A radiator for a tank containing a power transformer or the like submerged in a cooling fluid having a plurality of rectangular tubes arranged and secured in spaced relationship with substantially parallel longitudinal axes in combination with a shroud surrounding and spaced from the tubes forming at least a portion of one wall of the tank. The spaces between adjacent tubes and the shroud and the tubes are sealed at axially opposite ends to provide flow passages for cooling fluid within the tank while the axial ends of the tubes remain open to establish a flow of cooling ambient air.

In other embodiments of the invention, a plurality of air cooling tubes are placed within the confines of an oil-containing tank for a power transformer, to occupy spaces normally filled with oil and thus reduce the necessary volume of oil while at the same time serving as cooling radiator means.

7 Claims, 16 Drawing Figures
COOLING RADIATOR FOR FLUID COOLED POWER TRANSFORMERS AND THE LIKE

BACKGROUND AND SUMMARY OF THE INVENTION

This application is a continuation-in-part of copending application Ser. No. 435,329, filed Jan. 21, 1974, now abandoned which application in turn is a continuation of application Ser. No. 122,931 filed Mar. 10, 1971, now abandoned.

The present invention relates generally to radiators for tanks containing a transformer submerged in a cooling fluid, e.g., a liquid or gas such as oil, freon, etc., which are used to transfer heat from the cooling fluid to the ambient air. In this construction of an exemplary prior art radiator referred to as a fin type, a sheet of metal is formed and welded into a continuous corrugated panel. This manner of construction, obviously, results in a time consuming and expensive manufacturing operation. Alternatively, the welding operation can be avoided by using a continuous folding machine. However, these machines are exceptionally costly, and consequently, limited production runs cannot be economically accommodated with that method.

The present invention provides a radiator construction which features exceptional ease of manufacturing, even on a limited production basis, and additionally, provides a unit which has exceptional mechanical strength and durability, is easy to maintain, and provides good heat transfer from the cooling fluid to the ambient air. In general, a construction according to the present invention utilizes pipes or tubes which, for example, may be rectangular electro-welded seamless tube, a standard mass-produced structural shape which is readily obtainable at costs which are not substantially greater than raw steel costs. The rectangular tubes are positioned in adjacent spaced relation with substantially parallel longitudinal axes and are used in combination with a surrounding shroud which is spaced from the tubes to provide relatively narrow passages between adjacent tubes and between the tubes and the shroud. The narrow passages are sealed at opposite axial ends of the tubes, for example, by joined flared ends on the tubes and shroud, or spacers positioned intermediate the tubes and the shroud. The bores of the tubes are left open at each end to provide chimneys through which ambient air flows upwardly to be heated by heat transfer from the cooling fluid within the narrow passages. The shroud and tube assembly is joined to a tank containing the transformer and cooling fluid to serve at least a portion of one or more walls thereof with the narrow passage communicating with the interior of the tank so that the oil within the tank is allowed to flow through the narrow passages. The shroud used with the radiator presents a smooth, clean external appearance and acts as a shield against accidental bumps. In this regard, it will be appreciated that shrouds are especially provided in some prior art radiator constructions to protect the radiator.

In additional embodiments of the invention, the air cooling tubes are used to conserve oil by displacing areas within the confines of an oil-containing power transformer tank which contains normally oil-filled spaces not occupied by other apparatus. This construction saves weight and thereby shipping costs, serves as a cooling radiator and provides a unit with smaller overall dimensions. This concept is particularly appli-
use of filler slugs at the tube corners; FIG. 13 is a fragmentary perspective view showing still another configuration of the tube ends which is similar to FIG. 12 except that all four flanges at both ends of each tube are folded completely back, and FIG. 14 is an exploded view of yet another embodiment in which a preformed steel grating is used both as a fixture to space the tubes and as the spacer when welding.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1, a tank 10 is illustrated for a transformer or the like which is immersed in a cooling liquid or gas for the transformer such as oil, freon, etc. The tank 10 has a generally rectangular, projecting radiator 12 attached thereto and serving as a portion of one wall of the tank 10 which has a plurality of chimneys or vertical throughpassages 14 which provide numerous surface areas for establishing heat transfer between the cooling fluid and the ambient air.

Referring now to FIGS. 2 to 4, the radiator 12 is seen as comprising a plurality of spaced rectangular tubes 20 arranged, for example, in side-by-side relation with substantially parallel longitudinal axes as shown. More specifically, each of the tubes 20 have a pair of lateral sides with at least one of the lateral sides being in spaced confronting relationship with a lateral side of an adjacent tube 20 and each further includes an inwardly disposed end side, with respect to the tank 10, and an outwardly disposed end side. Preferably, the confronting lateral sides are in parallel relationship so as to provide a linear row or bank of tubes 20. The tubes 20 are secured in position by an inwardly disposed connecting bar 22 and an outwardly disposed connecting bar 24, each connecting respective end sides of the tubes 20. However, it has been found in practice that the incorporation of only an outwardly disposed bar 24 is sufficient for most applications.

The tubes 20 have inside bores of surface areas 14 which form the chimney or through passages. The openings or bore 14 of the tubes are preferably of sufficient size for cleaning and repainting in service. Rectangular tubes suitable for the radiators of this invention may be cut from readily available structural steel tubing which is mass produced in a wide variety of thicknesses and dimensions. Preferably, it is structural pipe which has been welded using a high welding frequency.

In representative constructions, tubes 20 have nominal dimensions of 3 x 5 and 3 x 9 inches have been used. As can be seen in the drawing, the distance between the tubes 20 is substantially less than the bore dimension of the tubes 20 to provide narrow cooling fluid passages 26 intermediate the tubes 20 to minimize the amount of cooling fluid in the radiator 12.

The row of rectangular tubes 20 is surrounded on three sides by a shroud 28 which is generally configured to be spaced from the rectangular tubes on all sides to permit a narrow flow passage for cooling fluid between the shroud 28 and the assembly of rectangular tubes 20. The shroud 28 includes an outside panel 30, a pair of inwardly extending side panels 32 perpendicularly disposed at each end of the outside panel 30 and a pair of flanges 34, each extending outwardly and perpendicularly with respect to a respective one of the side panels 32. The shroud is of an appropriate size such that the flange 34 mate with a rectangular opening 36 in one wall of the tank 10 so that the shroud 28 of the radiator 12 forms a portion of the one wall of the tank. The shroud 28 may be joined to the tank 10 by welding. To provide a unit of exceptional strength, the inside connecting bars 22 overlap the flange 34 and are secured to the flange 34 as by welding, and the outside connecting bar 24 abuts the outward walls of the tubes 20 on its one side and the inside wall of the shroud panel 30 at its other side. Preferably, the panel 30 is spot welded to the outside bars 24 at spaced locations shown at 37 in FIG. 2 to restrain the panel 30 from bowing outwardly.

With particular reference now to FIG. 4 in which the radiator 12 is illustrated as viewed from within the tank 10, it can be seen that the passageways 26 intermediate the rectangular tubes 20 are exposed to the cooling fluid within the tank substantially along their entire length. It can be also seen that the passageways 26 are closed at each axial end to contain the cooling fluid within the tank 10 whereas the bores 14 of the rectangular tubes 20 are open at each axial end to allow a flow of ambient air upwardly through the bore 14 as illustrated by the dashed arrows.

In 5a and 5b, a first exemplary manner in which the passageways 26 intermediate adjacent rectangular tubes 20 and the passage intermediate the rectangular tubes 20 and the shroud 28 may be closed is illustrated in detail. As can be seen in FIGS. 5a and 5b, opposite axial ends of the tubes 20 are outwardly flared at least at the two lateral sides and the outwardly disposed end sides to provide flanges 38 extending perpendicularly with respect to the longitudinal axes of the tubes 20. Additionally, the top and bottom ends of the shroud 28 are flared inwardly so that the flared ends of tubes and shroud abut to close the passages intermediate the tubes 20 and the shroud 28. The flared ends of the shroud 28 and the tubes 20 may be sealed as by welding. If desired, the tubes 20 may be flared on four sides with the inside flare extending within the tank 10.

Sealing of the passages at opposite ends may also be accomplished using spacer bars intermediate the tubes 20 and the shroud 28 proximate to each axial end as illustrated in FIGS. 6a and 6b. More particularly, bar stock spacers 40 are positioned between adjacent tubes 20 and between the tubes 20 at each end of the row and the shroud panels 32. A substantially longer bar stock spacer 42 is positioned between the tubes 20 and the shroud panel 30. Preferably, the bar stocks 40 and 42 all have the same width. The spacers 40 and 42 may be welded to the rectangular tubes 20 and the shroud 28 to seal the cooling fluid passages.

In FIG. 7, a variation in the construction of a cooling radiator according to the principles of this invention is illustrated. In the construction of FIG. 7, it can be seen that one wall is provided with two banks 44 of rectangular tubes 20 with the tubes of the adjacent banks 44 in spaced relationship to provide a narrow cooling fluid flow passage intermediate the banks. Consequently, both the number of coolant flow passages and the total area of the surfaces provided for the transfer of heat from the coolant to the ambient air are increased. Additionally, it can be seen that the double banks 44 overlap the tank side indicated at 46 so that the cooling radiator surrounds the tank 10. As can also be seen in FIG. 7, the side at 46 is provided with yet another cooling radiator bank 48 comprising a plurality of rectangular tubes 20 whereby the entire tank is surrounded by a cooling radiator.
In operation, cooling fluid, e.g. oil, heated by the transformer within the tank 10 rises upwardly about the transformer to the top of the tank. At the top of the tank 10, upward flow is restricted and lateral flow occurs. The cooling fluid flowing laterally enters the upper portion of the radiator 12, is cooled by the radiator surfaces, and flows downwardly through the radiator between adjacent tubes 20 and the shroud 28. The downward flow is limited by the bottom of the tank consequently establishing a lateral flow to again bring the coolant into engagement with the transformer to begin the cycle anew. The ambient air within the tubes 20 is heated so as to establish an upward air flow through the tubes 20 which draws in fresh ambient air at the bottom openings and discharges heated air at the top openings. Consequently, appropriate cooling fluid and ambient air flows are established without the need for pumps, fans, etc. However, these appliances may be provided to supplement self-induced cooling fluid and air flows if desired.

Although the exemplary radiators disclosed herein are seen to comprise a plurality of rectangular tubes, it will be appreciated that other tube configurations may be used. For example, some of the alternate configurations which may be used include: a row of circular tubes having ends flared to a rectangular configuration; a row of triangular tubes with the apices of adjacent tubes disposed in opposite directions to provide parallel confronting sides; or rows of diamond shaped tubes with tubes of adjacent rows being interfitting to provide parallel adjacent sides.

In view of the above description of exemplary forms of the present invention, it will be appreciated that a cooling radiator is provided for a power transformer tank which is not only a highly efficient heat transfer device, but may be readily and inexpensively fabricated. It provides an inconspicuous, clean exterior appearance which is easy to maintain, occupies a small volume per kilowatt capacity of the transformer, and is suitable for a wide variety of transformer mountings.

As a still further advantage, the radiator construction of this invention provides a structure of high overall mechanical strength and durability.

FIGS. 8 and 9 show another embodiment of the invention which particularly applies to pad mounted oil cooled transformers. Typically, a transformer such as that generally indicated at 101 has a rectangular oil tank generally indicated at 102 with a front panel 103, left and right side panels 104 and 105 and a rear panel 106. The tank is mounted by legs 107 on a pad 108. The minimum dimensions of tank 102 are usually controlled by the spacing and arrangement of high voltage terminals such as that indicated at 109 and low voltage terminals 111. Except for a relatively small depth requirement for cable terminations, the balance of the depth of the tank is dictated by the core and coil assembly 112. This assembly conventionally occupies about two-thirds of the tank length.

In accordance with the invention, a plurality of air cooling tubes, preferably of rectangular cross-sectional shape, are placed within tank 102 to serve the dual purpose of occupying some of the tank volume, thus reducing the oil required to fill the tank, and supplementing the cooling capacity of the unit. The embodiment of FIGS. 8 and 9 incorporates seven such cooling tubes indicated at 113 through 119. The tubes extend in parallel relation with their sides parallel to the corresponding sides of tank 102, and the tops and bottoms may be connected to the top 121 and the bottom 122 of the tank by any of the methods described in the application. As illustrated, tube 113 is between the high voltage terminal 109 and the low voltage terminals 111, and forwardly of assembly 112. Tubes 114 through 117 are in a rectangular arrangement on the left hand side of the unit as seen in FIG. 9, behind high voltage terminal 109. Tubes 118 and 119 are behind and on both sides of assembly 112. As in the previous embodiments, spaces are provided between adjacent tubes for oil circulation. It will be observed that with this arrangement, a substantial portion of the oil volume will be eliminated. This will not only conserve oil but reduce shipping weight and thus save costs. At the same time, the tubes 113 through 119 will serve as convective radiators in the manner described with respect to the previous embodiment so that the effect will be supplemental cooling of the transformer.

On transformer units which would normally not require supplemental cooling, the invention will result in a lesser increase in oil temperature if other factors remain the same. This feature of the invention in turn permits a higher voltage gradient for the coil, resulting in fewer coil ducts, smaller mean turn of coil, smaller core, and lower load loss, and lower coil loss.

The cooling function of air flowing through the tubes 113 through 119 is demonstrated by arrows in FIGS. 8 and 9. Oil adjacent the tube walls will be cooled and flow downwardly with a convective effect, while air within the tubes is heated and flows upwardly as in a chimney, the air being replaced by cooler air below.

FIGS. 10 and 11 illustrate another embodiment of the invention in which a rear portion of the transformer, similar to the area occupied by tubes 114 to 117 in FIG. 9, is partitioned off and occupied by cooling tubes. The unit is generally indicated at 201 and has a tank generally indicated at 202 with a front wall 203, side walls 204 and 205 and a rear wall 206. Front wall 203 carries a high voltage connection 207 and low voltage connections 208. Bottom 209 of the tank does not extend the complete width but terminates at a vertical wall 211, the remainder of the width of tank 202 being occupied by a raised bottom portion 212 and the bottoms of tubes 213. These tubes are shown as being rectangular cross-sectional shape with their bottoms above the level of bottom portion 206 of the tank and their tops below the level of tank top 214. The tubes are shown as being in three rows. As in the previous embodiments, the walls of adjacent tubes are parallel to each other, and the tube ends may be connected in one of the ways described in this application. The spaces 215 between adjacent tubes which face the main body of the tank 202 will be open to the oil in the tank so that this oil may circulate among the tubes and be cooled thereby, the balance of the air moving between the tubes.

FIG. 11 shows in partially schematic fashion a way in which unit 201 may be fabricated. A subassembly is shown comprising tubes 213, wall portions 216 and 217 of tank walls 206 and 204 respectively, a flanged member generally indicated at 218 having tank portions 211 and 212, and legs 219. Additionally, a Z-shaped member generally indicated at 221 is provided, this member having a panel 222 which serves as another portion of tank side wall 204, and panels 223 and 224 which extend upwardly from the tops of tubes 213 to top 214 of the tank.

When assembled, unit 201 will appear as in FIG. 10. An air intake grill 225 is provided between the lower
edge 226 of panel portion 216 and the bottom of the tank. Similarly, an exhaust intake grill 227 is provided over the tops of tubes 213, the top of this grill being flush with top 214 of the tank and the sides flush with walls 206 and 204. It will be observed that raising of the tank bottom beneath tubes 213 will result in additional reduction of oil volume.

FIGS. 12, 13 and 14 show various constructions for interconnecting the tops and bottoms of adjacent cooling tubes. In FIG. 12, tubes 301 alternate with tubes 302 and have their four upper edges flanged outwardly and indicated at 303, 304, 305 and 306. Tubes 302 have their bottom edges flanged outwardly, three edges being seen in FIG. 12 and being indicated at 307, 308, and 309. The flanges constitute the spacing means between the tubes and each flange will be welded or similarly attached to its adjacent tube edge. The width of these flanges will be equal to the desired size of oil spaces 310 between adjacent tubes. Each flange will abut the adjacent tube a slight distance from its edge 311 which will allow a space for a fillet weld 312.

Oblong sealing spacers 313 are provided at the bottoms of tubes 301 and the tops of tubes 302 which are adjacent the tank wall or shroud as in one of the previous embodiments and may similarly be attached by welding.

A plurality of filler slugs generally indicated at 314 are provided at the corners of the tubes to close the rectangular spaces formed by adjoining flanges. One such slug is illustrated in FIG. 12, the slug being a stamped piece of rectangular shape with cutaway corners 315 so as to fit between the tubes, and a self centering indentation 316 which will fit within space 317. Slug 314 will overlap the adjacent portions of the flanges and will be welded in place.

FIG. 13 shows another embodiment of the invention in which the tubes, indicated at 401 have their tops and bottoms interconnected and are similar to that of FIG. 12 but with both ends of each tube having the flanges 402 on all four sides. The four flanges on each end of each tube are folded completely back over the tube wall. When the tubes are assembled as shown partially in FIG. 13, these flanges 402 will abut each other and together act as separators, creating the spaces 403 between tubes through which the oil flows. As in the previous embodiment, filler slugs 314 or slugs similarly formed, may be provided to close the spaces 404 at the corners of the tubes. Sealing spacers 405 are used where facing flange edges create a gap adjacent the tank wall. The arrangement of FIG. 13 has been found particularly suitable for automatic welding.

FIG. 14 shows another manner of connecting the tube ends. In this case a preformed steel grating generally indicated at 501 is provided, this grating having portions 502 with a width equal to the desired spacing between the tubes. This grating is used both as the fixture to space the tubes 503 for welding and as the spacer when welding. Thus, steel grating fixture 501 will become part of the finished assembly, and spaces 504 will be provided between the tubes for oil flow.

While it will be apparent that the teachings herein are well calculated to teach one skilled in the art the method of making preferred embodiments of this invention, it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope of meaning of the subjoined claims.

What is claimed is:

1. A radiator for a tank which includes a wall with an opening therein and which is adapted to enclose a transformer or the like submerged in a cooling fluid, comprising:
   a plurality of parallel-sided, rectangular open-ended tubes in parallel relation and with spaces between said tubes communicating with the tank interior for providing passages for said cooling fluid;
   a shroud surrounding said tubes and spaced therefrom to provide a flow passage for said cooling fluid, said shroud forming a closure for sealing said opening of said wall of said tank, said tubes being arranged in a linear row;
   means at the opposite ends of said shroud and tubes sealing said cooling fluid passages comprising laterally outwardly bent portions at the ends of said tubes with said bent end portions being in abutting relation along the edges and welded thereto to seal said cooling fluid passages between said tubes, and inwardly bent portions at the ends of said shroud adjacent the tube ends being in abutting engagement with the outwardly bent portions of adjacent tube sides and welded thereto to seal the cooling fluid passage between the tubes and shroud, and;
   first bar means secured to one side of said tubes for fixing the tubes in spaced relationship whereby said shroud, tubes and first bar means are joined to provide said closure.

2. A radiator according to claim 1, wherein said first bar means is secured to said outward end sides of said tubes and further including second bar means secured to said inward end sides of said tubes.

3. The combination according to claim 1, said outwardly bent tube ends and inwardly bent shroud ends being perpendicular to the tube axes.

4. In a construction for reducing the oil volume and supplementing the cooling of a transformer tank of the type having terminals on the front wall of the tank and a core and coil assembly occupying a portion of the tank volume;
   a plurality of vertically disposed air cooling tubes within the confines of the transformer walls, the tops and bottoms of said tubes being opened and accessible to ambient air flowing upwardly therethrough for cooling purposes;
   the facing walls of juxtaposed tubes being spaced to permit oil flow therethrough, said tubes being located in at least some of the spaces within the transformer tank not occupied by said terminals and coil assembly, means sealing the tops and bottoms of adjacent tubes to each other, means sealing the tops and bottoms of those tubes adjacent the transformer tank walls to said walls, whereby the oil circulating in the spaces between said tubes and between the tubes and tank walls will be retained,
   at least the end portions of said tubes having rectangular cross-sectional shapes, said means for sealing the tops and bottoms of adjacent tubes to each other comprising outwardly bent flanges at the tops of alternate tubes and outwardly bent flanges at the bottoms of the tubes between said alternate tubes, means attaching each flange to the wall of the adjacent tube, and sealing spacers between the unflanged edges of the tubes and the adjacent portions of transformer walls.
5. In a construction for reducing the oil volume and supplementing the cooling of a transformer tank of the type having terminals on the front wall of the tank and a core and coil assembly occupying a portion of the tank volume; a plurality of vertically disposed air cooling tubes within the confines of the transformer walls, the tops and bottoms of said tubes being opened and accessible to ambient air flowing upwardly therethrough for cooling purposes; the facing walls of juxtaposed tubes being spaced to permit oil flow therethrough, said tubes being located in at least some of the spaces within the transformer tank not occupied by said terminals and coil assembly, means sealing the tops and bottoms of adjacent tubes to each other, means sealing the tops and bottoms of those tubes adjacent the transformer tank walls to said walls, whereby the oil circulating in the spaces between said tubes and between the tubes and tank walls will be retained, at least the end portions of said tubes having rectangular cross-sectional shapes, said means for sealing the tops and bottoms of adjacent tubes to each other comprising outwardly bent flanges at the tops of alternate tubes and outwardly bent flanges at the bottoms of the tubes between said alternate tubes, means attaching each flange to the wall of the adjacent tube, and filler slugs closing the spaces between flanges at the corners of said adjacent tubes, each filler slug comprising a generally rectangular member having a self-centering indentation, said member overlapping the adjacent tube flanges.

6. The combination according to claim 5, the corners of said filler slug member being removed so as to be in non-interfering relation with the adjacent tubes.

7. In a construction for reducing the oil volume and supplementing the cooling of a transformer tank of the type having terminals on the front wall of the tank and a core and coil assembly occupying a portion of the tank volume; a plurality of vertically disposed air cooling tubes within the confines of the transformer walls, the tops and bottoms of said tubes being opened and accessible to ambient air flowing upwardly therethrough for cooling purposes; the facing walls of juxtaposed tubes being spaced to permit oil flow therethrough, said tubes being located in at least some of the spaces within the transformer tank not occupied by said terminals and coil assembly, means sealing the tops and bottoms of adjacent tubes to each other, means sealing the tops and bottoms of those tubes adjacent the transformer tank walls to said walls, whereby the oil circulating in the spaces between said tubes and between the tubes and tank walls will be retained, at least the end portions of said tubes having rectangular cross-sectional shapes, said means for sealing the tops and bottoms of adjacent tubes to each other comprising outwardly bent flanges at the tops of alternate tubes and outwardly bent flanges at the bottoms of the tubes between said alternate tubes, means attaching each flange to the wall of the adjacent tube, each flange which abuts a wall of the adjacent tube being spaced a slight distance from its edge, said attaching means comprising a fillet weld in said space joining the flange and wall.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,921,112
DATED : November 18, 1975
INVENTOR(S) : Alvin Y. Broverman

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, line 44, "adjacnet" should be --adjacent--.

Column 10, lines 9 and 10, "theretrhough" should be --therethrough--.

Column 10, lines 28 and 29, delete "means attaching each flange to the wall of the adjacent tube, ".

Signed and Sealed this

thirteenth Day of April 1976

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,921,112
DATED : November 18, 1975
INVENTOR(S) : Alvin Y. Broverman

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, line 44, "adjacnet" should be --adjacent--.

Column 10, lines 9 and 10, "therethrough" should be --therethrough--.

Column 10, lines 28 and 29, delete "means attaching each flange to the wall of the adjacent tube, ".

Signed and Sealed this thirteenth Day of April 1976

[SEAL] Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks