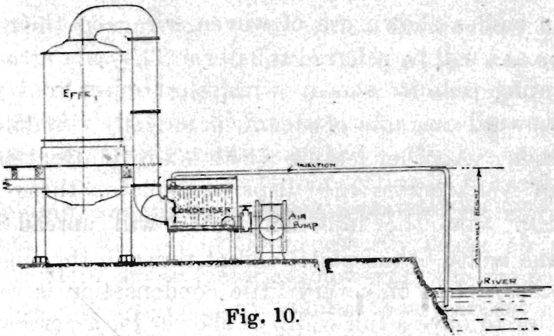
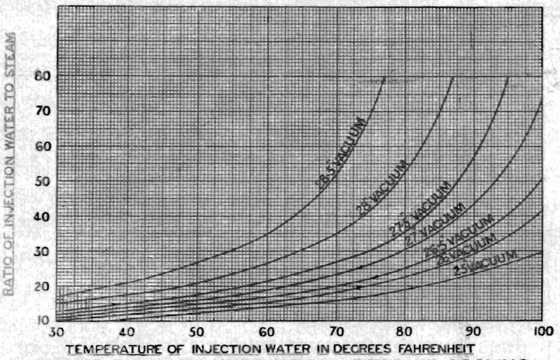


Fig. 10.

injection water is drawn from the river, so that the height to which it could be reasonably forced by atmospheric pressure when the condenser is under vacuum was limited, while the suction of the existing wet air pump could not, of course, be lowered. The available distance between injection inlet and air pump suction therefore rendered the installation of a "safe" condenser of the wet type the most satisfactory. Owing to the limited "fall" of the water in this type it is of the utmost importance that the holes should be of the least practicable diameter, and furthermore, the head of water on the plate should be as low as possible. Usually the height of fall is from 5 to 6 feet, the size of the holes $\frac{1}{8}''$ to 1-16″ in diameter and the head of water not more than 3″. The large area of spray plate available in this type renders these conditions more practicable than in any other type, and it is to a great extent the reason for their success. The actual size of the holes will naturally depend to a great extent upon the cleanliness of the water and the margin to be allowed for fouling. The air outlet for a condenser of this kind, working on the dry principle, should be placed at the end remote from the injection inlet, for owing to the perturbation of the water in the region of the latter, there is a risk of the air pump drawing over a considerable quantity of water.

The determination of the principal dimensions of a condenser of this kind does not call for the theoretical consideration that one of the vertical C.C. does. The height being known (and this should be of course as great as possible), and also the diameter of the steam inlet, the width inside the condenser should be no greater than the latter dimension. It will be readily realized that there is a practicable limit below which it would be unreasonable to go for the length of the condenser; usually this is not less than twice the diameter of the steam inlet; so that if the width is increased a larger condenser than is really necessary would result, while if the length is less than abovementioned the time of contact between steam and water would be too little.

The ratio of the quantity of injection water to steam may be easily found when the initial temperature of the injection water and the desired degree of vacuum are known. From the latter the probable final temperature of the injection water is assumed. With the many tables that have been set down from the calculated theoretical transfer of heat, there is very little call for further reference to the matter here, but the curves shown in the next Figure 11, and which have been



CURVES SHOWING THEORETICAL RATIO OF COOLING WATER REQUIRED AND CONDENSED STEAM

Fig 11.

plotted from such tables seem to be of so useful a nature that it was considered worth while to include them. From these there will be no difficulty in obtaining the theoretical ratio of injection water to steam for any set of conditions, and it only remains for the allowance of a reasonable difference between the temperature due to vacuum, and that of the waste water, to be added in order to obtain the actual approximate ratio.

Then with regard to the amount of water that will flow through the holes in ordinary spray plates, it would seem that with the plentiful data available, it would be unnecessary to go further than the usual formula for orifices, and to adopt a recognised coefficient for the kind being used. However, as it is known that the actual results differ from those theoretically calculated, the writer made a complete set of experiments and determined the actual amounts discharged through various sizes of holes, and with varying heads, and the results are given in the table shown by Figure 12. This

THE ACTUAL VOLUME OF WATER IN GALLONS DISCHARGED THROUGH HOLES IN PERFORATED PLATE 1/8" THICK.

HEAD OF WATER ON PLATE IN INCHES	THE VOLUME OF WATER IN GALLONS FLOWING THROUGH ONE HOLE IN ONE HOUR TO THE NEAREST QUARTER GALLON — DIAMETER OF THE HOLES IN PARTS OF AN INCH.					
	1/8	3/16	1/4	5/16	3/8	1/2
1/2	2.5	5.25	10.25	16.25	22.5	42.75
1	3.5	8.25	15.	24.	35.25	66.
1½	4.5	10.25	18.25	28.75	42.5	77.5
2	5.0	11.5	21.	32.5	48.	85.
2½	5.5	12.5	22.75	35.25	52.	92.
3	5.75	13.5	24.5	38.	56.	99.25
3½	6.25	14.5	26.25	40.75	60.	106.25
4	6.5	15.5	28.	43.5	64.	113.5
4½	7.0	16.5	29.75	46.25	68.	120.75
5	7.25	17.5	31.5	49.	72.	127.75
5½	7.75	18.5	33.25	51.75	76.	135.
6	8.25	19.5	35.	54.5	80.	142.
7	9.25	21.5	38.5	59.5	88.	156.
8	10.	23.5	42.	65.	96.	170.
9	10.75	25.5	45.5	70.5	104.	184.25
10	11.75	27.5	49.	76.	112.	198.25

HOLES DIVERGING 15° SO  WILL DISCHARGE THE SAME QUANTITY AS ABOVE.

Fig. 12.

certainly does not differ very materially from other actual results, but it does from those obtained by the formula $Q = 0.62 A\sqrt{2 G.H.}$, in which A = the area of the orifice in square feet, which seems to apply more accurately to larger holes than those under consideration; while furthermore, the results in the table were obtained with holes bored without any particular care as to smoothness at either entry or discharge. At the same time it was desired to obtain the comparative results with diverging holes in thicker plates, and as noted on the table, the coefficient for such orifices agreed exactly with the parallel holes in the thinner plate. Apparently the degree of divergency was too great, and the relative length of the holes to their diameters was too little to enhance the coefficient, as it is known it is enhanced by orifices diverging 5° and of greater length relative to the diameter. Of course, the object of the divergency in the case tried, and which agreed with the actual design of several condensers, was not to increase the capacity, but to make the holes self clearing on the underside. The plates were ½″ thick.

Knowing the actual quantity that certain holes will flow, it is of course necessary to allow a margin for fouling, or obstruction by leaves, twigs, or other foreign matter. The margin must be determined according to the quality of the water, but for ordinarily clean water from 15 to 20% in excess is a fair allowance.

Before leaving the subject of the "safe" or "waggon" type of condenser, it should be said that it possesses the advantages of simplicity, adaptability to confined spaces, and accessibility, whilst even though its rectangular form necessitates the flat areas that are the bête noir of designers of pressure vessels, the cost of these condensers is no more for condensing capacity than the vertical circular type—and it has been shown that as good a vacuum can be obtained therein as in other forms, although admittedly it is at the cost of rather more condensing water. There is very little opportunity for varying the internal arrangements of the condenser principally described heretofore, and at first sight it would appear that opportunity has been similarly limited in the vertical circular type; but it is remarkable the multitudinous array of different internal arrangements that have been adopted within the usually plain and simple looking exteriors. Here for instance, in Figure 13, are three designs by

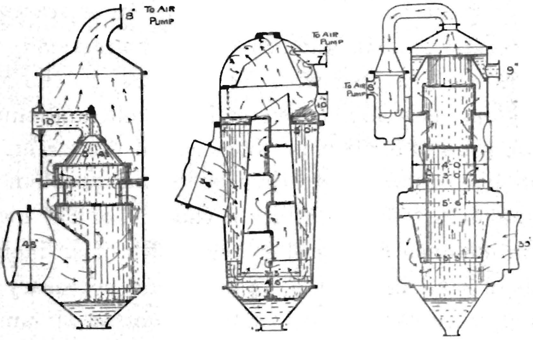


Fig. 13.

prominent makers of sugar machinery in Scotland. They are all for vacuum pans of the same capacity, and to work under the same conditions of condensing, and yet how widely dissimilar are the means adopted for obtaining mixing of the steam and water. In the first a rose is used for injecting the water, which then falls in three cascades to the bottom. In the second, part of the water is showered by a perforated plate, while the balance runs over a flat plate at the top and falls in six cascades to the bottom, while in the third the water overflows a weir and then falls by means of 4 cascades to the bottom. Doubtless all three would prove about equally efficient, although the actual consumption of water would probably vary. The centre condenser is really a combination of parallel and counter currents. On the outside of the central cone the steam flows downward with part of the injection water, the vapour and air afterwards rising through the central cone against the falling water. It is noticeable in this condenser that the theoretical condition of gradually reduced air volume is made use of. A condenser of this design is about to be tried by the C.S.R. Co. at their Pyrmont Refinery. The truncated cone in the roof of the condenser is a patented centrifugal air separator, the same object being attained in the third condenser by means of the baffling device which is not uncommon for separating steam and oil.

It has been proved in counter current condensers that unless it is possible to inject the water in a very finely divided state, very great height is necessary in order to obtain the desired transfer of heat, and consequently practically all such condensers are provided with interceptors, in the shape of trays or steps, to delay the water in its fall, and thus to increase the time of contact between it and the water. Hausbrand, in his valuable investigation of the problem of heat exchanges, determined that for a vacuum of $27\frac{3}{4}$ inches the minimum distance a drop of water 1-12th of an inch in diameter should fall in order to take up the necessary heat in the steam, was 10 ft. Such a fall is not at all unusual in condensers of moderate size, but the difficulty in most cases lies in the adoption of such small holes and their accommodation in a reasonable area of spray plate. It is seldom, therefore, that counter current condensers are without steps, although sometimes circumstances do permit such and in the next Figure, 14, is shown one that has been used in Continental beet factories. Its height compared to the diameter is striking. Generally it is impracticable to adopt such condensers, although if the conditions of fine injection and ample fall are obtainable there can be no doubt as to the efficiency, whilst its simplicity commends it. In the early stages of counter current designs much trouble was met with owing to the importance of ample height and area being underestimated. If a counter current condenser is too short or the diameter unduly small, the velocity or pressure of the uprising steam which is imperfectly condensed, is liable to carry with it a considerable quantity of the injection water. As against the simplicity of the plain condenser shown in the last figure, it is interesting to place the condenser shown in the next Figure, 15, which illustrates the Worthington Patent C.C. Condenser. In drawing attention to the disparity between them, it is distinctly not the intention to suggest that the latter one is placed at a disadvantage. Quite the reverse, for as stated above it is a question of practicability and from an examination of the figure before us it is evident that a well thought out design is brought out. The special feature of this condenser is that the injection water is projected from a series of trays, the jets being in the form of long-shaped sheets, which are arranged radially and between which the air and vapour rise without much obstruction.

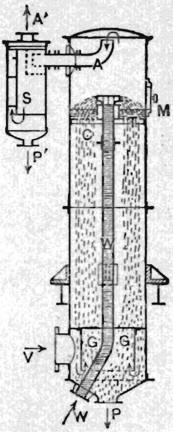


Fig. 14.

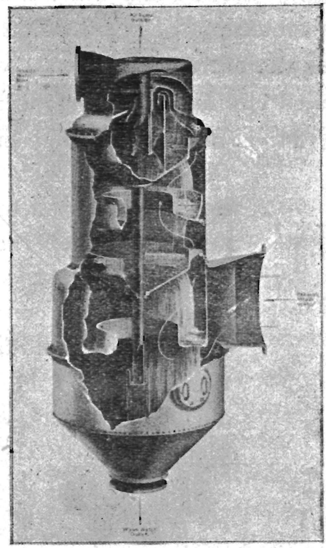


Fig. 15.

The area of water surface thus provided must effectually assist in the transmission of heat from steam to water. It is evident that in this, as in practically all condensers with steps, the latter interfere to a large extent with the clear passageway through the condenser and consequently increased diameter is necessary to compensate for such; and although on general principles it is undesirable to restrict the diameter, it is obviously unprofitable to make it unnecessarily large. For this reason the writer would draw attention to the use of woven wire water breaks, instead of steps or trays. These have been tried in several condensers in the C.S.R. Co., and have been quite satisfactory. They do not delay the water, but they disintegrate it to an extent that is rather surprising, and if, as already referred to, the atomisation of the water is sufficient the need for steps disappears. To clearly illustrate the effect of water dropping on to such breaks, two simple experiments were made by the writer. A piece of woven wire of ¼ inch mesh was placed three feet from the ground upon which had been laid sheets of white blotting paper. A small cup holding one cubic inch of dyed water was casually held 18 inches above the wire, and the water was allowed to fall through a $\frac{1}{4}$ inch hole in the bottom of the cup. The result is shown in the next Figure, 16, while the effect of

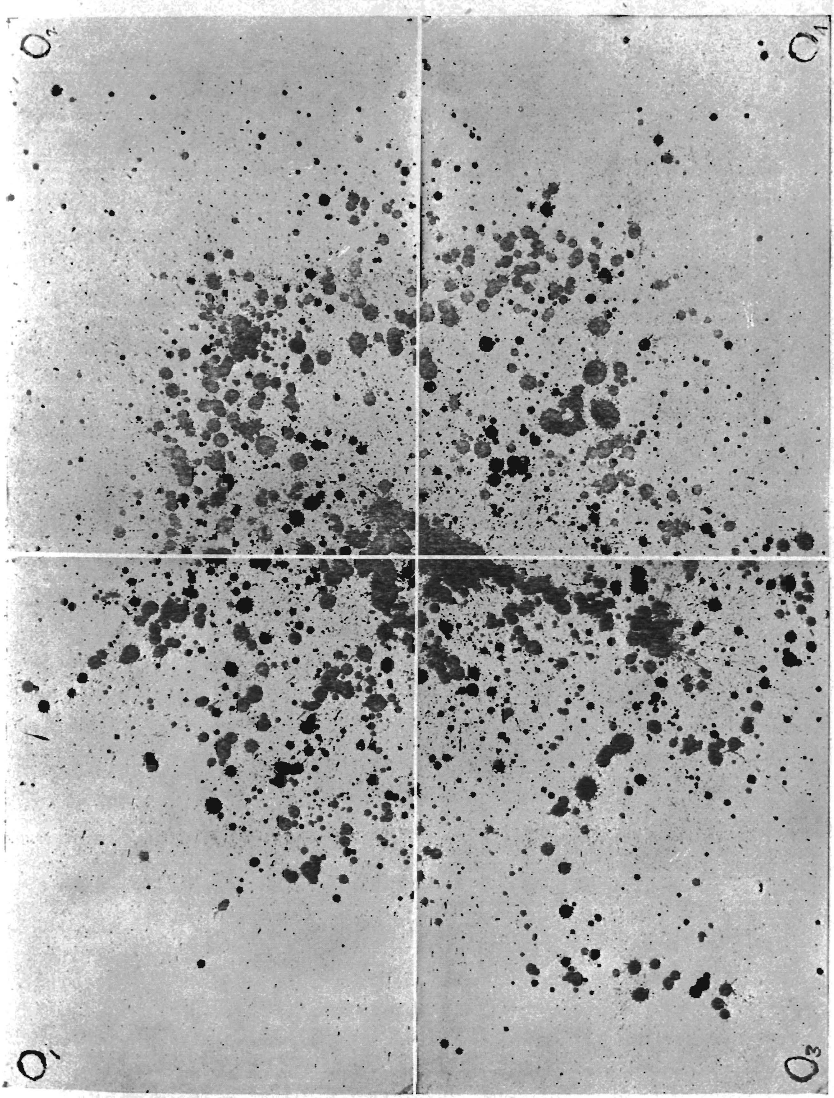


Fig. 16.

placing a second piece of wire 18 inches above the first and repeating the operation is shown in Figure 17. It is, as will

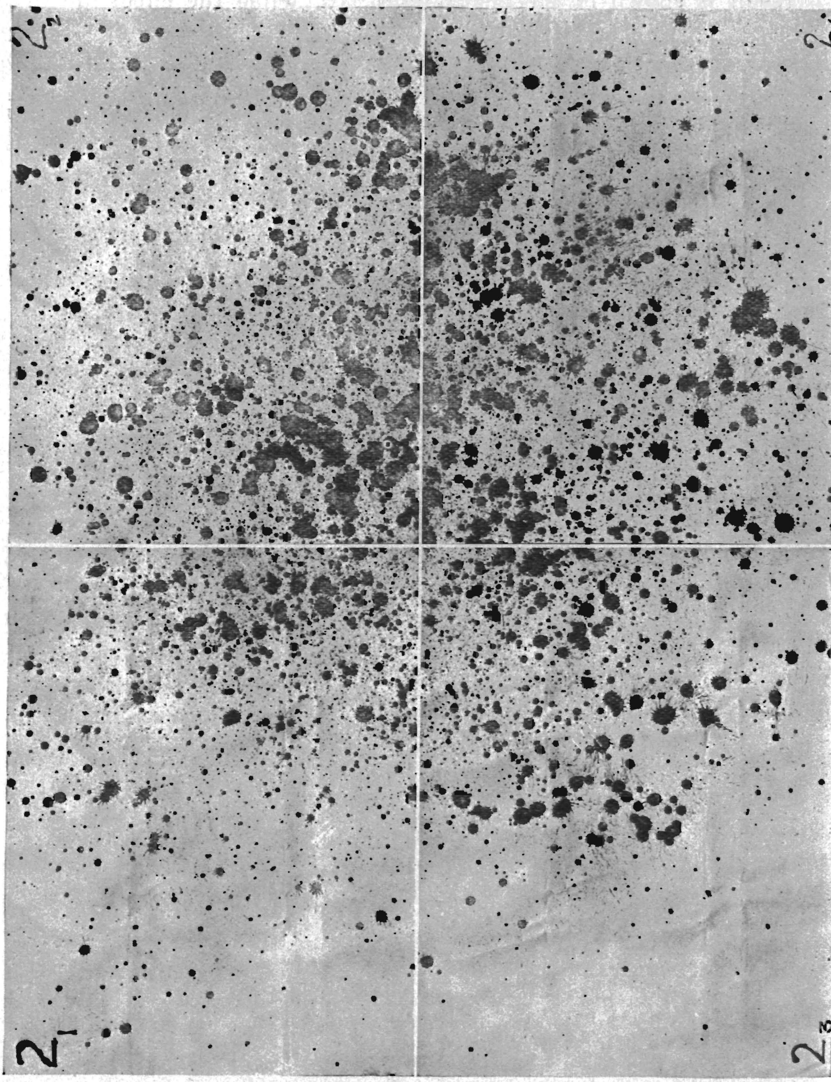


Fig. 17.

be understood, impossible to determine the exact amount of subdivision that took place, but counting the main drops and adding 25% for the myriads of subsidiary drops, the cubic inch of water was, in the second experiment, divided into about 500 drops, each of which would be approximately $\frac{1}{8}''$ in diameter. The gauge of the wire was 18 Imperial, and the actual percentage of obstruction is only = 35%. It will be seen that the use of such water breaks would enable a smaller diameter of condenser to be used than one with solid trays or steps. Even though the clear area through these breaks is very considerable, and they cannot possibly carry a head of water, it has been considered desirable to treat them partly as actual obstruction of the full area and to provide clear passageways through and around them as in the case of ordinary trays. The use of such water breaks would be most suitable in spray plate or rose pipe condensers, but the writer is strongly of the opinion that no other device excels the perforated plate for dispersing water in ordinary sugar factory condensers. The definite subdivision and insured intimacy of steam and water are, the writer thinks, more effectively obtained by such means than by any form of weir or rose. Although the weir has the advantage of being automatic, and is free from complete obstruction, it seems impossible in actual practice to obtain a regular overflow therefrom. The perturbation of the water and unevenness of the edges leads to large proportions of the water being discharged in such bulk that the heat of the steam cannot penetrate it thoroughly. And although it may be said that the holes in a perforated plate are liable to obstruction, long experience has shown that if the holes are made to diverge on the underside, and simple scrapers actuated from the outside, are adopted, practically no trouble is met with in this respect.

In the next Figure, 18, is illustrated a design of condenser, which, although it may not possess any exceptional features of interest, yet shows a combination of details which are by no means common. The conical bottom is familiar to all, but even in this simple detail there is room for trouble. Vortical action, if not prevented by the fitting of ribs or some such means to stop swirling, occurs in conical or similar discharges. The steam inlet enters some little distance above the bottom, but is angled so as to practically project the steam down into the bottom of the condenser.

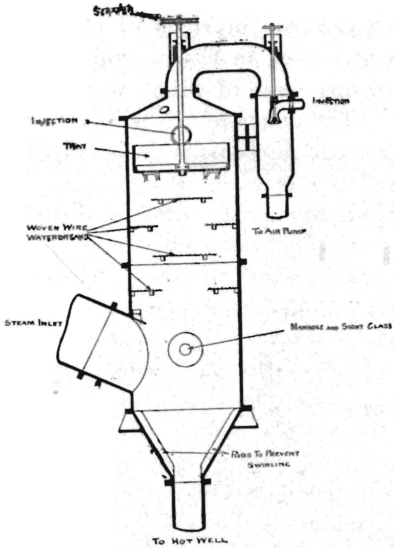


Fig. 18

In this way every use is made of the available height of the condenser, and although at first sight it might appear impossible to crowd (if such a word can be used) the steam down into the bottom, it seems quite reasonable to expect that owing to the almost instantaneous condensation of a portion of the steam, and the effect of its entering the increased area of the condenser, that the steam is really driven downwards, that is on the side next the inlet, before beginning its vertical rise. By angling the inlet as shown, there is also the safeguard against the salt injection water flowing back into the evaporator, either by adherence to the sides of the connecting pipes, or by back currents, if for any reason there is a sudden acquisition of pressure in the condenser. The water is sprayed into the condenser by means of a perforated plate, but this, instead of being built into the sides, is in the form of a high-sided tray, which is supported from the body of the condenser, and between which and the sides of the tray the air passes through to the top of the condenser. The tray is suitable for the fixing of a scraper therein, whilst it also provides an overflow in the event of the holes fouling to such an extent that they will not pass the required quantity of water, a remote contingency certainly, but one to be guarded against nevertheless.