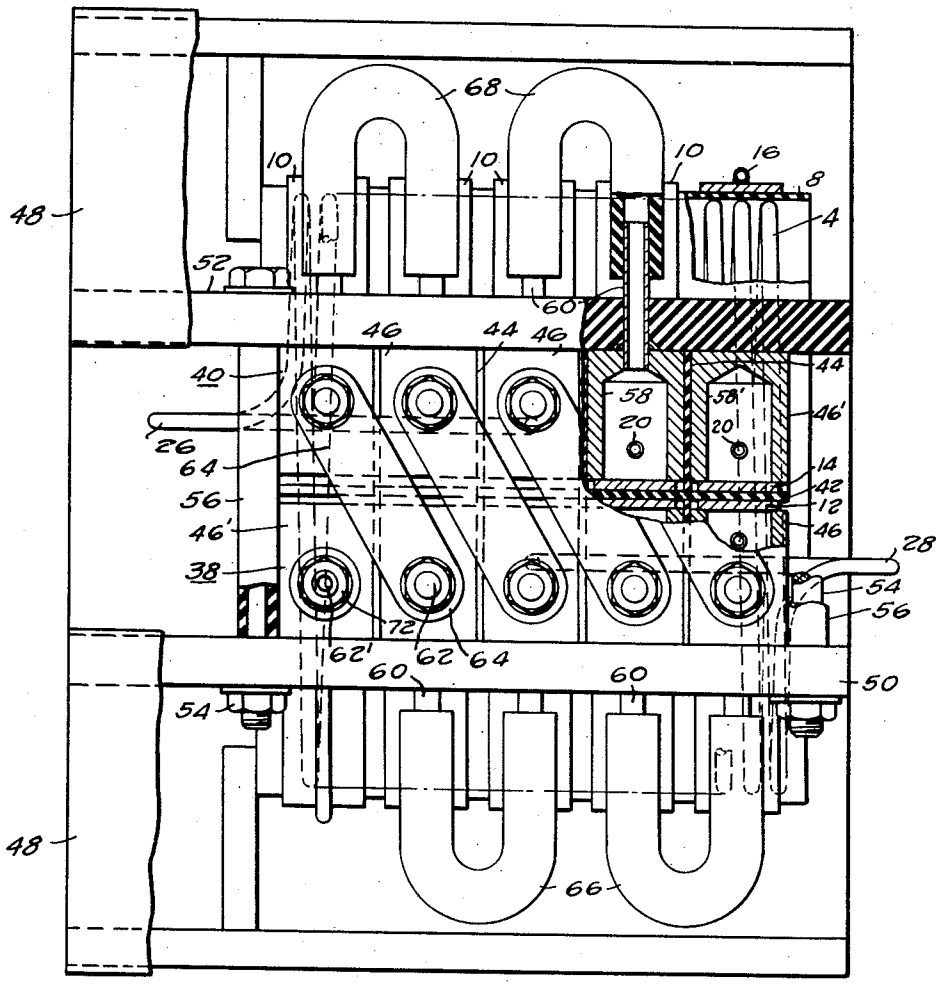
Feb. 21, 1950 R. M. BAKER ET AL 2,498,233

HIGH-FREQUENCY APPARATUS

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Fig. 1.



2

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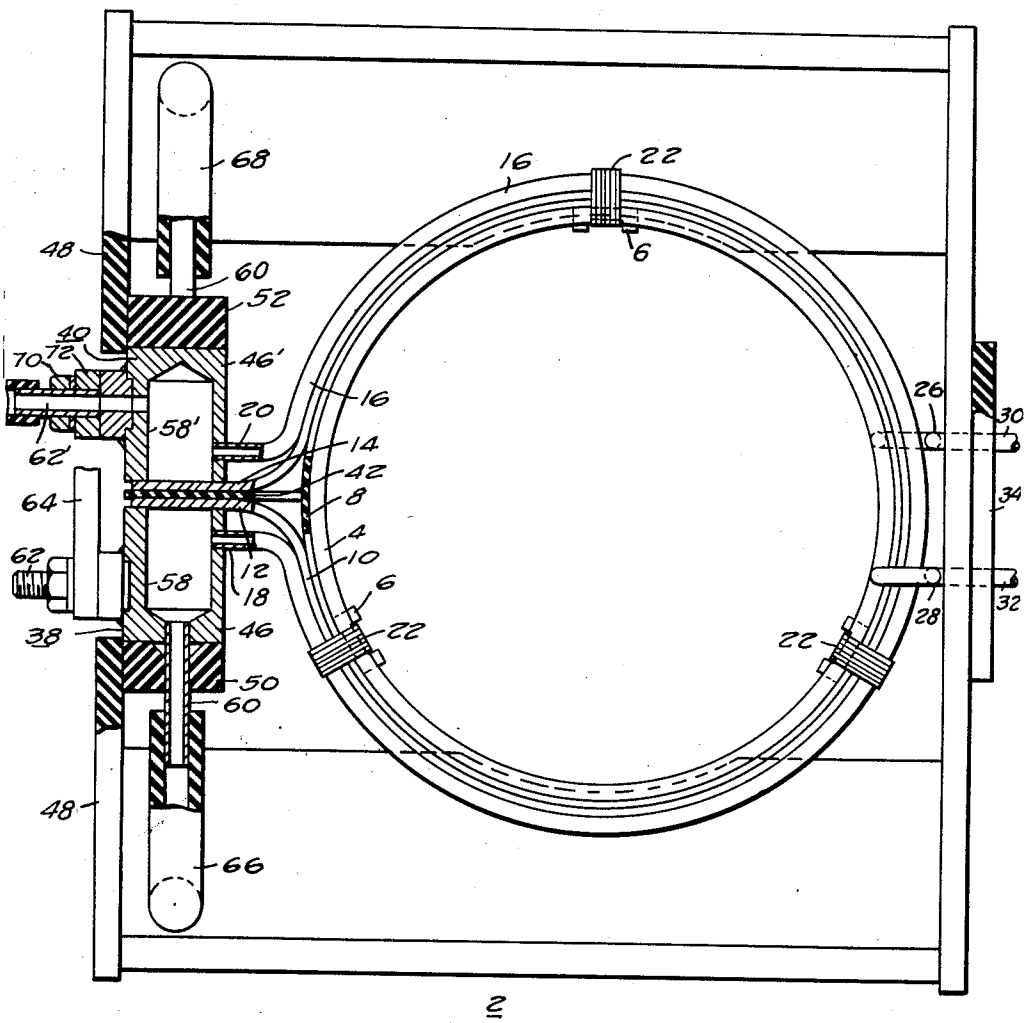
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HIGH-FREQUENCY APPARATUS

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Fig. 2.



2

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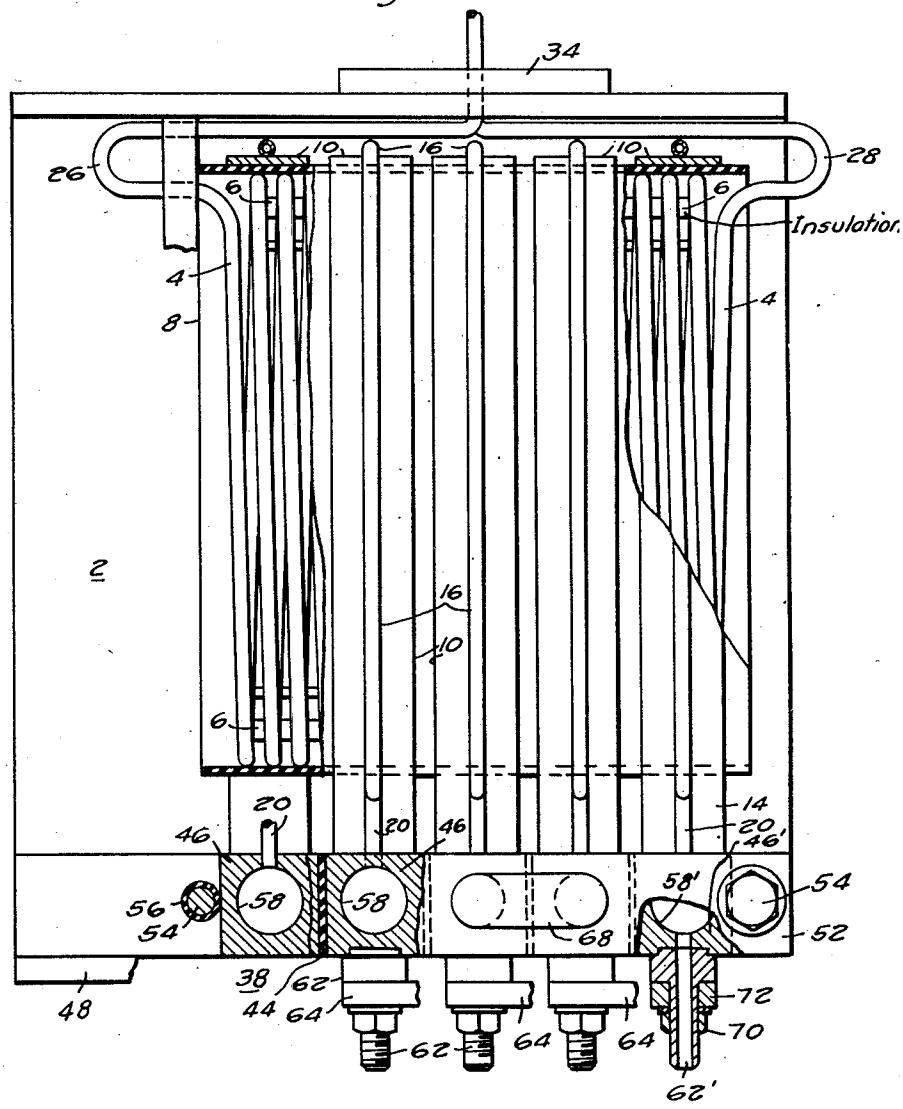
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HIGH-FREQUENCY APPARATUS

Filed July 2, 1945 3 Sheets-Sheet 3

Fig. 3.



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HIGH-FREQUENCY APPARATUS

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Application July 2, 1945, Serial No. 602,862

16 Claims. (Cl. 175—356)

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Our invention relates to coreless or air-cored transformers for use in induction heating systems powered by a generator which is called upon to deliver high powers at frequencies which may be as much as 500,000 cycles per second, and frequently much more.

Our invention is more particularly concerned with air-cored transformers and windings or coils for use in induction heating systems that include an inductor coil-means for heating a load or work to a desired extent at a desired speed. An inductor coil-means must provide a sufficiently high magnetomotive force at the surface of the metallic work being inductively heated, the force oscillating at a frequency such that the necessary heat will be generated or induced in the work in the required time. This magnetomotive force is a function of the ampere-turns in the energized inductor coil-means. However, the number of turns provided in an inductor coil-means may be limited by considerations of water-cooling, space limitations, size or form of the work being heat-treated and other factors. Frequently, only one or a relatively few turns are the most that can be practicably used. This means that currents of high magnitude must flow through the inductor coil-means, making a low impedance in the coil-means desirable.

Tube-oscillator generators inherently have high internal impedance. For practicable operation of such devices, with high efficiency at rated outputs, the apparent load impedance should be of a value in the order of that of the tube-oscillator generator. A transformer in accordance with our invention provides a means for reflecting the low impedance of the load, comprising the inductor coil-means and the work heated thereby, as a higher impedance at the output connections of the tube-oscillator generator.

An object of our invention is to provide a simple variable power-transformer for handling high-frequency high-amperage power.

A further object of our invention is to provide a compact transformer which can be associated with a predetermined tube-oscillator generator; the transformer being so constructed that the ratio of its primary and secondary turns can be quite easily changed so that the tube-oscillator generator can efficiently supply power to various kinds of loads or inductor coil-means.

Still another object of our invention is to provide a high-powered high-frequency transformer constructed of windings which are water-cooled, the ratio of the turns of the windings being adjustable without disturbing the path for the cooling water through the windings.

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Additional objects, features, combinations, elements and innovations of our invention will be discernible from the following description of the present preferred embodiment, when taken in conjunction with the accompanying drawings, in which:

Figure 1 is a front elevational view, with parts broken away and in section, of a transformer built in accordance with our invention;

Fig. 2 is a side elevational view, with parts broken away and in section; and

Fig. 3 is a horizontal view with parts broken away and in section.

Referring to the drawings, the transformer is indicated in its entirety by the reference numeral 2. It comprises a continuous primary winding 4 of a number of turns of continuous hollow copper tubing. Small circumferentially-spaced insulating spacers 6 keep the primary turns apart, only a few spacers being shown. The primary winding 4 is substantially coextensive with and inside a thin cylindrical member 8 made of an insulating material such as, for example, a laminated paper or cloth impregnated with a phenolic resin and molded under heat and pressure. A form of such insulation is sold under the trade-mark Micarta, and all of the bar and plate members hereinafter described are made of this material, unless otherwise specified, but other suitable insulation material may be used.

A secondary is around the outside of the cylindrical member 8, and comprises a plurality of separate single-turn coils 10, each comprising a flat solid copper strap having facing lower and upper ends 12 and 14 bent, as shown in Fig. 2, so as to be parallel to each other, but spaced slightly apart. The coils 10 are parallelly arranged on the cylindrical member 8, but are edgewise spaced so as to be insulated from each other. Each coil 10 has a central turn of hollow copper tubing 16 secured in good thermal contact with the strap of the coil so that cooling liquid passing therethrough can remove heat generated in the coil. The tubing 16 is narrower than the strap and has ends 18 and 20 near the strap ends 12 and 14, respectively.

The secondary winding, comprising the coils 10, the primary winding 4 and the cylindrical member 8, are assembled and held together with asbestos yarn 22. Several of the small spacers 6 may be U-shaped, as indicated in Fig. 2, for receiving and positioning the tying yarn 22.

A frame, which comprises a plurality of in-

sulating bars and plates giving it form and shape, carries the winding assembly. The primary winding 4 is provided with curved ends 26 and 28 clearing the cylindrical member 8 and having spaced tips 30 and 32 passing through holes in an insulating terminal plate 34 attached to the back of the frame. The tips 30 and 32 may be provided with water-connections and electric power may be delivered to them in any suitable manner.

At the front of the frame, a plurality of rectangular copper blocks are symmetrically arranged, a separate block being provided for each end of the coils 10. The blocks are carried by the frame on a side which is opposite to the terminal plate 34, the blocks being arranged in two horizontal rows, a lower row 38 and an upper row 40. The rows are vertically spaced apart for insulation, with mica insulation 42 in the space between rows. The several blocks in each row are also horizontally spaced apart for insulation, with mica insulation 44 between blocks. Consequently, each block is electrically isolated except for connections subsequently described. In the embodiment described, the rows 38 and 40 comprise blocks 46 which are generally alike except for the two diagonally opposite blocks 46' at the upper right and lower left corners of the block-assembly. These blocks 46' differ slightly from the others.

In order to position and help support the blocks, the frame is provided with lower and upper insulating plates 48 centrally spaced apart. Extending inwardly from the facing edges of the plates 48 are narrow parallel insulating bars 50 and 52, respectively, for receiving the rows 38 and 40 of blocks therebetween. The bars 50 and 52 are kept in spaced fixed position by elongated bolt and nut means 54, passing through holes in the ends of the bars, and insulating spacer tubes 56.

The blocks are electrically connected to the coils 10, and are provided with individual terminal studs so that the blocks can function as terminals or terminal members.

Each terminal block 46 is formed with an inner cavity 58 which is open only at the inner face of the block, which is toward the opposite row; the terminal blocks 46' having similar cavities 58'. Each opening in the inner faces of the lower row 38 of the blocks is liquid-tightly closed by an individual strap-end 12; and each opening in the inner faces of the upper row 40 is similarly closed by an individual strap-end 14. Each block is slightly wider than the associated strap-end.

Each terminal block also has an opening in its back side, passing to its cavity, near its associated strap-end, for receiving an end of the copper tubing 16. The terminal blocks of the lower row 38 receive the lower ends 18 of the tubing 16, and the terminal blocks of the upper row 40 receive the upper ends 20 of the tubing 16, the ends being abuttingly liquid-tightly secured to the blocks.

Each terminal block 46 is provided with a short pipe 60 which passes through an outer side of the block for communication with its inner cavity 58, the pipe being liquid-tightly secured to the block, with an end exposed. The pipes 60 secured to the lower row of blocks extend downwardly through spaced holes in the lower insulating bar 50, being held in position by lock nuts or other suitable means; and the pipes 60 secured to the blocks of the upper row extend upwardly through the upper insulating bar 52 in a corresponding manner. However, the outer sides of the terminal blocks 46' are solid, and are different in this respect from the blocks 46.

As shown in Fig. 2, the front or connection face of each terminal block 46 is also provided with a solid copper terminal stud 62; while the front or connection face of each of the two blocks 46' is provided with a hollow copper stud 62' extending into the cavity 58' of the associated block. As is clear from Figs. 2 and 3, the connection faces of the blocks which receive the terminal connection means comprising the aforesaid studs, face in the same direction and lie in a plane. The studs 62 and 62' provide a means for electrically connecting the single-turn coils 10 in any selected manner through suitable interconnecting means which bridge selected terminal studs. We have shown the single-turn coils connected in series by bridging members or jumpers 64 comprising flat bars which are slotted or perforated so as to fit diagonally opposite studs of adjacent vertical pairs of blocks, as indicated in Fig. 1. However, it is quite evident that the coils 10 may be connected in parallel by a suitable jumper spanning and interconnecting all the top studs and a suitable jumper interconnecting all the bottom studs. Different series-parallel combinations of the coils can be obtained in an obvious manner by using other kinds of jumpers, so that the ratio of a number of primary turns to secondary turns of the transformer can be easily changed. If desired, some of the single-turn coils may be left open circuited.

In high-power high-frequency apparatus of a type described, it is desirable to provide means for cooling the current carrying parts, and in accordance with our invention we provide a fixed conduit system through which cooling water may be caused to flow for cooling the secondary, irrespective of the manner in which the coils are electrically connected. In other words, it is not necessary, in our invention, to in any way change the cooling system when the electrical connections between the coils are altered by changing the manner in which they are bridged by any suitable jumpers. To this end, insulating hoses 66, of rubber or other insulating material, are connected between separate pairs of adjacent pipes 60 of the lower row of terminal blocks 46, and similar insulating hoses 68 are provided interconnecting the pipes 60 of each pair of adjacent blocks 46 in the upper row. Clamps or other means may be used to clamp or fasten the hoses water-tightly to the extending ends of the pipes 60. In the lower row of blocks, a hose 66 connects the first and second blocks 46 from the right, and the third and fourth blocks 46; while in the upper row, a hose 68 connects the first and second blocks 46 from the left and the third and fourth blocks 46. The hoses 66 and 68 are inside the frame and preferably as short as conveniently possible.

In the preferred form of our invention, the two diagonally opposite terminal blocks 46' are not provided with holes in their outer sides for receiving hoses. Instead each lug 62' on the front sides of these blocks is hollow, communicating with the associated cavity 58' of the associated block 46'. These lugs 62' constitute water inlet and water outlet means to which hoses or pipes may be connected leading respectively to a source of water supply and to an outlet or drain for the spent water. One or both connections to these studs 62' are conveniently of insulating hose, and are secured to the ends of the studs in a manner to permit a slotted or forked connector to be received by the studs, as schematically shown in

Fig. 2, where the nut 70 has room to move on the stud after a slotted connector 72 is slipped on.

When water is supplied to the lug 62' of one of the copper terminal blocks 46', it is evident that such water will first flow into the cavity 58' of this block. Assume it to be the block in the lower row 38. The water will then flow into the lower end 18 of the copper tubing 16 secured to this block, through this copper tubing to the upper end 20 thereof, and into the cavity 58 of the first left terminal block 46 of the upper row 40, this block 46 being immediately above the water-receiving block 46' of the row 38. The water then passes upwardly through the associated pipe 60 into a hose 68 from where it is delivered into the cavity 58 of the second left block 46 of the upper row 40. The water passes through this block and through the piping 16 associated therewith to the immediately underneath block 46 of the row 38. The water then passes through a lower hose 66 into the cavity of the next adjacent, or third from left, block 46 of the row 38, and in the obvious manner the water-flow path continues along course in which the water flows successively through each of the tubings 16 and the terminal blocks, coming out at the right-hand block 46' of the upper row 40.

With a thin cylindrical member 8, the water circulating through the primary can augment the cooling of the secondary coils 10 by the water circulating in the tubing 16.

While we have described our invention in a preferred embodiment, it is obvious that the teachings and principles thereof may be incorporated in other embodiments and in similar apparatus.

We claim as our invention:

1. Apparatus of a type described for high frequency use, comprising a support, a plurality of individual insulated hollow terminal blocks carried by said support, each block having an inner cavity, a plurality of separate conducting straps, each bent along a curve, each strap having ends secured to separate terminal blocks, a hollow tube secured to each strap in thermal relation therewith, means for providing a continuous duct from the cavity of a first of said terminal blocks through a hollow tube secured to a strap, to the cavity of a second of said terminal blocks, and hollow insulating connections connecting the inner cavities of predetermined terminal blocks, whereby to provide a conduit system for the flow of cooling fluid through said terminal blocks and said hollow tubes.

2. Apparatus of a type described for high frequency use, comprising a support, a plurality of individual insulated hollow terminal blocks carried by said support in spaced rows, each block having an inner cavity, a plurality of separate conducting straps, each bent along a curve, each strap having ends secured to separate terminal blocks, a hollow tube secured to each strap in thermal relation therewith, means for providing a continuous duct from the cavity of a first of said terminal blocks through a hollow tube secured to a strap, to the cavity of a second of said terminal blocks, hollow insulating connections connecting the inner cavities of predetermined terminal blocks, whereby to provide a conduit system for the flow of cooling fluid through said terminal blocks and said hollow tubes, said terminal blocks having connection faces facing in the same direction, and detachable short conducting members bridging certain of said faces of said terminal blocks.

3. Apparatus of a type described comprising a support, a plurality of individual hollow terminal blocks carried by said support in a pair of spaced rows, with insulation between said rows and between the terminal blocks of a row, a plurality of parallel single-turn conducting straps in edgewise spaced relation, the ends of said straps being abuttingly secured to separate sides of said terminal blocks, and means for cooling said straps and terminal blocks, comprising a plurality of individual metallic tubing, each secured to one of said straps, and duct-paths comprising insulating hoses between pairs of said terminal blocks.

4. Apparatus of a type described comprising a support, a plurality of individual terminal blocks carried by said support in a pair of spaced rows, with insulation between said rows and between the terminal blocks of a row, a plurality of parallel single-turn conducting straps in edgewise spaced relation, the ends of said straps being abuttingly secured to separate sides of said terminal blocks, means for cooling said straps comprising a plurality of individual metallic tubing, each secured to one of said straps, and insulating hoses therebetween, and a plurality of conducting bars bridging terminal blocks in different rows, each of said insulating hoses being associated with terminal blocks in the same row.

5. An air-cored transformer comprising a frame, an inner primary, a secondary comprising a plurality of separate straps around said primary, a plurality of insulated terminal blocks carried at a side of said frame, each terminal block having a cavity opening into a side of the associated terminal block, an end of a strap being secured to such side of a block for liquid tightly closing the associated cavity, individual metal cooling tubing for each of said straps, an end of such tubing being associated with an end of a strap, and communicating with the cavity of the associated block, means along a certain side of said terminal blocks for electrically interconnecting said terminal blocks, and insulating hose connections connecting the cavities of predetermined terminal blocks, the cavities terminating at other sides of said terminal blocks, whereby to provide a conduit-system for the flow of cooling fluid through said terminal blocks and said metal tubing.

6. A high-frequency transformer comprising a frame having a plurality of sides, an insulating hollow cylindrical member, a primary winding along the inside of said cylindrical member, a plurality of separate secondary coils around the outside of said cylindrical member, said coils comprising straps spaced edgewise, a hollow metal tube secured in good thermal contact to the outside of each of said straps, a plurality of insulated hollow terminal blocks on one side of said frame, each separately receiving an end of one of said secondary coils and an end of the associated metal tube, with the last in communication with the cavity in the associated block, and hoses for interconnecting the cavities of said terminal blocks.

7. Apparatus of a type described comprising a frame, a pair of rows of hollow terminal blocks carried by said frame, with insulation between the terminal blocks of a row and between rows, a plurality of separate coils arranged axially, each coil having strap-ends having faces conductively abuttingly secured to terminal blocks in different rows, each coil comprising cooling means in the form of tubing having ends connected to the cavities of terminal blocks to which the coil ends are conductively secured, and insulating hoses

connecting the cavities of adjacent terminal blocks in the same row.

8. The invention of claim 7 characterized by a pair of diagonally opposite blocks in said rows being provided with hollow connections for conveying water to and from said apparatus.

9. Apparatus of the type described comprising a support, a plurality of hollow terminal blocks insulatedly carried by said support, the cavity of each block extending to a side of the block to form an opening thereat, a winding comprising a plurality of turns of separate conducting straps, said conducting straps having flat end-portions conductively secured to said terminal blocks and closing said openings, and means for conducting cooling fluid to and from said blocks, the last said means including hollow portions associated with said straps for cooling them.

10. An invention including that of claim 9 but characterized further by having means for selectively electrically connecting said terminal blocks.

11. Apparatus of the induction type comprising a plurality of individual hollow terminal blocks arranged in a pair of spaced rows, with insulation between said rows and between terminal blocks of a row, a plurality of parellel single-turn conducting straps in edgewise spaced relation, the ends of said straps being abuttingly secured to separate sides of said terminal blocks, and means for cooling said straps and terminal blocks comprising a plurality of individual tubing, each secured to one of said straps, and a duct-path comprising an insulating hose between at least two of said terminal blocks.

12. Apparatus in accordance with that defined in claim 11 but further characterized by each of said terminal blocks having a connection face, and electrical connection means at each of said faces, all of said faces facing in the same direction.

13. Apparatus in accordance with claim 12 but further characterized by each of said connection faces lying substantially in a plane.

14. Apparatus in accordance with claim 1 but further characterized by said terminal blocks having connection faces lying substantially in a plane.

15. Apparatus in accordance with claim 3 but further characterized by said terminal blocks having connection faces lying substantially in a plane.

16. Apparatus in accordance with claim 4 but further characterized by said terminal blocks having connection faces lying substantially in a plane.

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