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HEAT EXCHANGER AND METHOD OF MAKING SAME

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This invention relates to heat exchangers and methods of making same, and while not limited to the field of condensing equipment it is especially advantageous in the construction and operation of steam condensers. More especially the invention relates to condenser tubes and methods of making or forming the same.

Among the primary objects of the invention are: to increase substantially the efficiency and thus the condensing capacity of condenser tubes of a given size, to make possible the assembly of a larger number of tubes within a given available space, to raise the efficiency and capacity of condenser equipment without a commensurate increase in costs of manufacture or maintenance, to strengthen condenser tubes without a proportionate increase of weight or size, to improve the conditions of flow and contact of the fluid media upon the inside and/or upon the outside of the tubes, and to obtain a closer spacing of the tubes in a bundle while at the same time maintaining or improving the sturdiness of the header or tube plates and of the joints between the tubes and such plates.

More particularly, the invention contemplates a tube construction of tapering formation throughout a substantial portion of the tube length, and specifically a taper-flattened tube in which the cross-sectional shape varies from a circular section adjacent one end to an elliptical or more preferably oval section adjacent the other end. The internal cross-sectional flow area progressively diminishing in the same direction along the tube. Still further, the invention contemplates such a construction in which the taper imposed on the tube is so proportioned with relation to the original diameter and length thereof that the maximum efficiency of heat transfer, and thus of condensing action (when the steam to be condensed is passed into the tube at the end of greatest cross-sectional area) is obtained with a minimum expenditure of energy required to force the steam through the tube and to bring it into contact with the condensing surface.

Stated in another way, the taper is such as to provide a maximum of cross-sectional flow area at the steam entrance end and a much reduced flow area at the condensate outlet end, as by a reduction of internal diameter of the tube in one plane, in such proportion that a minimum of back pressure is presented to the incoming steam and a maximum contact of the steam with the condensing surface is secured.

In a preferred form, the invention contemplates also the breaking up and the lateral division of the longitudinal steam flow in the tube, preferably by means such as internal projections, pins or baffles, integral with, or secured to the walls of the tube and located at intervals along the length thereof, preferably in staggered relation and/or with inclined surfaces on which the steam impinges, said projections preferably extending transversely with relation to the longest cross-sectional axis of the flattened tube and serving additionally to strengthen the tube in its tapered or flattened region and to conduct heat to the outer surface of the tube wall.

Still further, the invention contemplates the provision of a condenser tube of tapered, and especially taper-flattened, formation having external heat-transfer elements, such as finning, which may be of various forms, for example a spiral fin or a plurality of radial or circular fins positioned to increase the rate of heat transfer from the tube wall to a surrounding or externally flowing body of air, water or other cooling medium, and arranged, if desired, to set up a turbulent flow of such medium. It is preferable that said fins be integral with the tube wall and be themselves tapered in such manner that the fins progressively increase in radial dimension toward that end of the tube which is of smallest cross-sectional flow area. In addition, where the taper-flattened formation is imposed upon such an externally finned tube, the tube itself may be of tapered circular section initially so that the final major cross-sectional axis, after the taper-flattening operation, is not so great as to hinder the close spacing of the tubes when assembled in a tube bundle.

Still another object of the invention is to facilitate the making of joints between the tubes and tube plates, and to improve and strengthen the joints and said plates, by retaining a circular cross-section at each end of the tube, and preferably also by swaging or rolling down one or both of said ends to a reduced diameter so that the "bridges" between the tube receiving openings in the tube plates are of ample width and strength even though an extremely close spacing of tubes is employed. The lower or outlet end of such a steam condensing tube may be swaged down considerably, since the volume of condensate to be discharged therefrom is relatively small compared to the volume of steam entering the upper end, and by this arrangement space may be provided for a packing gland in the tube plate if a sliding expansion joint be required at one end of the tube between said tube and said plate.

The invention further involves the arrange-
ment or assembly of a plurality of flattened, and particularly taper-flattened, tubes in such manner that when the tube bundle is viewed in cross-section the tubes of one row are in staggered relation to those of an adjacent row, and one tube has its longer cross-sectional dimension, in the flattened region, at an angle, preferably 90°, to the similar axis of an adjacent tube, all the tubes in one row preferably having their longer cross-sectional axes in parallelism and extending at oblique angles to the plane of the row, whereby an extremely close spacing of the tube centers is possible and at the same time a substantial turbulence is set up in the external cooling stream which passes in general at right angles to the longitudinal axes of the tubes.

The invention also involves methods of producing or forming tubing of the characteristics specified hereinafore; particularly the formation of the tubes from a deformable material of good heat conducting properties, such as copper, brass, aluminum, or various alloys, by operating upon a plain round or tapered round tube by means of dies orinclined press members, which latter may have plane faces; or more preferably, for the sake of greater accuracy, each press member may have a contour equivalent to half the contour of the desired final taper-flattened shape to be imposed upon the tube. The press members terminate short of the tube ends if a round section is to be retained for joint purposes, and if one or both ends is or are to be of reduced diameter I swage or roll down such ends prior to the taper-flattening operation upon the intermediate region.

The internal projections or baffles are, according to one method of the present invention, formed upon the tubes simultaneously with the taper-flattening operation, by imposing indentations upon the flattened sides of the tube walls by means of protruberances on the faces of the press members. Alternatively, the internal baffles are separately formed, and inserted either punch the baffles-receiving holes in the tube walls prior to the flattening process, by means of a recessed punch while the tube is held upon a mandrel, the baffles being inserted and welded or otherwise secured in place after the step of taper-flattening; or else I drill holes through the tube walls after the taper-flattening step and then insert and secure the baffles members.

How the foregoing objects, advantages and features of the invention are obtained, together with such others as may be incident to the invention, will be evident in the light of the following description, taken with the accompanying drawings, in which drawings:

Figures 1 to 9 illustrate one form of tube and the method of making the same, as follows: Figure 1 is a longitudinal sectional view of a plain round or taper-flattened tube, after a swaging or rolling operation has been imposed on the two ends thereof to reduce the diameter of the end portions; Figure 2 is a similar section of the tube, shown in position between two relatively reciprocable dies or press members each of which has an operative face shaped to the form of one-half of the finally deformed external contour of the intermediate portion of the tube; Figure 3 is a view similar to Figure 2, with the press members in fully compressed position; Figure 4 is a longitudinal sectional view of the completed tube, as removed from the press, with a row of internal pin baffles secured in place; Figure 5 is a longitudinal section taken at right angles to the section of Figure 4, as indicated by the line 5—5 of Figure 4; Figure 6 is a section through the circular inlet end portion of the finished tube of Figure 4, on the line 6—6 of that figure; and Figures 7, 8 and 9 are similar sections, taken respectively on the lines 7—7, 8—8 and 9—9 of Figure 4, illustrating the different degrees of taper-flattening at different points along the length of the tube, preferably 90°.

Figures 10 and 11 are longitudinal sectional views, taken at right angles to one another, through a steam condensing tube, illustrating a pin baffle arrangement in which the pin projections are of larger diameter and are arranged in staggered relationship;

Figures 12 and 13 are similar views, showing a third arrangement of pin baffles, said baffles being flattened in cross-section and angled with respect to the longitudinal axis of the tube and to each other;

Figures 14 and 15 illustrate a similar tube, with baffles formed as integral internal projections;

Figure 16 being a section on the line 16—16 of Figure 14;

Figures 17 and 18 show a tube and baffle arrangement similar to that of Figures 12 and 13, but in which the baffles are made with round ends for securing in the tube walls; a detail of such baffle being shown in perspective in Figure 19;

Figures 20, 21 and 22 illustrate the making of a second general form of the tube itself (without projections or baffles); Figure 20 showing the tube partially formed, in which the round blank has been swaged down to a considerably smaller diameter at one end only, and Figures 21 and 22 being longitudinal sections at right angles to one another through the finished tube, and illustrating the upper end rolled into a groove in the wall of a steam inlet header and the lower end mounted by a packing gland in a condensate outlet header;

Figures 23, 24 and 25 are sectional views through the tube bundle of a condenser, assembled in accordance with the present invention, the tubes here employed being of the type shown in Figures 4 to 9 inclusive, and the three sections being illustrative, respectively, of the three individual cross-sections shown in Figures 6, 7 and 9;

Figures 26 to 36 inclusive illustrate the taper-flattening of an externally-finned tube and the finished tube itself, as follows: Figure 26 is a vertical longitudinal section (broken away in the middle) through a tube of round section having a spiral fin of progressively varying radial dimension, and showing the tube within a vertical mold by means of which molten lead may be delivered to the fin interspaces for solidification therein, only one-half of the mold being shown; Figure 27 is a section through the complete mold with the tube and lead filling in place therein, the section being taken on the line 27—27 of Figure 26; Figure 28 is a longitudinal section (broken out in the middle) of the lead-encased tube of Figure 26 as removed from the mold and positioned between a pair of press members preparatory to the taper-flattening operation; Figure 29 is a view similar to Figure 28 but showing the taper-flattened formation of the tube as imposed by the pressure of the press members; Figure 30 is a section on the line 30—30 of Figure 29, illustrating the contour of the press members adjacent one end thereof and the cross-sectional form of the tube as compressed therein; Figure 31 is a section on the line 31—31 of Figure 29, showing the curvature of the press members at the end opposite to that shown in Figure 30, and showing the section of the finished...
tube at said end; Figures 32 and 33 are longitudinal sections taken at right angles to one another of the finished tube as removed from the press members, after melting off the lead fillers; and Figures 34, 35, and 36 are sections taken on the corresponding lines in Figure 32, to illustrate the taper-flattening of the tube wall;

Figures 37 and 38 are, respectively, a longitudinal section and a transverse section taken on line 38—38 of Figure 37, through a circular tube having an initial taper, and with a plurality of circular fins which increase in diameter progressively toward that end of the tube which is of smallest diameter; Figures 39 and 40 are longitudinal sections, at right angles to one another, through a tube of the type shown in Figure 37, after a taper-flattening process similar to that illustrated in Figures 26 to 31 inclusive has been imposed upon the tube; and Figures 41 and 42 are sections taken respectively on the lines 41—41 and 42—42 in Figure 39, to illustrate the final shape of the taper-flattened tube wall.

Referring now to Figures 1 to 9 inclusive, it should first be observed that I may take a straight tube blank 1 and swage down, roll or otherwise reduce the diameter of the end portions, as indicated at 2, although it will be understood that other features of the invention may be independently employed without the advantage of the reduced tube mounting ends.

The round tube is then placed between the press members 3a, 3b, the internal faces 4a, 4b of which are respectively shaped to a contour of one-half of the desired final taper shape of the intermediate portion of the tube. The press members are then brought together, until their outside edges meet along the line 5; the ends of said members preferably having slightly rounded edges, as indicated at 6, so as to prevent cutting into the tube wall. This operation, resulting in a taper-flattened tube body 1a, as shown in Figures 4 and 5, the tube being of progressively flattened section as illustrated by Figure 6 in which are shown the progressively flattened converging side walls 7, the curved wall portions which connect the flat sides being initially daggerted as shown at 8. Holes are now drilled through the flat faces of the tube, i.e. parallel to the minor cross-sectional axis, and the pin baffles 9 are inserted therein and secured in place by any suitable means, such as welding.

It is obvious from the foregoing that by operating upon an elongated tube of initially uniform circular section, it is possible by the simple procedure of this invention to secure a taper-flattened tube of substantially constant perimeter, with walls converging substantially uniformly and unidirectionally from adjacent one end toward the other (as seen in Figure 4), and with uniform spacing of the flattened wall faces at any cross-section (as will be seen in Figures 8, 9) and Figure 6. It will also be observed (from Figures 4 and 5) that the tube can readily be produced with integral taper-flattened portion symmetrically disposed with reference to the axis of the circular end portions.

In the modification shown in Figures 10 and 11, the tube 1a itself is the same as that shown in the preceding figures, having the reduced end portions 2, but the baffle pins 10 are of somewhat larger size and arranged in staggered relation, as shown, to further divide the steam flow and break up the formation of a dead film of condensate on the surface of the tube.

In the form shown in Figures 12 and 13, the tube 1a is provided with baffle elements 11 which are flattened in cross-section and arranged at right angles to each other and to the longitudinal axis of the tube, so as to stir up eddies or vortices in the flow of the stream through the tube. In applying these baffles, I prefer to mount the round tube upon a mandrel, prior to the taper-flattening process, and perforate the elongated baffle-receiving apertures by means of any suitable recessed punch. After the flattening operation, the baffles are inserted and secured in position.

In the embodiment shown in Figures 14, 15 and 16, the tube 1a is of a taper-flattened form similar to the tubes shown in the preceding figures, having swaged-down end portions 2, but the internal projections or baffles are in the shape of pressed bosses, which may be formed in the tube wall by projections 12' on the forming face of the press members 3a, 3b (which are fragmentarily illustrated in Figure 14).

In Figures 17 to 19 I have illustrated a construction in which the tube 1a is of the same shape as the previous tubes but wherein the baffles 14, though of a shape and disposition similar to baffles 11 seen in Figures 12 and 13, are applicable to the tube by a drilling and welding method similar to that employed with the plain baffles 9 or 10 (shown in Figures 7 and 11). This application of a flat-section baffle is accomplished by providing the baffle 14 with circular end portions 14' which fit the drilled holes in the flat sides of the tube 1a.

Referring now to Figures 20, 21 and 22, Figure 20 shows a plain round tube 1 with only its lower end 2a reduced in diameter, but the reduction of diameter being more substantial than in the case of the blank shown in Figure 1. After the taper-flattening process, the tube 1b is in the form shown in Figures 21 and 22 (these two views being longitudinal sections taken at right angles one to another) and it will be seen that such tubes lend themselves readily to a very close spacing in an upper steam header wall 15 and a lower condensate header wall 16 even where it is necessary, as here shown, to employ a packing gland 17 or similar sliding expansion joint at one end of the tube. In fact, if these two figures be considered as representing adjacent tubes mounted in the same pair of tube plates, with their flattened sides set at right angles to one another, it can readily be seen that the one tube could be brought over quite close to the adjacent tube, leaving only a small gap between the shoulder 18 of one tube and the indentation 19 of the next, the reduction of this gap being limited only by the space requirements for the packing glands and the necessary space for the cooling medium circulating between the tubes.

By reference now to Figures 23, 24 and 25, which are sections through a bundle of tubes of the type shown in Figures 4 to 9 inclusive, it will be observed that the steam inlet end of the tubes may be secured into the tube sheet 20 (fragmentarily illustrated) on relatively close center, and with a symmetrical arrangement of staggered rows, four such rows being here shown for purposes of illustration, the direction of flow of the external cooling medium, such as air, being illustrated by the arrows which are at right angles to the longitudinal axis of the tubes and to the planes of the rows.

The progressive taper, by flattening, is shown in Figures 24 and 25, and it will be observed that the major cross-sectional axis of the flattened 75.
portion of each tube is set at an oblique angle, for example 45°, to the plane of the row in which the tube is located, the flattened faces of the tubes parallel to each other but sub-
stantially at right angles to the corresponding planes of similar portions of the tubes in an ad-

cjacent row. This alternating reverse inclination of the flattened portions of the tubes, and the relatively staggered positions of the tubes of ad-

visated rows, cooperate in making possible the close spacing of the tubes as shown, the clear-

ances between which may be even further re-
duced if desired, without interfering with indi-

cidual removal and replacement of tubes, about

the only limiting factor being the width of the bridges required in the tube sheet between the tube-receiving apertures, this width depending in large part upon the pressures to be employed.

Additionally, the arrangement serves to impose a

zigzag flow upon the external cooling medium, tending to break up any dead air film upon the surfaces of the tubes.

It will thus be evident that not only is the ca-
pacity of a condenser of given overall size in-
creased by virtue of the construction of the in-
dividual tube but also by virtue of the arrange-
ment of the assembly of tubes in which they are thereby made possible. Although Figures 23 to 25 illus-

trate only one tube plate or header, it will of

course be understood (in view of the previous de-
scription of Figures 21 and 22) that the inlet ends of the tubes, i.e., the ends of largest cross-sec-
tional flow area, are arranged in co-operative rel-
ad to one such header or the like for a rela-
tively hot fluid medium, and the other ends are

arranged in co-operative relation with another header or the like for said medium in its rela-
tively cool condition.

The third general form of tubing according to

this invention, along with the method of making the same, is illustrated in Figures 26 to 36 inclusive.

A tube of circular section, having a tapering spiral fin 21 integral therewith is shown in Figures 26 and 27 in position within a vertical mold which is formed of two halves 22, 22c, this mold having a tapered bore to fit the progressively varying external diameter of the finning, the upper and lower ends of the mold being enclosed by sleeves or ferrules 23, 23a which are in sur-

rounding relation to the end portions 2b of the mold tube.

The tube to be operated upon, as shown in Figure 26, may have its spiral finning 21 formed by any one of several known processes, such as swaging, rolling, etc., by which the metal is upset to form the external finning 21, an internal spiral groove or indentation 21a being commonly inci-
dent to such tubing. I take such a known tube and preferably effect a tapering of the fin dimen-
sion from the lower end of the tube to the upper end by turning the same down on any suitable lathe, although in its broader aspects the invention is not limited to the use of a tapering fin dimension since a tube with finning of uniform radial dimension may be advantageously taper-

flattened in accordance with this invention.

The essential purpose of the mold is similar to

that described in the copending application of Albert F. Townsend and Frank J. Bascombe, Se-

erial No. 55,072, filed December 18, 1935, i.e., to facilitate the pouring of molten lead or equiva-

len t material, indicated at 24, which solidifies in the fin interspaces, where it protects the finning during the tube deforming operation, the lead filler or matrix being subsequently melted off. To this end, the mold is provided with a lead de-

livery bore 25 having a feed slot 26 extending substantially the tube length of the mold and communicating with the tube-receiving bore, and an air relief passage 27 with similar communicating slot 28 is also provided, a supplementary air relief passage 29 being formed in the upper fer-

rule 23 to vent the portion formed by the invariably capillary nature of said upper ferrule. The mold differs from that shown in said copending application primarily by virtue of its tapered tube-

receiving bore, and from this point on the de-

forming process imposed upon the tube is differ-

ent from that of the copending application.

When the lead has solidified, the encased tube

is removed from the mold and is placed between a pair of dies or press members 31 as shown in Figure 28. These press members may, of course, stand vertically on end but if placed horizontal-

ly, as shown, it may be desirable to provide a suitable support for that end of the tube where the finning is of too small a diameter to contact with the upper and lower internal faces 31a, 31b, of the press. Such support may take the form of a link 32 having a slot 33, the narrow dimension of which is equal to the width of the end of the tube 3b, said link being suitably supported on or carried by the upper press member 31, as by means of the guide 34 and the adjusting screw 35.

As soon as the press members start to move toward each other, the left-hand end of the finned portion of the tube (viewing it in Figure 28) will commence to be compressed or flattened, and as this process proceeds a more extensive length of the tube will come into contact with the faces of the press members, and the right-hand end of the tube will ride up in the slot 33, support at that end being then no longer necessary.

Figure 29 shows the press members in fully compressed position, the end portions 2b of the tube remaining at their original diameter, but the intermediate portion of the tube being taper-

flattened, in accordance with this invention, by virtue of the fact that the press members are brought together in parallelism whereas the origi-
nal finning was of a progressive taper. The sec-

tional contour of the press members, and the re-
sultant deformation of the sectional contour of the tube, is illustrated in Figures 30 and 31.

The completed tube 1c, after melting off of the lead filler subsequent to the taper-flattening pro-

cess, is clearly shown in Figures 32 and 33, which are longitudinal sections taken at right angles to each other; and the taper-flattening of the tube is well illustrated by the three sectional views, Figures 34, 35 and 36.

In Figures 37 and 38 (which are respectively a longitudinal section and a transverse section) I have shown a modified form of finned tube, in which the integral fins are produced by a spin-

ning process. To form this tube, a blank having uniform diameter equal to that of the end por-
tions 2b is rotated about its own longitudinal axis between a circumferentially spaced series of roll-
ers or rotating dies, the peripheries of which are wedge shaped so that as the rollers are brought closer to the central axis of the rotating tube, the tube wall will be con-

tinuously thinned until the wall thickness will be extruded from the wall material itself. This operation is done at intervals throughout

that portion of the tube on which it is desired to form the fins, as shown; and by exerting a pro-
ger爱吃 greater pressure upon the rolls, when forming the successive fins (beginning adjacent to the upper end of the tube and ending adjacent
the bottom end, as in Figure 37) a taper of the tube wall and a reversed taper of the fin diameter will result. These fins 38 are, of course, individual circular fins and not spiral as in the preceding figures, and their formation leaves small internal annular grooves §64. Part of the advantage of the present invention is thus secured by leaving the tube in the form shown in Figures 37 and 38. However, in order that all of the advantages may be fully secured I prefer to further operate upon the tube, in the following manner.

The tube shown in Figure 37 is placed within a mold such as seen in Figure 36, and a liquid filling is placed therein and the tube taper-flattened in accordance with the process depicted in Figures 27 to 31.

The resultant finished tube 1d, after melting off the lead, is illustrated by the longitudinal sections of Figures 39 and 40 and the transverse sections of Figures 41 and 42.

While tubes constructed in accordance with the present invention are adaptable to various uses, they are as hereinbefore stated especially advantageous for the purpose of condensing steam, and I will now briefly describe their operation, as follows:

For steam condensation, the tubes are advantageously placed in an upright position, with their ends largest cross-sectional area uppermost. The steam to be condensed is admitted to the inside of the tube through the upper, inlet, end which is of the maximum flow area, and the condensate is discharged through the reduced area of the lower, outlet, end; the cooling medium, water, air, or other fluid, flowing over the outside of the tubes, for example transversely. During operation, the steam is in contact with the tube wall which condenses. This steam, as it condenses upon the inner periphery of the tube, is continuously replaced by steam from the center of the tube, so that there is a radial flow of steam in the tube as well as the longitudinal flow of the incoming supply of steam.

Since the volume of steam is many times the condensate volume (being, for example, 1200 times the condensate volume, at 5 pounds gauge pressure) it follows that the rate of radial flow of the steam within a tube would normally be very low. Further, the velocity head required for this radial flow is equivalent to a certain amount of heat energy which must be absorbed by the cooling medium, so it follows that any reduction in the radial velocity head results in an increase of the condensing capacity of the cooling medium, since a larger proportion of the heat absorbed by said medium is being utilized for the condensing action.

By flattening the tube I obtain a reduction in the radial velocity head perpendicular to the flattened portion. In addition, by tapering the flattening I am enabled to maintain the desired entrance area for steam admission, as in a plain round tube, while at the same time I secure a progressive reduction in the radial dimension across which the steam passes in its flow toward the cooling walls, and thereby avoid such losses as would occur in a tube of constant flattened section, the reduced inlet area of which would require an increase in longitudinal velocity.

The taper-flattening does not hinder the longitudinal flow, because the steam is progressively condensing as it passes downwardly through the tube, and the total flow area required therefore gradually becomes less. Thus the taper-flattened tube meets the requirements of providing ample inlet area and highly efficient condensing action.

I have further found that the provision of internal projections or baffles, in addition to strengthening the tube in its flattened region and acting also as condensing elements by conducting heat outwardly to the condensing surfaces of the tube, apparently also act to convert a portion of the longitudinal velocity at or near the center of the tube into a radial velocity head, and further seem to break up the longitudinal flowing stream in a way to prevent the formation of relatively dead or insulating films of condensate on the tube walls. Therefore, in the internally pinned or baffled taper-flattened tube, the baffles and the taper-flattened section count in a novel manner to reduce the external energy required to bring the steam into contact with the condensing surface, thereby making more of the cooling medium energy available for actual heat exchange.

Certain of the specific embodiments of the invention have advantages peculiar to themselves. For instance, the form shown in Figures 10 and 11, with a staggered arrangement of internal pins, is an especially sturdy tube and in operation the pins are particularly effective in breaking up the steam flow.

The flattened pin baffles, in the form shown in Figures 12 and 13, act to divert a portion of the steam toward the extreme edges of the longer cross-section of the tube.

The tube shown in Figures 14 to 16 has at least a portion of the advantage of internal projections, even though such projections do not in this instance extend across the full width of the tube section, and has the added advantages of simplicity and lower manufacturing cost, and an imperforate wall from end to end.

The embodiment shown in Figures 17 to 19 provides a number of the advantages incident to that shown in Figures 12 and 13 combined with the advantage of easier installation of the pin baffles.

The form shown in Figures 21 and 22 has the advantage of minimum manufacturing cost, and is capable of the closest spacing when assembled in a tube bundle.

Certain other advantages, peculiar to the externally finned taper-flattened tube should also be briefly mentioned. In addition to the advantages of taper-flattening, which are similar to those above described, the external radiating fins on the latter types of tubes set up a turbulence in the flow of the surrounding cooling medium and also act to carry the heat off from the tube wall more rapidly, in proportion to the more effective delivery of the steam to the inside of the wall due to the taper-flattening. Furthermore, with taper-flattened finned tubes (whether the fins are of uniform radial width or are of tapering radial dimension from one end of the tube toward the other) I am enabled to obtain this substantial increase in radiation without interfering with a very close spacing and arrangement of the tubes, similar to the spacing and arrangement of the smooth-surfaced taper-flattened tubes illustrated in the arrangement of Figures 23, 24 and 25; the tapering-fin taper-flattened tube being apparently susceptible of a somewhat closer spacing than a uniform-fin taper-flattened tube of equal total fin area.

With each of the various embodiments of the present invention I have found by test that a substantial improvement in condensing capacity has been obtained, as compared with a plain
round tube of continuous cross-sectional area equal to the inlet area of the taper-flattened tubes as will be evident from the following table of test results:

<table>
<thead>
<tr>
<th>Type of tube</th>
<th>Tube length</th>
<th>Area of steam condenser at inlet end (in square inches)</th>
<th>Area of condenser at outlet end (in square inches)</th>
<th>Weight of steam condensed per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant circular section</td>
<td>Inches</td>
<td>0.442</td>
<td>0.442</td>
<td>Pounds</td>
</tr>
<tr>
<td>Taper-flattened (Figure 21)</td>
<td>64</td>
<td>0.442</td>
<td>0.442</td>
<td>27</td>
</tr>
<tr>
<td>Taper-flattened internally baffled (Figure 33)</td>
<td>64</td>
<td>0.442</td>
<td>0.442</td>
<td>32</td>
</tr>
<tr>
<td>Taper-flattened externally finned (Figure 33)</td>
<td>64</td>
<td>0.442</td>
<td>0.442</td>
<td>38</td>
</tr>
</tbody>
</table>

Note.—This figure estimated from actual test of aluminum tube of slightly larger size.

In making the above tests, all tubes tested (with the one exception noted) were of copper, the entering steam pressure and temperature being the same for all tubes, the rate of circulation of the cooling water around the tubes was identical, and any other factors subject to variation were kept within reasonably close limits. The tube length given in the table is the length of the tube exposed to the cooling water, the overall length of each tube being 8 to 10 inches longer than shown in the table, the additional length being represented by the end portions of the tubes which were utilized for pipe connections and packing glands.

It should be understood, of course, that the proportions chosen for the particular tubes tested are merely illustrative of examples of tubing made in accordance with the present invention and are not to be taken in any way as limitations upon the invention or the scope of the claims. They serve to illustrate, however, that such embodiments of the present invention effect a very marked improvement in the weight of steam condensed per hour as compared with the plain round tube of comparable size appearing at the head of the table, the improvement ranging from 18.5% to 40.5%.

The term "integral", as used in the claims, means formed integrally ab initio, or of one piece; and does not refer to separate pieces integrally joined.

I claim:

1. For a heat exchanger having headers or the like, one for a relatively hot fluid medium and another for said medium in relatively cool condition, an elongated heat-transfer tube with one end co-operative with the first header and the other end with the second, said tube being of substantially constant perimeter and having flattened opposed wall portions substantially uniformly unidirectionally converging from adjacent the first-mentioned end of the tube to adjacent the other end, the flattened faces being spaced apart from each other throughout their length and of substantially uniform spacing at any cross-section.

2. For a heat exchanger having headers or the like, one for a relatively hot fluid medium and another for said medium in relatively cool condition, an elongated heat-transfer tube with one end co-operative with the first header and the other end with the second, said tube having flattened opposed wall portions unidirectionally converging from adjacent the first-mentioned end of the tube to adjacent the other end, the flattened faces being spaced apart from each other throughout their length and of substantially uniform spacing at any cross-section, the end portions of said tube being of circular section and gradually merging into the tapered portion.

3. For a heat exchanger having headers or the like, one for a relatively hot fluid medium and another for said medium in relatively cool condition, an elongated heat-transfer tube with one end co-operative with the first header and the other end with the second, said tube having flattened opposed wall portions unidirectionally converging from adjacent the first-mentioned end of the tube to adjacent the other end, the flattened faces being spaced apart from each other throughout their length and of substantially uniform spacing at any cross-section, the end portions of said tube being of circular section and gradually merging into the tapered portion.

4. For a heat exchanger having headers or the like, one for a relatively hot fluid medium and another for said medium in relatively cool condition, an elongated heat-transfer tube with one end co-operative with the first header and the other end with the second, said tube having flattened opposed wall portions unidirectionally converging from adjacent the first-mentioned end of the tube to adjacent the other end, the flattened faces being spaced apart from each other throughout their length and of substantially uniform spacing at any cross-section, and having flattened opposed wall portions substantially uniformly unidirectionally converging from adjacent the first-mentioned end of the tube to adjacent the other end, the flattened faces being spaced apart from each other throughout their length and of substantially uniform spacing at any cross-section and the second-mentioned end being of a reduced diameter as compared with the first end.

5. For a heat exchanger having headers or the like, one for a relatively hot fluid medium and another for said medium in relatively cool condition, an elongated heat-transfer tube of ductile metal with one end co-operative with the first header and the other end with the second, said tube being of substantially constant perimeter and having flattened opposed wall portions substantially uniformly unidirectionally converging from adjacent the first-mentioned end of the tube to adjacent the other end, the flattened faces being spaced apart from each other throughout their length and of substantially uniform spacing at any cross-section.

6. For a heat exchanger having headers or the like, one for a relatively hot fluid medium and another for said medium in relatively cool condition, an elongated heat-transfer tube disposed in a substantially upright position, with its upper end co-operative with the first header and its lower end with the second, said tube being of substantially constant perimeter and having flattened opposed wall portions substantially uniformly unidirectionally converging from adjacent the first-mentioned end of the tube to adjacent the other end, the flattened faces being spaced apart from each other throughout their length and of substantially uniform spacing at any cross-section.

7. For a heat exchanger having headers or the like, one for a relatively hot fluid medium and another for said medium in relatively cool condition, an elongated heat-transfer tube with one end co-operative with the first header and the other end with the second, said tube being of substantially constant perimeter and having flattened opposed wall portions substantially uniformly unidirectionally converging from adjacent the first-mentioned end of the tube to adjacent the other end, the flattened faces being spaced apart from each other throughout their length and of substantially uniform spacing at any cross-section.

8. For a heat exchanger having headers or the like, one for a relatively hot fluid medium and another for said medium in relatively cool condition, an elongated heat-transfer tube with one end co-operative with the first header and the other end with the second, said tube being of substantially constant perimeter and having flattened opposed wall portions substantially uniformly unidirectionally converging from adjacent the first-mentioned end of the tube to adjacent the other end, the flattened faces being spaced apart from each other throughout their length and of substantially uniform spacing at any cross-section.
jacent the other end, the flattened faces being spaced apart from each other throughout their length and of substantially uniform spacing at any cross-section, and heat-conducting elements extending from a face of the tube wall.

8. For a heat exchanger having headers or the like, one for a relatively hot fluid medium and another for said medium in relatively cool condition, an elongated heat-transfer tube with one end co-operative with the first header and the other end with the second, said tube being of substantially constant perimeter and having flattened opposed wall portions substantially uniformly unidirectionally converging from adjacent the first-mentioned end of the tube to adjacent the other end, the flattened faces being spaced apart from each other throughout their length and of substantially uniform spacing at any cross-section, and integral heat-conducting elements extending from a face of the tube wall.

9. For a heat exchanger having headers or the like, one for a relatively hot fluid medium and another for said medium in relatively cool condition, an elongated heat-transfer tube with one end co-operative with the first header and the other end with the second, said tube having flattened opposed wall portions unidirectionally converging from adjacent the first-mentioned end of the tube to adjacent the other end, the flattened faces being spaced apart from each other throughout their length and of substantially uniform spacing at any cross-section, said tube having integral radiating finning in the taper-flattened region.

10. For a heat exchanger having headers or the like, one for a relatively hot fluid medium and another for said medium in relatively cool condition, an elongated heat-transfer tube with one end co-operative with the first header and the other end with the second, said tube being of substantially constant perimeter and having flattened opposed wall portions substantially uniformly unidirectionally converging from adjacent the first-mentioned end of the tube to adjacent the other end, the flattened faces being spaced apart from each other throughout their length and of substantially uniform spacing at any cross-section, said tube further having finning radially extending from the exterior face of the tube throughout a substantial portion of the length of the tube, the radial dimension of said finning, measured from the tube wall, increasing progressively along the tube unidirectionally toward the latter end of the tube.

11. For a heat exchanger having headers or the like, one for a relatively hot fluid medium and another for said medium in relatively cool condition, an elongated heat-transfer tube of ductile metal with one end co-operative with the first header and the other end with the second, said tube being tapered progressively to a smaller cross-sectional flow area, unidirectionally, from adjacent the first-mentioned end of the tube to adjacent the other end, and having integral finning radially-extending from the exterior face of the tube throughout a substantial portion of the length of the tube, the radial dimension of said finning, measured from the tube wall, increasing progressively along the tube unidirectionally toward the latter end of the tube.

12. For a heat exchanger having headers or the like, one for a relatively hot fluid medium and another for said medium in relatively cool condition, an elongated heat-transfer tube of ductile metal having integral external finning, with one end of said tube co-operative with the first header and the other end with the second, said tube, as viewed in section on at least one plane containing the longitudinal axis, being formed with an internal tube dimension progressively decreasing unidirectionally from adjacent the first-mentioned end of the tube to adjacent the other end and with the outside dimension over the finning remaining substantially constant.

13. The method of forming a taper-flattened externally finned tube which comprises encasing a finned tube at least throughout the fin interspaces with a deformable material, imposing a progressively variable squeezing action upon the encased tube at opposite sides thereof, and thereafter removing said material.

14. The method of forming a finned tube of the character herein described, from a round section finned tube of constant diameter and fin width, which comprises the steps of reducing the radial fin dimension progressively from adjacent one end of the tube to adjacent the other end, and thereafter progressively flattening the tube in the opposite direction.

15. The method of forming a taper-flattened finned tube of the character herein described, from a ductile metallic tube of circular section, which comprises: forming upon said tube, from the metal thereof, exterior finning projecting radially therefrom to a dimension which decreases progressively from adjacent one end of the tube to adjacent the other when viewed upon a longitudinal sectional plane through the tube; and thereafter progressively flattening the tube by a squeezing action at right angles to said plane and thus deforming said tube to a progressively diminishing cross-sectional dimension in said plane toward the end of the tube of maximum fin width.

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