Condensers.

(Pounds of Water required per Pound of Steam.)

T—t	TEMPERATURE OF AIR PUMP DISCHARGE.														
	90	95	100	102	104	106	108	110	112	114	116	118	120	125	130
5	220	219	218	217.6	217.2	216.8	216.4	216	215.6	215.2	214.8	214.4	214	213	212
10	110	109.5	109	108.8	108.6	108.4	108.2	108	107.8	107.6	107.4	107.2	107	106.5	106
15	73.3	73	72.7	72.5	72.4	72.3	72.1	72	71.9	71.7	71.6	71.5	71.3	71	70.7
20	55	54.7	54.5	54.4	54.3	54.2	54.1	54	53.9	53.8	53.7	53.6	53.5	53.2	53
25	44	43.8	43.	43.5	43.4	43.4	43.3	43.2	43.1	43	42.9	42.9	42.8	42.6	42.4
30	36.7	36.5	36.3	36.3	36.2	36.2	36.1	36	35.9	35.9	35.8	35.7	35.7	35.5	35.3
35	31.4	31.3	31.1	31.1	31.0	31	30.9	30.8	30.8	30.7	0.7	30.6	30.5	30.4	30.3
40	27.5	27.4	27.2	27.2	27.1	27.1	27	27	26.9	26.9	26.8	26.8	26.7	26.6	26.5
45	24.4	24.3	24.2	24.2	24.1	24.1	24	24	23.9	23.9	23.9	23.8	23.8	23.7	23.5
50	22	21.9	21.8	21.8	21.7	21.7	21.6	21.6	21.6	21.5	21.5	21.4	21.4	21.3	21.2
55	20	19.9	19.8	19.8	19.7	19.7	19.7	19.6	19.6	19.6	19.5	19.5	19.4	19.4	19.3
60	18.3	18.2	18.2	18.1	18.1	18.1	18	18	18	17.9	17.9	17.9	17.8	17.7	17.7
65	16.9	16.8	16.8	16.7	16.7	16.7	16.6	16.6	16.6	16.5	16.5	16.5	16.5	16.4	16.3
70	15.7	15.6	15.6	15.5	15.5	15.5	15.4	15.4	15.4	15.4	15.3	15.3	15.3	15.2	15.1
75	14.7	14.6	14.5	14.5	14.5	14.4	14.4	14.4	14.4	14.3	14.3	14.3	14.3	14.2	14.1
80	13.7	13.6	13.6	13.6	13.6	13.5	13.5	13.5	13.5	13.4	13.4	13.4	13.4	13.3	13.2
85	12.9	12.8	12.8	12.8	12.8	12.7	12.7	12.7	12.7	12.6	12.6	12.6	12.6	12.5	12.5
90	12.2	12.2	12.1	12.1	12.1	12	12	12	12	11.9	11.9	11.9	11.9	11.8	11.8

Amount of Water for Jet Condensers.

Temp. of Discharge from Air Pump T	Entering Temperature of Injection Water t. 35	40	45	50	55	60	65	70	75	80	85	90	95	100
	Pounds of Condensing Water Required per Pound of Steam. $Q = \frac{1190 - T}{T - t}$													
90	20.0	22.0	24.4	27.5	31.4	36.7	44.0	55.0	73.8	110.0	220.0	....	....	....
92	19.2	21.1	23.4	26.1	29.7	34.3	40.7	49.9	64.6	91.5	156.8	549.0	....	....
94	18.6	20.3	22.4	24.9	28.1	32.2	37.8	45.7	57.7	78.1	121.8	274.0	....	....
96	17.9	19.5	21.4	23.6	26.7	30.4	35.3	42.1	52.1	68.4	99.4	182.3	.	....
98	17.3	18.8	20.6	22.7	25.4	28.7	30.1	39.0	47.5	60.7	84.0	136.5	364.0	....
100	16.8	18.2	19.3	21.8	24.2	27.2	31.1	36.3	43.6	54.5	72.7	109.0	218.0	....
102	16.2	17.5	19.1	20.9	23.1	25.9	29.4	34.0	40.3	49.5	61.0	90.7	155.4	544.0
104	15.7	17.0	18.4	20.1	22.2	24.7	27.8	31.9	37.4	45.2	57.2	77.6	120.7	271.5
106	15.3	16.4	17.8	19.4	21.3	23.6	26.4	30.1	35.0	41.7	51.6	67.7	98.5	180.7
108	14.8	15.9	17.2	18.7	20.4	22.5	25.2	28.5	32.8	38.6	47.0	60.1	83.2	135.2
110	14.4	15.4	16.6	18.0	19.6	21.6	24.0	27.0	30.9	36.0	43.2	54.0	72.0	108.0
112	14.0	15.0	16.1	17.4	18.9	20.7	22.9	25.7	29.1	33.6	39.9	49.0	63.4	89.8
114	13.6	14.5	15.6	16.8	18.2	19.9	22.0	24.5	27.6	31.6	37.1	44.8	56.6	76.9
116	13.3	14.1	15.1	16.3	17.6	19.2	21.1	23.3	26.2	29.8	34.6	41.3	51.1	67.1
118	12.9	13.7	14.7	15.8	17.0	18.5	20.2	22.3	24.9	28.2	32.5	38.3	46.6	59.6
120	12.6	13.4	14.3	15.3	16.5	17.8	19.5	21.4	23.8	26.7	30.6	35.7	42.8	53.5
122	12.3	13.0	13.9	14.8	15.9	17.2	18.7	20.5	22.7	25.4	28.9	33.4	39.6	48.5
124	12.0	12.7	13.5	14.4	15.4	16.7	18.1	19.7	21.8	24.2	27.3	31.4	36.8	44.4
126	11.7	12.4	13.1	14.0	15.0	16.1	17.4	19.0	20.9	23.1	26.0	29.6	34.3	40.9
128	11.4	12.1	12.8	13.6	14.5	15.6	16.9	18.3	20.0	22.1	24.7	27.9	32.2	37.9
130	11.2	11.8	12.5	13.2	14.1	15.1	16.3	17.7	19.3	21.2	23.6	26.5	30.3	35.3
132	10.9	11.5	12.2	12.9	13.7	14.7	15.7	17.1	18.6	20.3	22.5	25.2	28.6	33.1
134	10.7	11.2	11.9	12.6	13.4	14.8	15.3	16.5	17.9	19.6	21.6	24.0	27.1	31.0
136	10.4	11.0	11.6	12.3	13.0	13.9	14.8	16.0	17.3	18.8	20.7	22.9	25.7	29.2
138	10.2	10.7	11.3	12.0	12.7	13.5	14.4	15.5	16.7	18.1	19.8	21.9	24.5	27.7
140	10.0	10.5	11.1	11.7	12.4	13.1	14.0	15.0	16.2	17.5	19.1	21.0	23.3	26.2

Experiments made with a Blackman Disk Fan, *4 ft.* diam., by Geo. A. Suter, to determine the volumes of air delivered under various conditions, and the power required; with calculations of efficiency and ratio of increase of power to increase of velocity, by G. H. Babcock. (Trans. A. S. M. E., vii. 547):

Rev. per min.	Cu. ft. of Air delivered per min., V.	Horse-power, HP.	Water-gauge, in., h.	Ratio of Increase of Speed.	Ratio of Increase of Delivery.	Ratio of Increase of Power.	Exponent x, $HP \propto V^x$.	Exponent y, $h \propto V^y$.	Efficiency of Fan.
350	25,797	0.65	....	....	....	....	.....	......	1.682
440	32,575	2.29	....	1.257	1.262	3.523	5.4	......	.9553
534	41,929	4.42	....	1.186	1.287	1.843	2.4	......	1.062
612	47,756	7.41	....	1.146	1.139	1.677	3.97	......	.9358
	For	series	....	1.749	1.851	11.140	4.	......	....
340	20,372	0.76	....	....	....	....	.....	......	.7110
453	26,660	1.99	....	1.332	1.308	2.618	3.55	......	.6063
536	31,649	3.86	....	1.183	1.187	1.940	3.86	......	.5205
627	36,543	6.47	....	1.167	1.155	1.676	3.59	......	.4802
	For	series	....	1.761	1.794	8.513	3.63	......	....
340	9,983	1.12	0.28	....	....	....	.....	.....	.3989
430	13,017	3.17	0.47	1.265	1.304	2.837	3.93	1.95	.3046
534	17,018	6.07	0.75	1.242	1.307	1.915	2.25	1.74	.3319
570	18,649	8.46	0.87	1.068	1.096	1.394	3.63	1.60	.3027
	For	series	....	1.676	1.704	7.554	3.24	1.81	....
330	8,399	1.31	0.26	....	....	....	.....	......	.2631
437	10,071	3.27	0.45	1.324	1.199	3.142	6.31	3.06	.2180
516	11,157	6.00	0.75	1.181	1.108	1.457	3.66	4.96	.2203
	For	series	....	1.563	1.329	4.580	5.35	3.72	....

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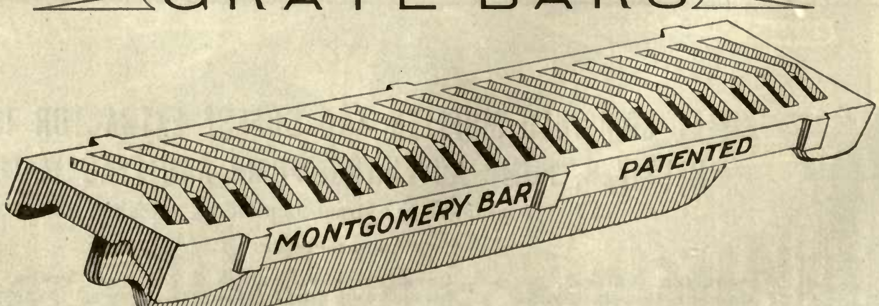

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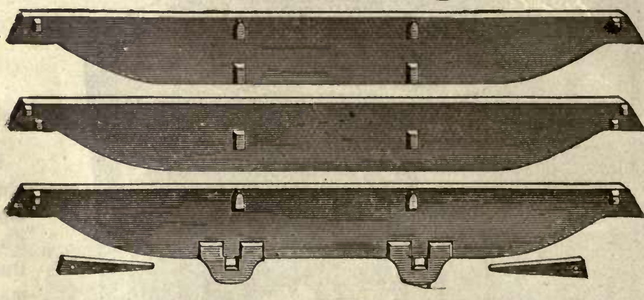

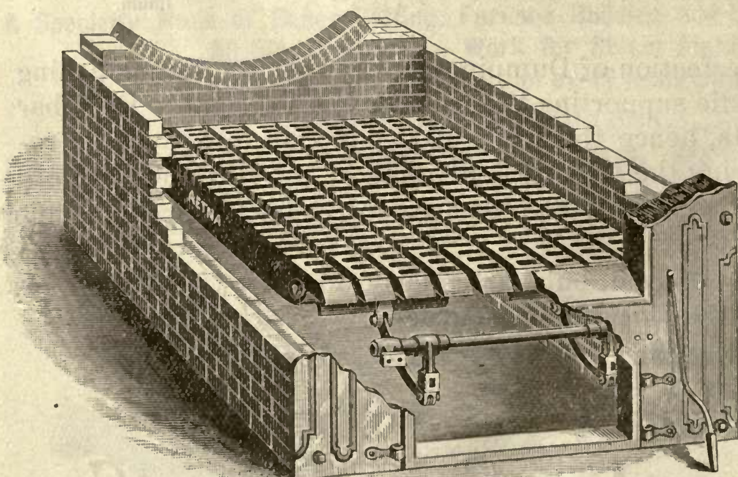
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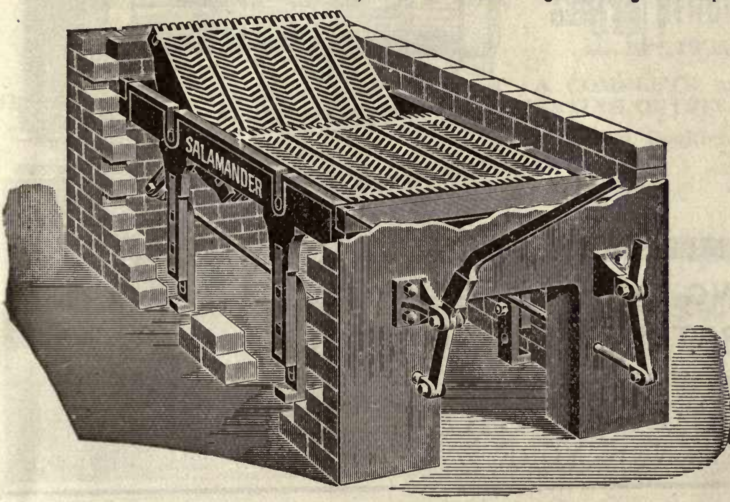
Salamander Grate Bar Co.

The Salamander Dumping Grate

With Solid Iron Frame, With Extension Legs Resting on Ashpit Floor.



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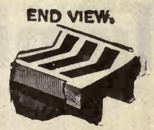

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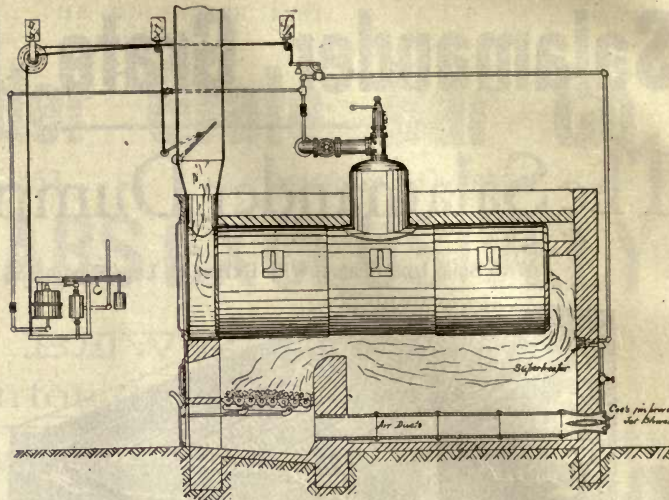

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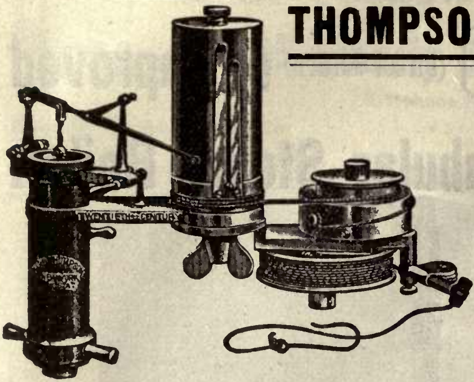

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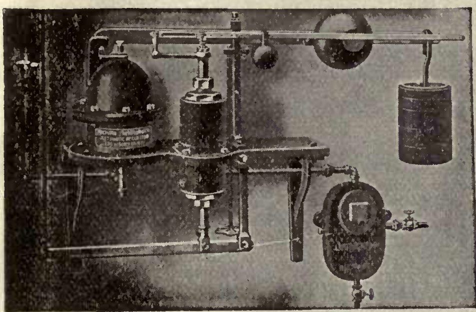

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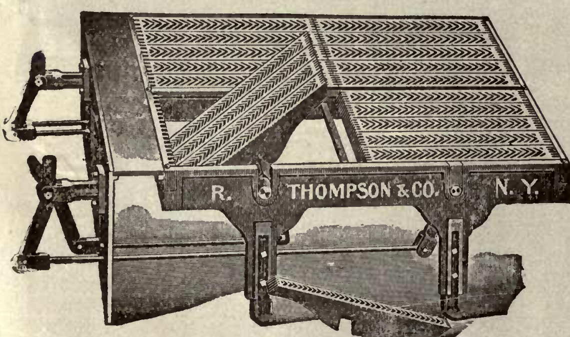

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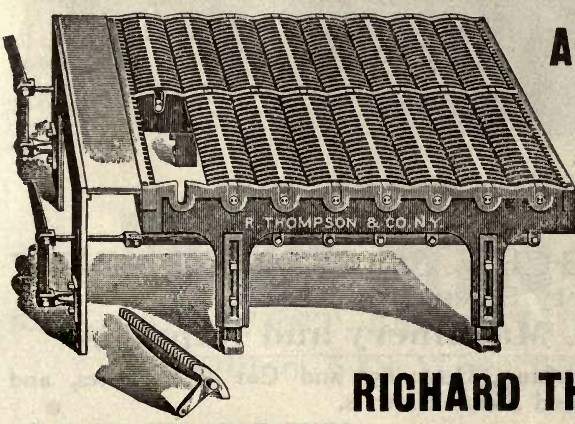

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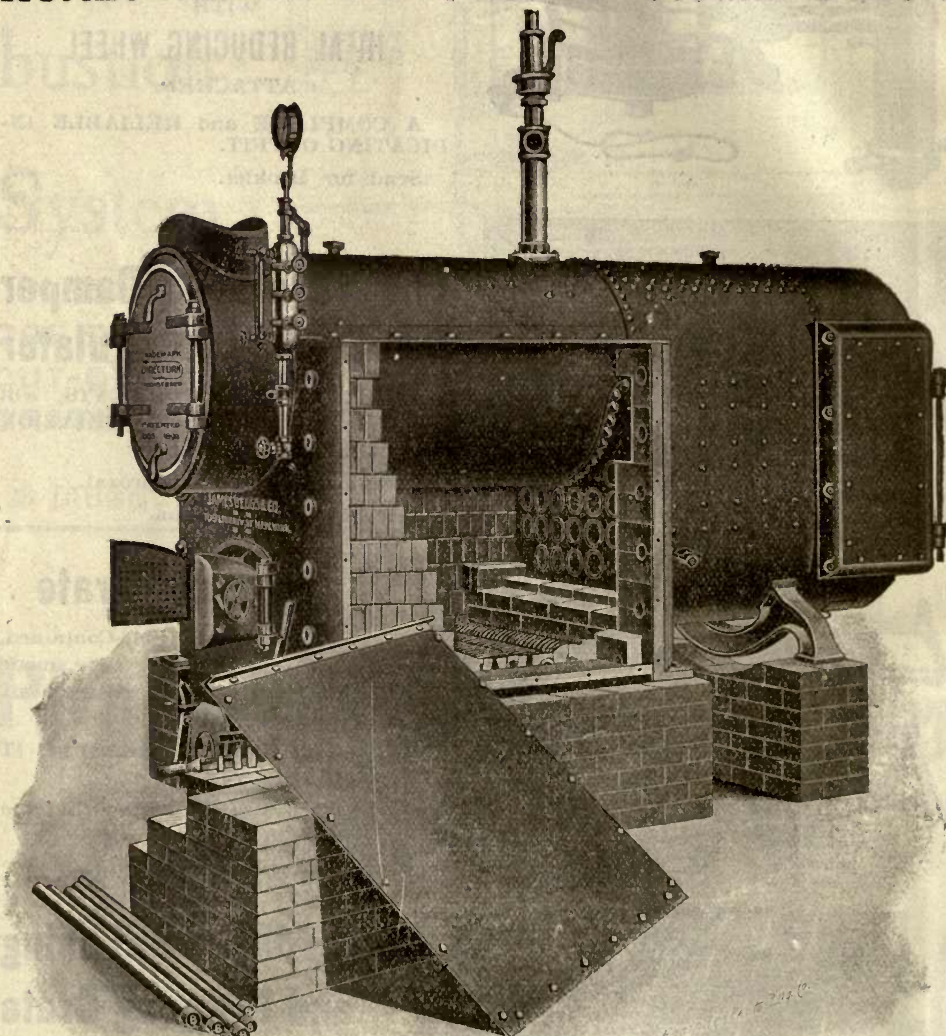

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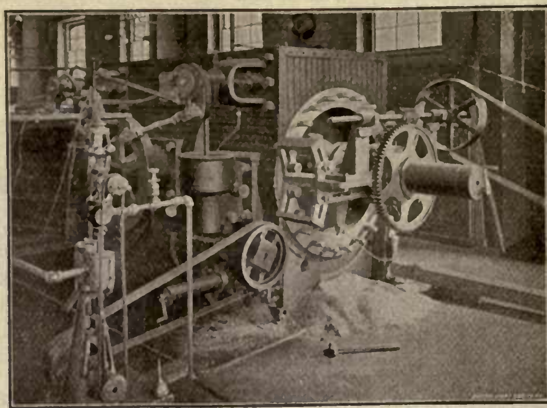

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