Oct. 9, 1962

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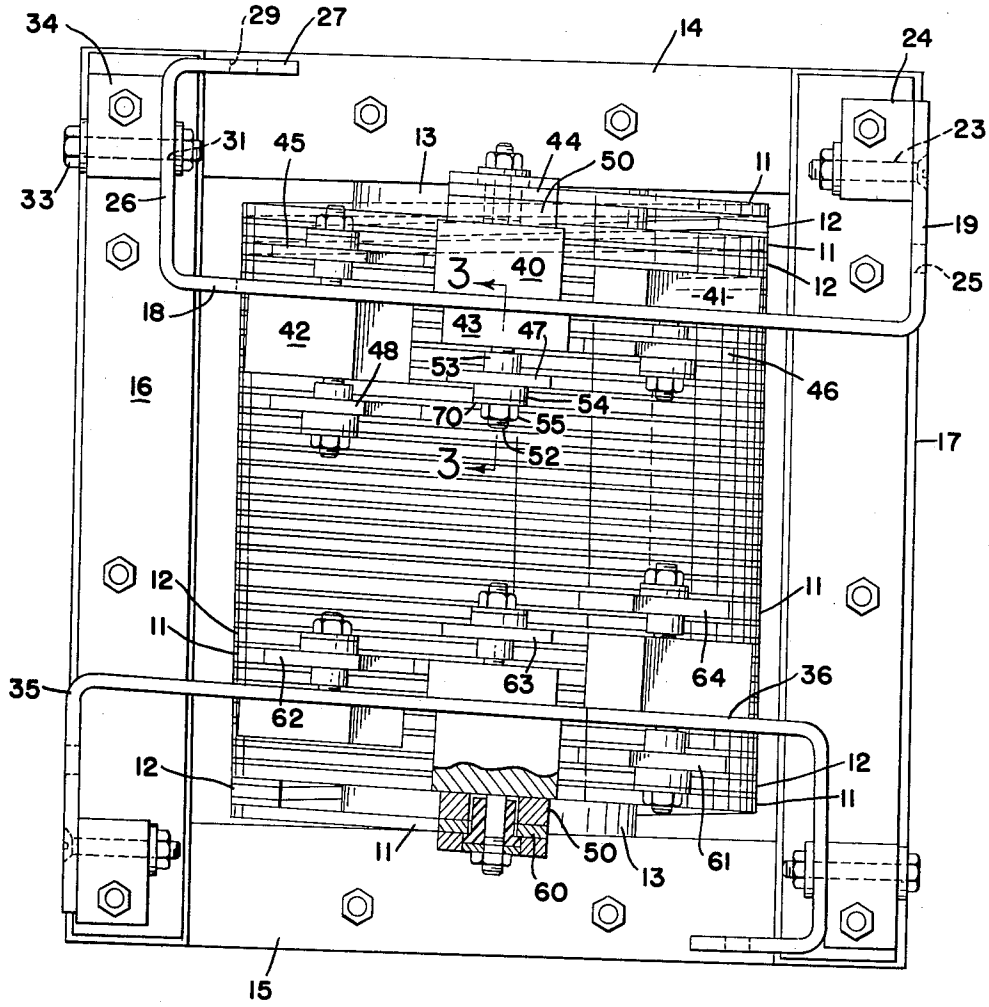
3,058,077

VARIABLE RATIO TRANSFORMER

Filed Jan. 7, 1959

2 Sheets-Sheet 1

FIG. 1



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2 Sheets-Sheet 2

FIG. 2

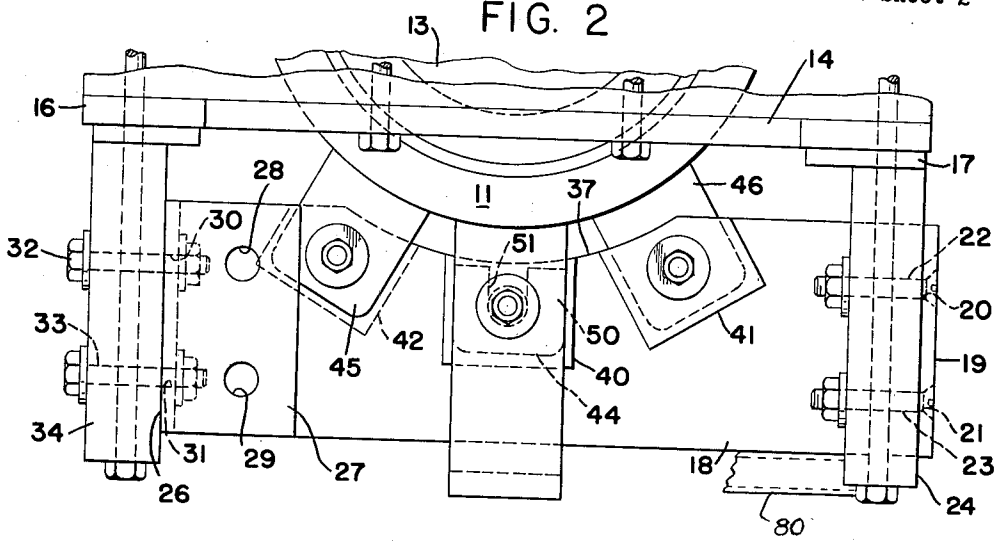


FIG. 3

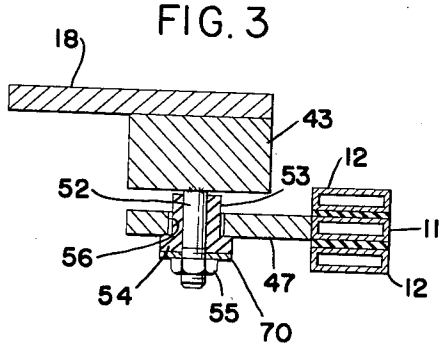


FIG. 4

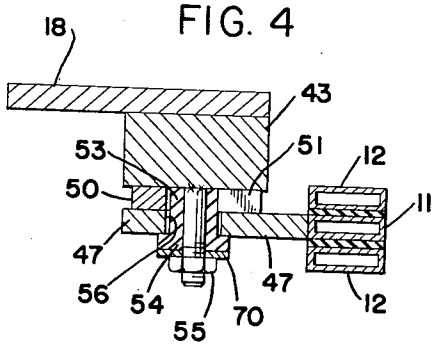
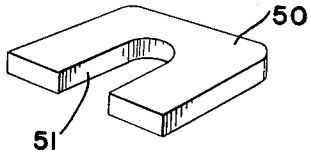


FIG. 5



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VARIABLE RATIO TRANSFORMER

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13 Claims. (Cl. 336—150)

This invention relates to a variable ratio transformer.

In high frequency induction heating equipment, stationary transformers are provided which must be capable of handling extremely high current. It has been a recognized requirement for such transformers that the parts be water-cooled to remove the heat generated in the transformer during its operation. The present invention is particularly applicable to a transformer of this type, although, of course, it is not limited to this particular application.

Various types of variable ratio transformers have been proposed heretofore. In such transformers, the primary or the secondary, or both the primary and secondary, are provided with a plurality of taps connected thereto. These taps may be selectively connected to respective busses to give the desired ratio of power transformation in the transformer.

In United States Letters Patent No. 2,655,636 such selective connections are provided by rigid connectors which are adapted to be selectively connected to the desired tap on the transformer and to the collector busses. While the tap-changing arrangement of said patent is completely well suited for the larger sized variable ratio transformers, it is not entirely practical for the smaller sized transformers. One reason for this is the problem of physically adapting the connectors therein to the smaller dimensions of the smaller transformers. Also, when such smaller size transformers are provided with the variable-tap arrangement of said patent the cost of manufacture of such transformers tends to be excessively high.

In order to overcome these problems it has been attempted to make such tap connections by means of flexible copper braids having a hole at each end. At one end the braid is connected to the desired tap lug on the transformer. At its opposite end the braid is connected to a bus extending across the end of the transformer. With such an arrangement, when it is desired to change the transformer connection it is necessary to disconnect two nut and bolt connections for each braid, relocate the braid, and reconnect the nut and bolt fasteners. This involved considerable manual work which makes that arrangement unattractive from the practical standpoint. An even more serious disadvantage of that arrangement is that the braids themselves impose a limitation on the current-carrying capacity of the transformer. For example, even with a flexible copper braid 2" wide such braid can safely carry only about 900 amperes of 10 kc. current in a well-ventilated cabinet. In actual practice, however, each braid is sheathed by a plastic sleeve and the transformer often is mounted in a cabinet which has limited ventilation. Therefore, under such circumstances, the current carrying capacity of the braid is well below 900 amperes. In any event, the magnitude of the current supplied to the transformer primary cannot safely exceed what the braid connectors can safely carry. With such braid connectors, there is no practical method of using circulating water to cool them directly for the purpose of increasing their current-carrying capacity. The required length of such braid connectors is too great to depend on heat removal by conduction along the strands of the connector to either the collector bus or the tap on the transformer winding.

Essentially the same disadvantages, to a somewhat lesser extent, are associated also with connectors made of copper ribbon stock.

Thus, prior to the present invention, there has existed a need for an improved arrangement on smaller sized transformers for providing adjustable connections to vary the power ratio of the transformer. The present invention is directed to a novel arrangement which avoids all of the foregoing difficulties.

In accordance with the present invention, the respective upper and lower collector busses extend across one side of the transformer windings, each at a location disposed toward the middle of a group of taps, of which one is to be selected. Each collector bus is provided with a plurality of built-up land surfaces which extend closely adjacent to respective tap lugs connected to one of the transformer windings at spaced locations along the latter's length. Threaded studs are anchored in such lands on the collector busses and these studs extend through openings in the respective transformer tap lugs in insulated relationship thereto. A nut is threaded onto the free end of each of these studs. A removable copper bar spacer may be inserted between one of the lands and the corresponding transformer tap lug. The length of the electrical connection provided by the removable insert is so short that there is no necessity of water cooling the insert directly. The heat generated in this insert by the current which it carries is largely dissipated by conduction to the water-cooled collector bus and to the water-cooled transformer coil through the corresponding transformer tap lug. With this novel arrangement, the connector between the transformer tap lug and the collector bus does not reduce the current carrying capacity of the transformer.

It is an object of this invention to provide a novel and improved variable ratio transformer.

It is also an object of this invention to provide a variable ratio transformer which has a novel and improved arrangement for selectively changing the transformer ratio.

Another object of this invention is to provide in a variable ratio transformer a novel and improved arrangement for making selective connections to the transformer taps which is particularly well adapted for use on smaller sized transformers.

Another object of this invention is to provide a variable ratio transformer having a novel and improved arrangement for selectively connecting the collector busses to different taps on the transformer which does not reduce the current-carrying capacity of the transformer.

Another object of this invention is to provide in a variable ratio transformer a releasable connector for connecting the collector bus to one of a plurality of taps on the transformer which may be inserted and removed readily and easily.

A further object of this invention is to provide a variable ratio transformer having a novel collector bus arrangement which enables the transformer to be connected to an external bus in any of a number of different ways.

Further objects and advantages of this invention will be apparent from the following detailed description of a presently-preferred embodiment thereof which is illustrated in the accompanying drawings.

In the drawings:

FIGURE 1 is an elevational view showing the back of a variable ratio transformer in accordance with the present invention;

FIGURE 2 is a top view of the back portion of this transformer;

FIGURE 3 is a fragmentary vertical section taken along the line 3—3 in FIGURE 1 and showing the relationship between one of the transformer tap lugs and

the corresponding land on the collector bus to which it may be connected electrically;

FIGURE 4 is a view similar to FIGURE 3 and showing a conductive insert engaged between this transformer tap lug and the collector bus land so as to connect these members together electrically; and

FIGURE 5 is a perspective view showing one of these inserts.

Referring first to FIGURE 1, the transformer proper is of known construction. It comprises a primary winding **11** having a plurality of turns which extend in a continuous helix and a secondary winding **12** of similar configuration presenting a series of turns which are disposed between the adjacent turns of the primary windings. These windings extend around the center leg **13** of a core. In one practical embodiment, both the primary and secondary windings are rectangular in cross-section and hollow so that cooling water can be circulated therethrough. The successive primary and secondary turns are insulated from each other by suitable insulation, as shown in FIGS. 3 and 4. The opposite ends of this center leg are connected to top and bottom legs **14** and **15** of the core, which extend across the opposite axial ends of the windings **11** and **12**. The core also has end legs, not shown, which are disposed behind the frame members **16** and **17** in FIGURE 1. These end legs of the core join the top and bottom legs **14** and **15** of the core and are disposed on opposite sides of the windings **11** and **12**. Thus far, the transformer is essentially conventional in construction.

In accordance with the present invention, there are provided a pair of collector busses which extend across the back of the transformer windings between the respective axial ends of those windings. Referring to FIGURE 1, the upper collector bus presents an elongated portion **18** which extends across the back of the transformer at the level of the fourth turn of the primary winding from the top. This elongated portion **18** of the upper collector bus is disposed at an angle to the horizontal which is equal to the helix angle of the transformer windings. This upper collector bus at its right end in FIGURE 1 terminates in an upstanding leg **19** which is disposed in line with the outer edge of the right hand frame member **17**. Toward its upper end, this leg **19** presents a pair of openings **20** and **21** (FIG. 2) for receiving bolts **22** and **23** which connect this leg of the upper collector bus to an arm **24** attached to the side member **17** of the frame and extending forward horizontally therefrom. Below these openings **20** and **21**, the upstanding leg **19** of the upper collector bus also is provided with a pair of openings **25** at which the collector bus may be connected to an external bus (not shown).

At its left end in FIGURE 1, the upper collector bus is provided with an upstanding leg **26** which terminates at its upper end in a horizontally inturned segment **27**. The latter is provided with a pair of openings **28** and **29**, as shown in FIGURE 2, which enable it to be attached to an external bus (not shown). Thus, with the present novel construction of the collector bus as shown, this collector bus may be attached to an external bus at either its right end leg **19** or at its top left extremity **27**. The upstanding leg **26** of the upper collector bus is provided with a pair of openings **30** and **31** for receiving bolts **32** and **33** which attach it to an arm **34** connected to the left side frame member **16** and extending forward horizontally therefrom.

An identical mounting is provided for the lower collector bus **35**. This lower collector bus presents an elongated leg **36** which extends across the back of the transformer windings. This leg **36** extends downward at the same helix angle as that of the transformer windings and it is located opposite the fourth turn of the primary winding from the bottom.

As best seen in FIGURE 2, each of the laterally extending legs of the upper and lower collector busses is cut away at its inner edge to present an arcuate edge portion **37** which is evenly and closely spaced from the adjacent turn of the primary winding **11**.

Each collector bus preferably has a cooling water duct brazed to its outer edge and extending completely thereacross, one such cooling duct being shown fragmentarily at **80** in FIG. 2.

As shown in FIGURE 1, the laterally extending leg **18** of the upper collector bus carries on its upper face a pair of laterally spaced, upstanding lands or bosses **40** and **41**. Another pair of laterally spaced lands or bosses **42** and **43** are attached to the bottom of the laterally extending leg **18** of the upper collector bus and extend downward therefrom. In one practical embodiment each of these lands is of cylindrical copper bar stock. These lands are aligned vertically respectively with five terminal tap lugs **44**, **45**, **46**, **47** and **48**, respectively, of copper or other suitable material. These tap lugs at their inner ends are brazed to corresponding turns of the primary winding **11** of the transformer and extend forward therefrom at an acute angle to the horizontal which is equal to the helix angle of the primary winding. As shown in FIGURE 1, the terminal tap lug **44** closely overlies the boss **50** on the laterally extending leg **18** of the upper collector bus, the terminal tap lug **45** closely overlies the laterally extending leg **18** of the upper collector bus and the tap lug **46** closely underlies this leg, the tap lug **47** closely underlies the bottom face of the land **43** of the upper collector bus, and the tap lug **48** extends closely beneath the bottom face of the land **42**. The respective tap lugs **44–48** are attached directly to the primary winding **11** at spaced locations along the latter's length so that by connecting the upper collector bus electrically to a particular one of these tap lugs, the power ratio of the transformer can be determined accordingly.

In accordance with the present invention, such connection can be provided by means of a removable copper insert **50**, shown in FIGURE 5. In one practical embodiment, this insert has a thickness of about $\frac{5}{16}''$ and a length and width appreciably greater than its thickness, so that the insert is capable of carrying currents of the magnitude required for the proper operation of the transformer. As shown in this figure, the insert is approximately U-shaped in cross section, having a slit **51** therein which is open at one end of the insert.

In FIGURE 1 this insert **50** is shown engaged between the collector bus land **40** and the tap lug **44** which is connected to one end of the transformer primary winding **11**. In order to change the transformer ratio, this insert **50** may be removed from this location and inserted between the tap lug **45** and the laterally extending leg **18** of the upper collector bus, or between the tap lug **46** and the laterally extending leg **18** of the upper collector bus, or between the tap lug **47** and the boss **43** on the collector bus, or between the tap lug **48** and the boss **42** on the collector bus. The particular manner in which such connections can be made selectively will now be described with reference to FIGURES 3 and 4.

As shown in FIGURE 3, a stud **52** is secured to the boss **43** and extends downward therefrom. A bushing **53** of electrical insulation material extends around this stud **52** and presents a transverse lower flange **54**. A nut **55** is threaded onto the lower end of the stud **52** below the flange **54** on the bushing, there being a metal washer **70** engaged between them. The adjacent transformer tap lug **47** is formed with an opening **56** through which the stud **52** and the insulating bushing **53** extend. The flange **54** on the bushing engages the under side of this tap lug **47**. Due to the presence of the insulation bushing **53**, the boss **43** on the collector bus **18** is normally insulated from the transformer tap lug **47**.

However, as shown in FIGURE 4, the boss **43** may be connected electrically to the tap lug **47** by positioning the insert **50** between them and tightening the nut **55** a

fraction of a turn. When this is done, the tap lug **47** is tightened against the under side of the insert **50** and the insert is forced tightly up against the underside of the boss **43** so as to connect the boss **43** electrically to the tap lug **47**. Such insertion may be made readily since the slit **51** in the insert **50** is dimensioned to receive the bushing **53**, as shown in FIGURE 4.

A similar arrangement is provided at each of the other transformer terminal lugs **44**, **45**, **46**, and **48**. In the case of the tap lug **45**, the corresponding stud is anchored in the land **42** and extends up through the laterally extending leg **18** of the upper collector bus. The insert **50**, when inserted here, provides an electrical connection between the tap lug **45** and the upper face of this leg **18** of the collector bus. Similarly, at the tap lug **46** the corresponding stud is anchored in the land **41** and extends down through the laterally extending leg **18** of the upper collector bus. When inserted here, the insert **50** provides an electrical connection between the tap lug **46** and the bottom face of this leg **18** of the upper collector bus.

From the foregoing, it will be apparent that this novel arrangement enables the connection between the upper collector bus and the desired tap lug on the primary winding **11** of the transformer to be changed quite readily. All that is necessary is to loosen the nut **55** where the insert **50** is located a fraction of a turn, slide the insert back out, slide the insert between the selected tap lug and the adjacent portion of the upper collector bus, and tighten the corresponding nut a fraction of a turn.

A similar arrangement is provided at the lower collector bus **35** which may be connected selectively to one of five different tap lugs **60–64**, which are connected to the transformer primary winding **11** at different locations along the latter toward its lower end. Accordingly, connections of the lower connector bus **35** to any one of the selected tap lugs **60–64** at the lower end of the transformer primary winding **11** may be made with the same ease and convenience as the above described selective connection of the upper collector bus to any desired one of the tap lugs **44–48** at the upper end of the transformer primary winding.

It is important to note that the present arrangement has each of the upper and lower collector busses located approximately midway between the several tap lugs in the group to which it may be connected selectively. In this way the distance from either collector bus to any one of these tap lugs is reduced to such an extent that there is no necessity for artificially cooling the transferable connector **50** which makes the connection between the bus and the tap lug.

The connector **50** itself is so dimensioned that it provides an electrical path between the collector bus and the tap lug which is short in length and broad in cross section so that it does not limit the current-carrying capacity of the transformer as a whole.

Moreover, this spacer may be inserted or removed to close or open the appropriate connection with a minimum of difficulty and time. Such insertion or removal is performed completely from outside the transformer.

Also, it will be apparent that the present arrangement adds little to the manufacturing cost of the basic transformer.

From the foregoing, it will be apparent that the illustrated embodiment eliminates the difficulties previously associated with such variable ratio transformers. While there has been described in detail herein and illustrated in the accompanying drawing a particular presently preferred embodiment of this invention, it is to be understood that various modifications, omissions and refinements which depart from the disclosed embodiment may be adopted without departing from the spirit and scope of this invention. For example, the present removable connector arrangement may be applied to an autotransformer, if desired, or to other types of transformers which have their windings positioned differently from the arrangement shown.

Having thus described my invention, I claim:

1. In combination with a transformer having a helical winding and a plurality of tap lugs which are connected to different turns of said winding and project outward transversely therefrom, the improvement which comprises: a collector bus extending laterally across the outside of the transformer between the ends of said winding and in spaced relation to said winding, said collector bus lying in a plane substantially perpendicular to said winding, said collector bus having integral therewith a plurality of built-up lands which extend from the collector bus substantially perpendicular to said tap lugs and which terminate in closely spaced relationship to corresponding ones of said tap lugs on the transformer, a removable electrically conductive insert engaged directly between a selected one of said tap lugs and the adjacent surface of said collector bus in contact with both, said insert being movable in a direction perpendicular to said winding whereby removal of the insert disconnects said selected tap from said connector bus and means remaining at each tap lug releasably clamping said insert between said selected tap lug and said adjacent surface of the collector bus to form an electrical connection between said selected tap lug and the collector bus.

2. The combination of claim, 1, wherein said insert has a relatively small thickness in a direction from the collector bus directly to the selected tap lug and has, directly between the collector bus and the selected tap lug, a relatively large cross-section perpendicular to its thickness.

3. The combination of claim 2, wherein said releasable clamping means comprises a stud mounted on and directly connected to the collector bus at one side of the selected tap lug and extending therefrom to the opposite side of said selected tap lug, and means threaded onto said stud at said opposite side of said selected tap lug and operable when turned to clamp said selected tap lug against said insert to force said insert tightly against the collector bus.

4. The combination of claim 2, wherein said releasable clamping means comprises a stud anchored at one end to the collector bus and extending therefrom substantially perpendicular to said selected tap lug, said tap lug having an opening through which the stud extends, said insert having a slit therein which is open at one end and which receives the stud when the insert is positioned between the tap lug and the collector bus, a nut threaded onto the stud beyond said tap lug and adapted when tightened to clamp said tap lug against said insert and force said insert tightly against the collector bus, and means insulating said stud from the insert and from said tap lug and insulating said nut from said tap lug.

5. The combination of claim 4 wherein there are provided supports for the transformer at opposite sides of the transformer, said collector bus is connected to said supports, said collector bus at one end presents a first flat attachment portion at one side of the transformer which extends substantially parallel to the transformer axis for connecting the collector bus in one manner to an external bus, and said collector bus at its opposite end presents a second flat attachment portion at one end of the transformer which extends substantially perpendicular to the transformer axis for connecting the collector bus in a different manner to an external bus.

6. In combination with a transformer, and support members at opposite sides of the transformer which support the transformer, the improvement which comprises: a collector bus connected to said support members and extending therefrom laterally across the outside of the transformer in spaced relation thereto between the ends of the transformer, said collector bus at one of its ends presenting a first flat attachment portion at one side of the transformer which extends substantially parallel to the longitudinal axis of the transformer for connecting the collector bus in one manner to an external bus, and said collec-

tor bus at its opposite end presenting a second flat attachment portion at one end of the transformer which extends substantially perpendicular to the longitudinal axis of the transformer for connecting the collector bus in a different manner to an external bus.

7. The combination of claim 6 wherein said transformer has a plurality of taps at spaced locations thereon which extend laterally beyond the transformer, and wherein there are provided a removable electrically conductive insert engaged directly between said collector bus and a selected one of said taps in contact with both, and means at each tap for releasably clamping said insert between said collector bus and said selected tap to form an electrical connection between them.

8. The combination of claim 7, wherein said collector bus has bosses thereon which extend close to respective ones of said taps on the transformer, and said releasable clamping means are mounted individually on said bosses.

9. A transformer having a helical winding, a plurality of laterally extending tap lugs connected to different turns of said winding and a collector bus extending across one surface of said winding and having a surface facing said tap lugs whereby an insert is positioned between said surface and one of said tap lugs to determine the number of active turns in said winding, the improvement comprising: said connector bus lying in a plane substantially perpendicular to said winding whereby the surface facing said tap lugs is substantially flat, said connector bus having a plurality of bosses extending perpendicularly from its surface and said bosses being close to a surface of said tap lugs which lug surface is substantially perpendicular to said windings to thereby create a space between said lugs and said bossses that extend in a direction substantially perpendicular to said winding, an electrically conductive insert adapted to pass between said bus and one of said lugs to connect said lug with said connector bus and a means permanently associated with said lug and said bus to clamp said insert between the lug and the connector bus.

10. The improvement defined in claim 9 wherein said insert is a slotted relatively flat block and said clamping means extends from said lug to said collector bus and insulated therefrom whereby said clamping means exerts force to hold said insert between said lug and said collector bus.

11. A transformer having a helical winding, a plurality of laterally extending tap lugs connected to different turns of said winding and a collector bus extending across one surface of said winding and having a surface facing said lugs whereby an electrically conductive insert is positioned between said surface and one of said lugs to determine the number of active turns in said winding, the improvement comprising: said insert being of low electrical resistance and having a slot extending from one end thereof and a means remaining on said transformer for clamping said insert between said collector bus and one of said lugs.

12. The improvement as defined in claim 11 wherein said clamping means comprises a member permanently affixed to and extending from said lugs, said member passing through said connector bus and said member electrically insulated from said collector bus and camming means on the side of said bus opposite said lugs to clamp the lugs and bus together after the slotted insert is in position over said member.

13. The improvement defined in claim 11 wherein said clamping means comprises a member permanently affixed and extending from said collector bus, said member passing through said lug and said member electrically insulated from said lug and camming means on the side of said lug opposite said collector bus to clamp the lug and collector bus together after the slotted insert is in position over said member.

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