A NEW FORM OF CONDENSER.

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The form of condenser with which Liebig's name is inseparably connected has served its purpose so well and has been in use for so long that it seems almost sacrilege to attack such a venerable institution. There can be no doubt, however, that theoretically it is most inefficient in proportion to its size, and that practically, in addition to being very cumbrous and heavy, it is in many other ways extremely inconvenient.

A number of other forms have from time to time been introduced, but up to the present not one of them has been at all largely adopted.

With regard to the efficiency of the Liebig condenser, the chemist whose laboratory operations are generally conducted on a small scale has but little reason to trouble. Provided condensation be complete, the actual amount of cooling water used is of little importance, but the absurd size of the present apparatus is a matter much more worthy of consideration. The great amount of bench-room taken up by condensers, and the expense involved in laying on water over large areas, renders it desirable that the space given up to distillation purposes should be as small as is conveniently possible. Any reduction in the size of the condensers must, to be of service, be accompanied by a corresponding increase in efficiency.

A theoretically perfect condenser should present to the vapour a cooled surface as large as possible, while the space into which the vapour has to pass should be as

small as possible consistent with its offering only a very low resistance to the passage of vapour into it. In any case, whatever its absolute or relative size may be, it should be of such form and disposition that the stream of incoming vapour can drive the air before it, so that the major part of the condensing space is filled with the pure vapour.

The Liebig condenser is obviously far from fulfilling these conditions; the worm condenser has nearly all the bad points of the Liebig, of which it is really only a coiled form. The spherical condensers also, now becoming so popular on account of their smallness, are as a rule made with the condensing chamber much too large.

The general plan of the form now exhibited is shown in the accompanying sketches. The vapour enters through the tube A into the condensing space B between the two tubes, C and D; after condensation the distillate passes out through E. The cooling water passes down the tube F into the interior of C, which it fills, and, running over the rim at the top, passes in a thin stream down the outside of D, finally flowing away through the escape pipe G. When used as a reflux condenser, the vapour, of course, passes up through E. After allowing the liquid to get into full ebullition, so that the air is driven out of the condensing space, the mouth of A may be completely closed with a cork, thus avoiding even the possibility of loss with volatile liquids such as ether. The apparatus must obviously always be used in one and the same position, *i.e.*, with its axis vertical. This is a distinct advantage, because it is very easily so supported, and because, when thus disposed, it takes up a minimum of space on the bench. An absolutely vertical position, however, is not necessary. It is preferable that the top of the condenser should slope, if at all, towards the flask or retort from which the liquid is being distilled. To obtain the greatest possible efficiency in working, special steps should be taken to ensure the even distribution of the water over the outside of the condenser, as the adhesion between the water and the glass or metal, and the surface tension of the water itself, are reduced to a

FIG. 1.

minimum at high temperatures, so that the cooling water tends to run in narrow streams outside D, instead of spreading out. This is easily remedied by covering D externally, either partially or entirely, with some absorbent material, such as blotting-paper or linen (the latter as a permanence is to be preferred). In addition to this a cork I (Fig. 1), with a number of vertical grooves cut round its outside, is inserted into the mouth of C. The cork is perforated for the cold-water supply tube F, and the water leaves the interior of C by the grooves in the cork, thus getting well distributed round the outside of the condenser. This little device has

the further advantage of preventing any water getting spilt if the condenser receives a sudden knock or jerk whilst in action. With metal condensers the cork may be replaced by a metal disc H (Fig. 2) attached to the cold-water supply tube, and arranged so as to leave space either below it (as in the sketch), or outside it for the water to flow out of the cup on to the exterior of D.

To ensure the utilization of the whole available cooling surface, a wire or band of metal K (Fig. 2) may be coiled spirally round the interior of the condensing space, thus converting it into a flat spiral channel.*

Efficiency.—This may be treated both from a theoretical and from a practical standpoint.

Theoretically it is obvious that the new form has many points of superiority over the Liebig, the worm, or even the spherical condenser as at present made.

The condensing space in the small metal condenser exhibited, of which the outside dimensions of the body are $\frac{1\frac{5}{8}}{16}$ inch $\times$ $4\frac{1}{4}$ inch, is only 9 cubic centimetres. The glass one shown—measuring outside $1\frac{3}{8} \times 5\frac{3}{8}$ inches—has an internal capacity of 30 c.c., while a Liebig's condenser, of which the water-cooled part measured $19 \times \frac{7}{16}$, was found to hold 55 c.c., and a ball condenser $3\frac{1}{2}$ inches in diameter was found to contain over a hundred cubic centimetres.

That the practical performance of the condenser is at least equal to its theoretical promise may be seen from the following figures :—

FIG. 2.

	Small Metal Condenser.			Glass Condenser.	
	(1).	(2).	(3).	(4).	(5).
Temperature of effluent cooling water ...	52° C.	65° C.	76° C.	61° C.	47·5° C.
Temperature of distillate ...	48° C.	60° C.	61° C.	41° C.	35·5° C.
C.c. of cooling water used per hour ...	40,000	40,000	7,200	6020	2093
C.c. of distillate per hour ...	2,642	4,128	1,017	765	355
Ratio of quantity of distillate to that of cooling water ...	$\frac{1}{15\cdot14}$	$\frac{1}{9\cdot69}$	$\frac{1}{7\cdot8}$	$\frac{1}{7\cdot87}$	$\frac{1}{5\cdot9}$

The resistance of the metal condenser, working as in column (2), was roughly equal to one inch of mercury, the volume of the steam condensed in one second being two hundred times the actual capacity of the condenser. When the water supply was stopped, the resistance rose to $1\frac{3}{4}$ inches of mercury.

One of the metal condensers with a body measuring $4\frac{1}{4} \times 1\frac{7}{8}$ outside, but with an unnecessarily large condensing space, when connected up to a high-pressure boiler

* For all ordinary purposes this is quite unnecessary.

(working at 43 lbs. pressure), yielded 8,040 c.c. of distillate per hour. It was, however, working under somewhat disadvantageous circumstances, as it was found impossible to fix it except in a somewhat slanting position, so that the water ran mainly down one side of the exterior.

The glass condensers have not yet been tested as to their extreme capacity, but they have been found ample for any and all of the ordinary laboratory operations, in which 500 c.c. per hour may be taken as the maximum rate of distillation. The metal forms can be used with a ratio of distillate to cooling water as high as $\frac{1}{3}$ without any steam escaping, though the distillate itself is nearly boiling.

In addition to its great efficiency and extremely small size and weight, the new form of condenser has the following advantages :—

It is always used in one and the same position, *i.e.*, *vertical*, in which it takes up a minimum of bench room, and in which also it is very easily fixed, a little bracket projecting from the wall, or a hole in a block sliding up and down a retort stand being ample for the purpose. If greater rigidity is required, the upper end may also be held by a wire or spring clamp attached to the top of the tube F. It can be made, if necessary, in both metal and glass, so that the inner tube C can be withdrawn from the outer. The whole of the interior of the condensing space is thus at once open to view, and can be wiped dry and clean with a duster.

To effect this in the metal condensers a slip-in or a screw joint is made at J (Fig. 2); in glass condensers the fused joint at J (Fig. 1) is replaced by an india-rubber joint. Owing to the cooling water running down *outside* the condenser, it is practically impossible for the escape tube to get choked up with fur, as happens sometimes to a Liebig's condenser after long-continued use. The escape tube G should be made about twice the diameter of the cold-water delivery tube as a further safeguard.

Owing to the vertical position and to the small diameter of the extremity, the condenser is very easily connected in an air-tight manner to a receiver, so that, with the addition of a little side tube at L for attachment to a pump, distillation may be conducted under reduced pressures. Or, if a suitable mercury valve be attached to L, and a little air be sucked out at the commencement of the operation, distillation or digestion may be carried on in an entirely closed space.

In tropical climates, or with liquids of exceptionally low boiling-point, the tube C may be filled with ice, and the water allowed to flow up through it.

The very thin layer into which the water is spread when pouring down the outside of the condenser greatly facilitates evaporation, so that the latent heat of vaporization, which has mainly to be derived from the vapour undergoing condensation, effects a great saving in the cooling water used. This is especially the case with liquids boiling above 100° C., but may be easily shown in the case of water by cutting down the supply of cooling water to a minimum, when the water at the top of C is sometimes as much as 10° hotter than that issuing from G.

Finally, its simplicity renders it easy of construction in almost any material likely to be employed.

The condensers can be obtained from Messrs. J. J. Griffin and Sons, Garrick Street, and from Messrs. C. E. Müller and Co., High Holborn.