FIG. 1.

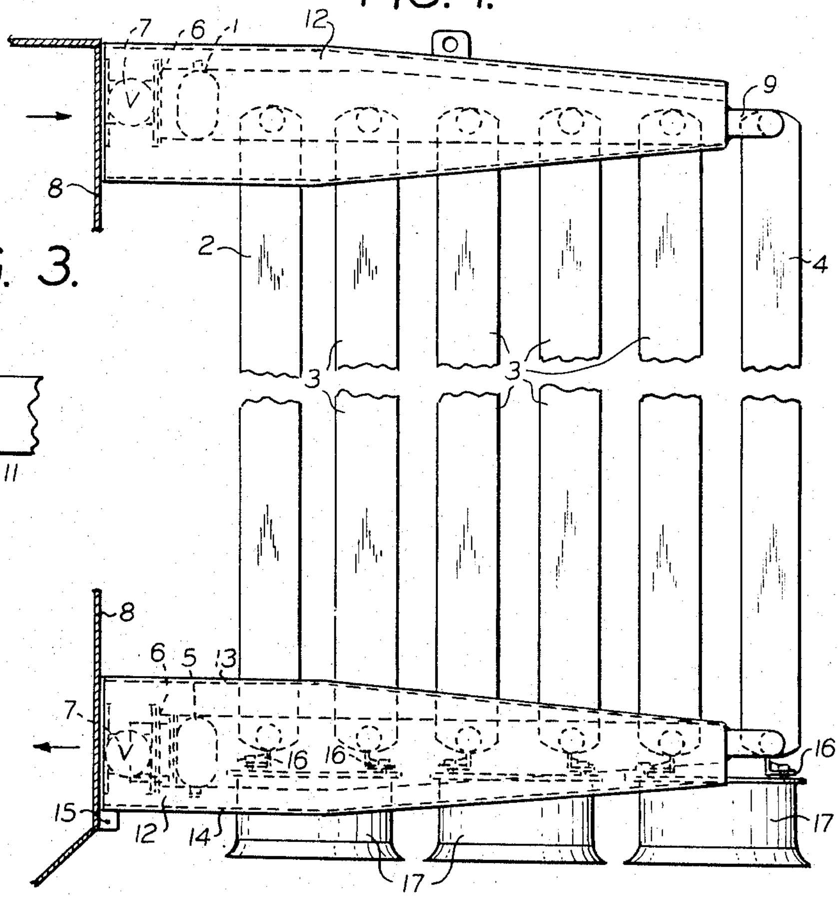
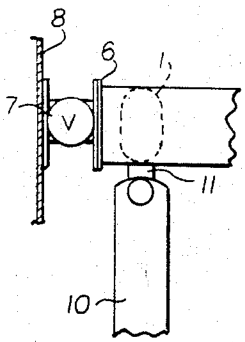


FIG. 3.



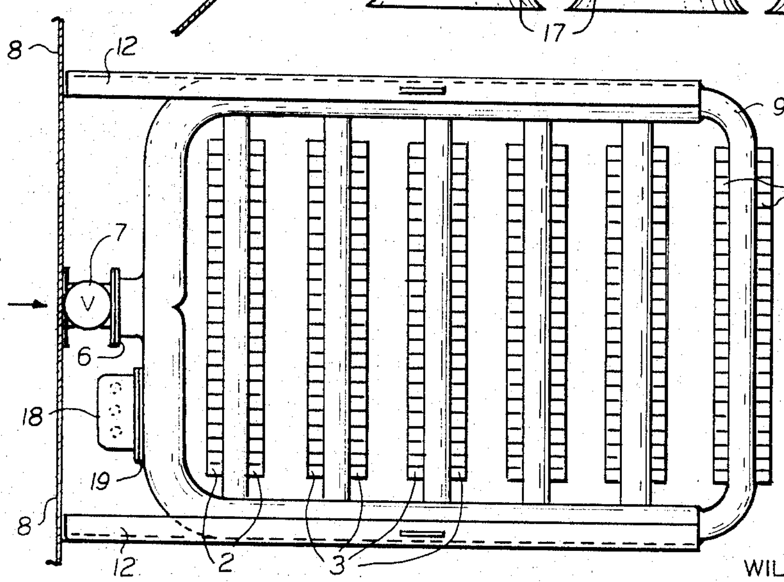


FIG. 2.

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FIG. 4.

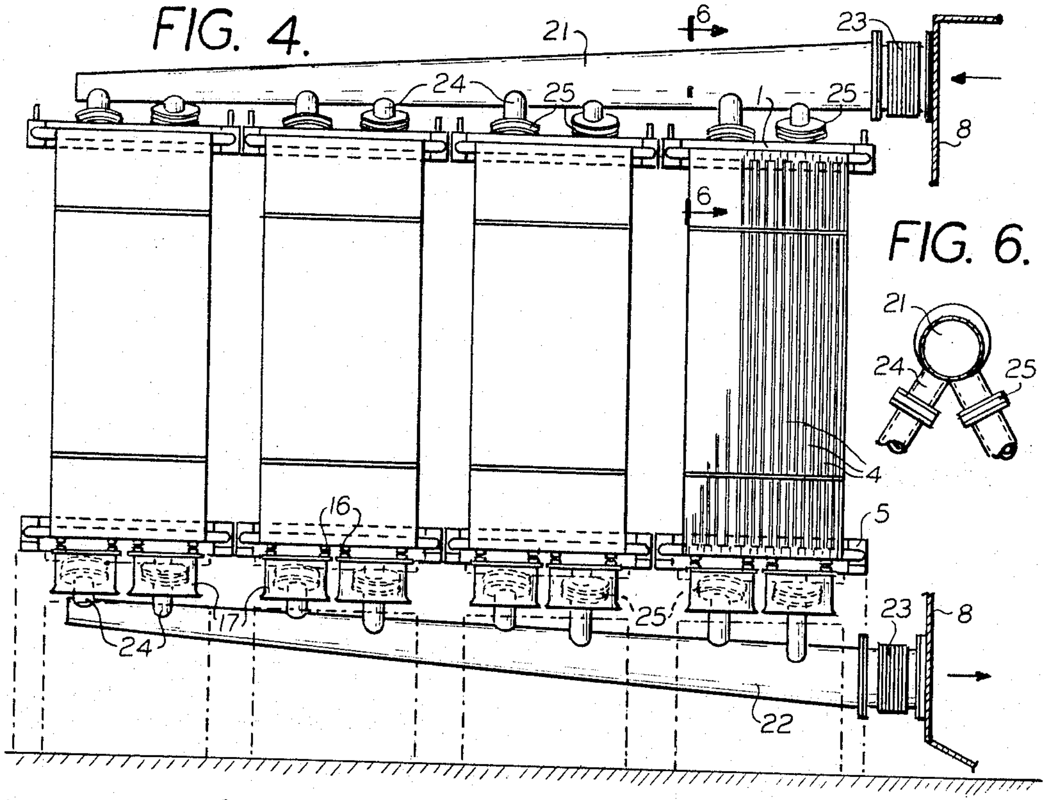

FIG. 6.

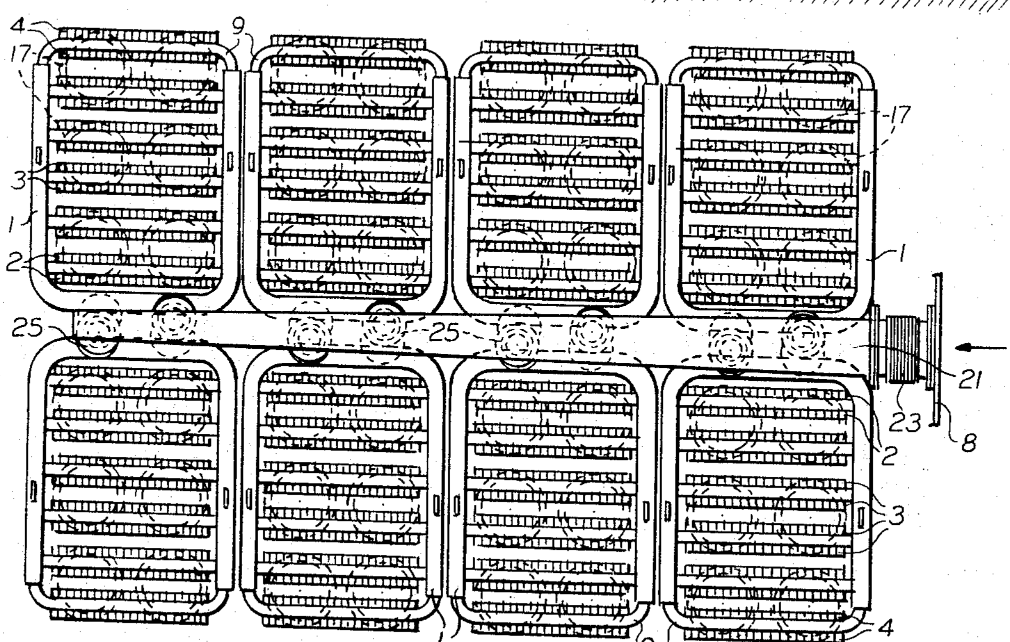

FIG. 5.

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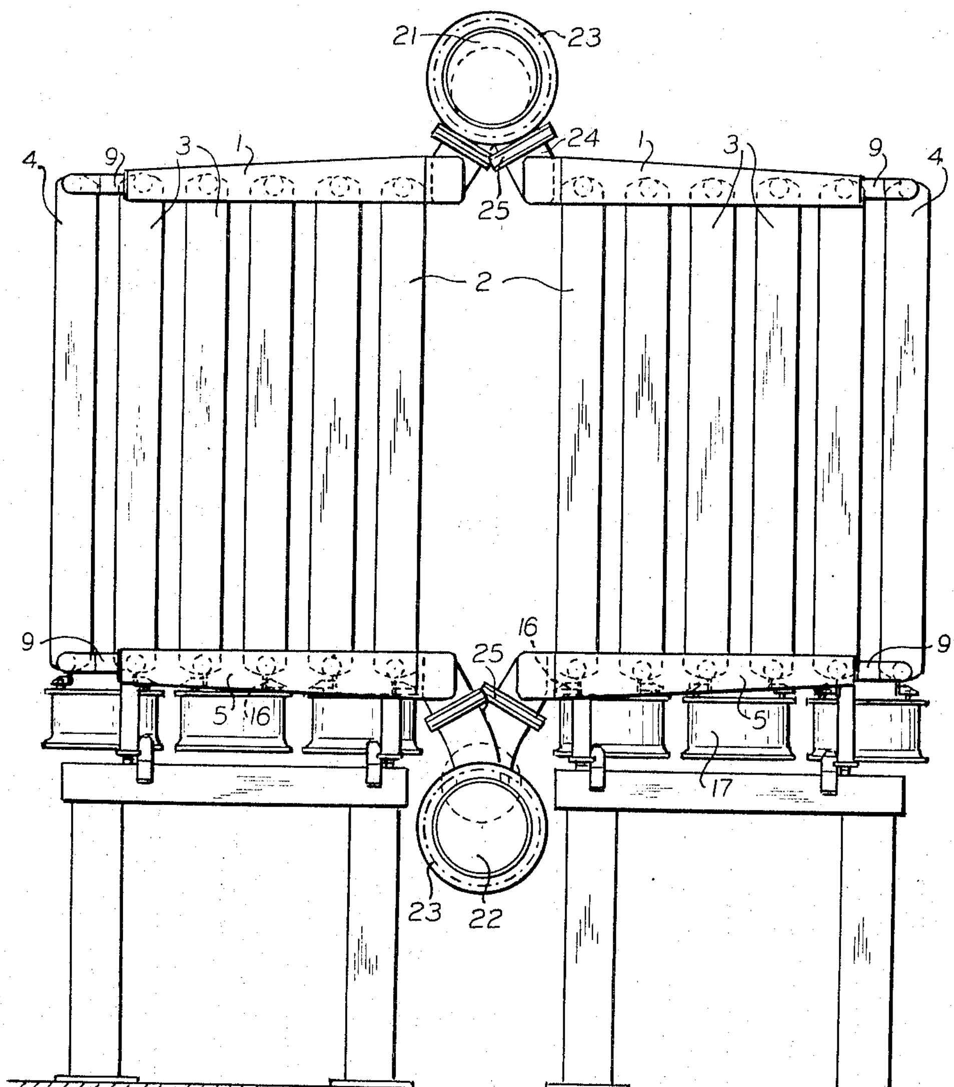
FIG. 7.



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3,372,738

COOLING ARRANGEMENT FOR OIL-FILLED ELECTRIC TRANSFORMERS OR REACTORS

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7 Claims. (Cl. 165—47)

The present invention relates to a cooling arrangement for oil-filled electric transformers or reactors, and more particularly to such an arrangement wherein vertical sections of the cooling risers are arranged between the legs of horizontal, U-shaped distributing and collecting header members.

In designing oil-cooled transformers or reactors it is a known measure to remove or dissipate the heat resulting from power losses, by means of self-cooling radiators (having natural air circulation) or radiators cooled by ventilators (with forced air circulation). Since, however, the capacities installed in transformer units increase continually, it becomes increasingly difficult to dissipate the heat by the usual radiator cooling. In many cases a change has been made to cooling with oil-water coolers.

Forced circulation of the transformer oil through a water cooler necessitates, however, a considerable expenditure of pumping installations and has, moreover, the great disadvantage that it is necessary to put the transformer out of service if troubles occur in the pumping installation, as the attained self-cooling is not sufficient to dissipate the heat produced by transformer losses.

The same applies to forced cooling by means of fans, even if the radiators are designed in such cases so that it is at least possible to operate the transformer with a partial load, should the transformer fans fail. The trend is, therefore, to dissipate the heat resulting from transformer losses, as far as possible, exclusively by natural air circulation along the cooling surfaces of the radiators, and to provide fans only for producing an additional air circulation during peak loads.

It is the object of this invention to provide a radiator construction and a cooling arrangement which makes it possible to dissipate the transformer-loss heat by natural cooling alone, even when using large transformer units.

The present invention relates to a cooling arrangement for dissipating the heat produced by losses in oil-filled electric transformers or reactors, having a plurality of vertical riser groups or sections (cooling pipes) which are fed with the tank oil to be cooled by way of horizontal U-shaped distributing and collecting header members, connected to the transformer tank at the middle of the base line of the U, directly or by the intermediary of a further main distributing and collecting header pipe, wherein one of the main features resides in that the U-shaped distributing and collecting header members for the individual vertical riser groups or sections are horizontally situated, and that these riser sections are arranged between the two legs of the U-shaped header members.

The various objects, features and attendant advantages of the present invention will become more apparent from the following description of a preferred embodiment of the transformer cooling arrangement according to this invention, when considered in conjunction with the accompanying drawings, wherein

FIG. 1 is a side elevational view of a transformer radiator element incorporating the cooling arrangement of this invention (the transformer tank being omitted);

FIG. 2 is a top elevational view of the radiator element according to FIG. 1;

FIG. 3 is an enlarged partial view of a constructional detail, showing the connection between a U-shaped header and one of the riser sections;

FIG. 4 is a side elevational view of an arrangement for supplying with oil a plurality of radiator elements;

FIG. 5 is a top elevational view of the set-up according to FIG. 4;

FIG. 6 is a sectional, partial view of a structural detail, taken along line **6—6** of FIG. 4; and

FIG. 7 is a side view of the cooling arrangement of FIGS. 4 to 6, viewed in the axial direction of the main distributing and collecting headers, toward the first group of radiator elements.

In the FIGS. 1 and 2, illustrating a first preferred embodiment, numeral **1** identifies a top (distributing) header pipe or member and **5** a bottom (collecting) header pipe of a radiator element comprising vertical riser sections (cooling pipes) **2**, **3** and **4**. In accordance with the invention, the header members **1** and **5** are horizontal U-shaped bent pipes (see FIG. 2) which, on the base line of the U, are connected by means of flanges **6** and shut-off devices **7** to a transformer tank wall **8** (the rest of the tank has been omitted for the sake of clarity), and include between the legs of the U the vertically disposed inner risers **2**, intermediate risers **3** and outer risers **4**. The outermost riser section **4** receives oil from and delivers oil to the header members **1**, **5** through pipe elbows **9** attached to respective limbs of the U-shaped header members **1** and **5**, at the top and the bottom, respectively.

As indicated in FIG. 3, an innermost riser section **10** may be connected to the header members **1**, **5** by vertical short pieces of pipe **11** welded to the basis of the U-shaped header members.

A radiator block built up in such a manner, as shown in FIGS. 1 and 2, is supported by C-shaped cantilever beams **12** having flanges **13**, **14** which are directed toward the radiator block. The vertical load resulting at the bottom connecting point from the above-mentioned attachment of the radiator block is taken up by structural steel plates **15** welded to the tank wall **8**, or to stiffening ribs of the transformer tank.

For forced cooling, fans **17** (see FIG. 1) having suitable mounting flanges **16** are provided which, in the illustrated, preferred and exemplary embodiment, blow cooling air in vertical direction. In FIG. 2, numerals **18**, **19** identify on the header **5** a terminal box, and its attachment to the structure, for the fan motors.

The U-shaped header members **1**, **5** have a cross-section tapering off from the feeding point **6** for the innermost riser section **10**, or the inner section **2**, towards the outermost riser, e.g. **4** (declining top edge of header pipe **1** and declining bottom edge of header pipe **5**, respectively) in order to keep constant as far as possible the oil-flow velocity in these pipes.

It should be mentioned that oil flow or circulation in each radiator element or block is the result of the well-known, so-called thermosiphon effect, that is, natural circulation owing to the weight difference between the heated-up and the cooled-down transformer oil. The hot oil rises in the transformer owing to the said effect, is then led to the individual cooling elements or riser sections by way of the distributing header pipe, whereupon it is cooled down in the riser sections. The oil descends by its increased weight and is then allowed to return to the bottom of the transformer tank by way of the collecting header pipe.

This is a natural, automatic circulation, as against the forced circulation mentioned in the introduction, making use of pumping means and separate water coolers. The latter are dispensed with in the natural-circulation system provided in the inventive arrangement. The rate and efficiency of the inventive oil circulation may be increased (if necessary at all) by blowing air onto the radiator elements with the aid of the forced-cooling fans. This may be required in the case of full load, or for short-period overloads of the transformer.

When the fans are energized, the air flow along the individual cooling elements or riser sections is accelerated so that heat dissipation is increased within the sections. This expedient is also used in conventional radiators having so-called forced air cooling.

The FIGS. 4 and 5 show a second preferred embodiment, with the supply of a plurality of radiator blocks as illustrated in FIGS. 1 and 2 taken from a common main header. Such an arrangement will be found appropriate if the radiators are supported by separate fundaments or bases (separately installed cooler units), making it possible to series-connect several radiator blocks with respect to the oil flow from and back to the transformer tank.

It will be noted that FIGS. 4 and 5 are reversed as to the left and right-hand sides of the illustration, as compared to FIGS. 1 and 2 (oil connections from the right and the left, respectively, in the aforementioned views).

In this embodiment the hot oil is supplied to the various radiator blocks through a main distributing header **21** and the cooled oil is returned to the transformer tank through a main collecting header **22**. In order to keep constant the velocity of the oil stream, the main distributing header **21** tapers off outwards, as shown. Likewise, the main collecting header **22** has a narrowing cross-section; moreover, it has a slight slope towards the transformer tank, that is, the right-hand side of FIGS. 4 and 5.

Although the supporting structures of both embodiments have been described with reference to the figures, it may be emphasized that C-shaped cantilever beams are provided which surround the upper and lower header pipes, as shown in FIGS. 1 and 2, and are secured to the transformer tank wall so as to transmit the vertical load to the wall. The weight of the radiator block actually rests on the plates **15** interposed between the lower C-shaped beam **12** and the tank wall **8**.

In FIGS. 4 and 5, there are no cantilever beams (that is, beams clamped on one end only) but girders with a C-shaped cross-section. The upper ones preferably serve for transporting one or more radiator blocks by means of a crane (e.g., during installation or repair), while the lower ones are adapted to mount the radiator installation onto a separate foundation or base (as shown in FIG. 4 in broken lines). The attachment of the individual radiator batteries to the girders can be provided in numerous conventional ways, and this is a structural expedient well known to those skilled in this art.

In order to feed a maximum number of radiator blocks (as shown in FIGS. 1 and 2) at a given length of the header members **21**, **22**, as it is shown in FIG. 6, pipe connections **24** to flanges **25**, for joining the U-shaped header members **1**, **5** to the headers **21**, **22**, are made slanting to the right and to the left, respectively, from the main headers **21**, **22**, and are symmetrically staggered with regard to the central plane of the radiator block (FIG. 5). Owing to the symmetrical arrangement of the pipe connections **24**, equal flow resistances result for each of two radiator blocks lying in parallel (top and bottom in FIG. 5) for the oil stream from the upper headers **1** to the lower headers **5**. Finally, at **23** expansion pipes are indicated between the main headers **21**, **22** and the outer wall of the transformer tank **8**, by means of which unavoidable inaccuracies of assembly or thermal expansions may be compensated for.

FIG. 7 shows the first two radiator elements connected to the respective distributing and collecting headers 21 and 22, with the pipe elbows **9** protruding from the respective top and bottom header pipes **1** and **5**.

It will be understood that features described and illustrated for the first embodiment (FIGS. 1 to 3) are also

applicable to the second embodiment (FIGS. 4 to 7). Thus, the riser sections **2**, **3** and **4** may be supplemented by innermost riser sections **10** and pertaining short pipe sections **11**, connected to the header members **1**, **5** as shown in FIG. 3. Elbows **9** are shown in FIGS. 5 and 7 for riser sections **4**, as in FIG. 2.

Also, flanges **6** and shut-off devices **7** are employed between the main headers **21**, **22**, on the one hand, and the transformer tank **8**, on the other, in addition to, or instead of the illustrated expansion pipes **23** (as shown for the header members **1**, **5** of FIGS. 1 to 3).

FIGS. 4, 5 and 7 also show the forced-cooling fans **17** and their mounting flanges **16**; the pertaining terminal boxes **18** and their attachments **19** are exemplified in FIG. 2 only but are of course applicable to the second embodiment as well.

It may be summarized that the embodiment of FIGS. 4 to 7 is characterized by the distributing and collecting main headers **21**, **22** before and after the U-shaped header members **1**, **5**, when considering the direction of the oil flow. The arrows in the drawings clearly show the direction of the natural or thermosiphon oil circulation. This actually constitutes a combined series-parallel connection for the various oil paths. The series connection relates to the oil flow in axial direction of the main headers, in combination with the flow in the direction of each leg of the U-shaped header member (both at the distributing and at the collecting side). Each parallel connection or path actually bisects the flow resistance in a known manner (analogous to the parallel connection of electrical resistors). The principle of parallel connections starts with the pipe connections and flanges **24**, **25** where the first bifurcation of the oil flow takes place, and then it continues in the U-shaped header members **1** where the oil stream branches off to the two limbs of the U.

It will be understood that the individual header members **1** and **5** of FIGS. 4 to 7 may also have flanges connected to the straight portions, between the two limbs or legs, and these flanges may be similar to those shown in FIG. 2 with numeral **6**. When considering the top elevational view of FIG. 5, it will be seen that the branching off of the oil flow from the top or distributing header **21** alternates between the two opposite rows of radiator blocks (upper and lower rows, as shown in the drawing). This makes for optimally uniform distribution of the warm or headed-up oil among the individual radiator units. The bottom or collecting header **22** has a similar arrangement with respect to the header members **5** connected thereto (see also FIG. 4).

Compared with known radiator structures, the cooler arrangement in accordance with this invention makes it possible to provide a greater number of cooling elements with a given required space, or to accomplish the oil circulation with less resistance to the oil flow with a given number of cooling elements. In doing so it becomes possible to eliminate the heat due to transformer losses, even with large transformer capacities, only by air-cooled radiators, possibly even without forced cooling by fans.

Moreover, compared with similar known radiator arrangements, the number of shut-off devices and packings is essentially reduced, maintaining good interchangeability and accessibility of the cooling elements which form an assembly unit. This is an advantage in regard to maintenance, repair and supervision, and also reduces the material and labor costs.

A substantial number of transformer-cooling radiator units can be supplied with oil, even at low flow velocities, particularly when using the second embodiment of the invention, as described hereinabove. The number of such units is considerably higher than could be attained with hitherto known devices. The inventive arrangement allows to dissipate the heat of very large transformers by the natural circulation of the cooling oil, as described earlier, entirely without, or only with intermittent, forced-air cooling.

It is important in the inventive cooling arrangement to keep the surface at a maximum which is available for the heat exchange between the warmed-up transformer oil flowing from the upper transformer tank portion toward the radiator elements. This is of course enhanced by the above-described series-parallel connection of the oil flow paths, while the cooling air sweeps along the individual riser sections in an upward direction (that is, countercurrent to the downwardly oil flow), either as a result of natural draft (actually a chimney effect) or on account of the forced-cooling fans. Oil and air-flow arrows are shown in FIG. 1.

While keeping the heat-exchange surface at a maximum, care has to be taken not to allow the flow resistance of the oil stream to reach excessively high values on account of the repeated ramification or branching effect, which could eventually render ineffective the increased cooling surface. In other words, it is important to achieve a compromise between the size of the cooling surface and the flow resistance by which maximum heat dissipation can be achieved. It is not enough to provide a series connection of any desired number of cooling elements if this should result in an increase of the oil flow resistance to a value which would then tend to decrease the cooling capacity as an end result.

The double-sided oil supply provided by the U-shaped header members, forming the important feature of both described embodiments, is considered to be an essential factor in achieving the optimum compromise possible in such cooling arangements. The multiple set-up of the second embodiment provides even better results than the first one as a result of the described combined and multiple oil paths. There is of course the added advantage of accommodating a large number of radiator units in a relatively limited space, which has serious economic benefits in such installations.

The foregoing disclosure relates only to preferred, exemplary embodiments of the invention, and to applications thereof, which is intended to include all changes and modifications of the examples described within the scope of the invention as set forth in the appended claims.

What we claim is:

1. A cooling arrangement for dissipating the heat produced by losses in an oil-filled electric transformer or reactor, the latter including an oil tank, the arrangement comprising at least two groups of a plurality of substantially vertical riser sections to and from which the oil to be cooled is supplied from said tank in parallel connection, by way of at least two pairs of substantially horizontal, U-shaped upper distributing and lower collecting header members having each a base of the U and two flanking legs between which said riser sections are connected, upper distributing and lower collecting main header pipes in series communication between said tank and said header members, the latter being connected on opposite sides of said main header pipes, substantially at the middle of their bases, and facing in opposite directions, alternately laterally slanting pipe connections between said header members and at least one of said main header pipes, and means for supporting said header members from the wall of said tank.

2. The cooling arrangement as defined in claim 1, further comprising short pipes welded to said base of the U-shaped header members for providing connection to at least one of said riser sections.

3. The cooling arrangement as defined in claim 1, further comprising a flange and a shut-off device attached to said base of the U-shaped header members for providing selectively operable communication to said main header pipes.

4. The cooling arrangement as defined in claim 1, further comprising a pipe elbow attached to one of said riser sections for connection to the outer ends of said header members.

5. The cooling arrangement as defined in claim 1, wherein said main header pipes have a cross-section tapering off from the side of said tank toward the outermost one of said header members.

6. The cooling arrangement as defined in claim 1, further comprising an expansion pipe between said tank and at least one of said main header pipes.

7. The cooling arrangement as defined in claim 1, further comprising means for forced air cooling of at least some of said riser sections in a substantially vertical, upward direction, countercurrent to the downward flow of the oil to be cooled within said riser sections.

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