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Fisher

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[54] **TRANSFORMER WITH CONNECTOR AND METHOD OF ASSEMBLY**

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[52] **U.S. Cl.** ..... **336/192,** 29/602, 336/58, 339/595 A

[51] **Int. Cl.** **H01f 15/10**

[58] **Field of Search** ..... 336/192, 58; 339/95 A; 29/602

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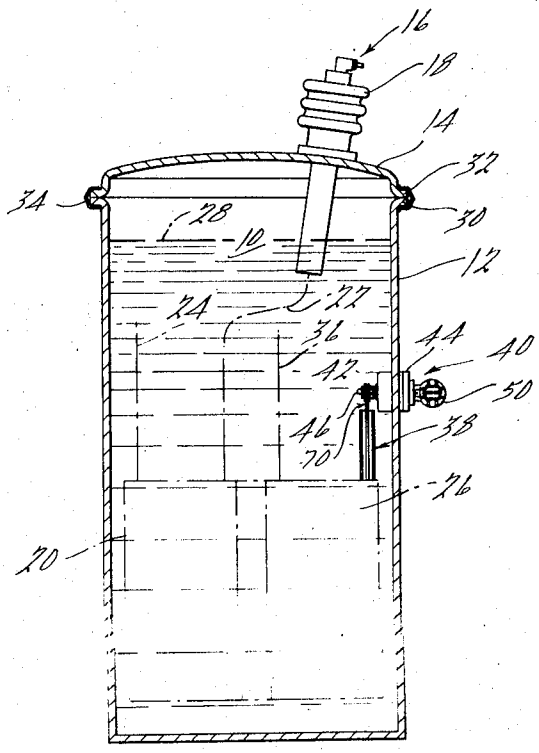
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[57] **ABSTRACT**

A connector assembly for the low voltage, aluminum, output conductors of a transformer which includes a copper stud forming the through connection from the interior of a transformer casing to the external connector. The low voltage leads from the transformer assembly are preferably formed of aluminum and are attached to the copper stud by means of a concentrically grooved brass washer which is forced into the face of dead-soft aluminum strip by means of a compression nut. The electrical path for the connector assembly includes the dead-soft aluminum strip, the concentrically grooved brass washer, the brass compression nuts and the copper stud.

22 Claims, 8 Drawing Figures



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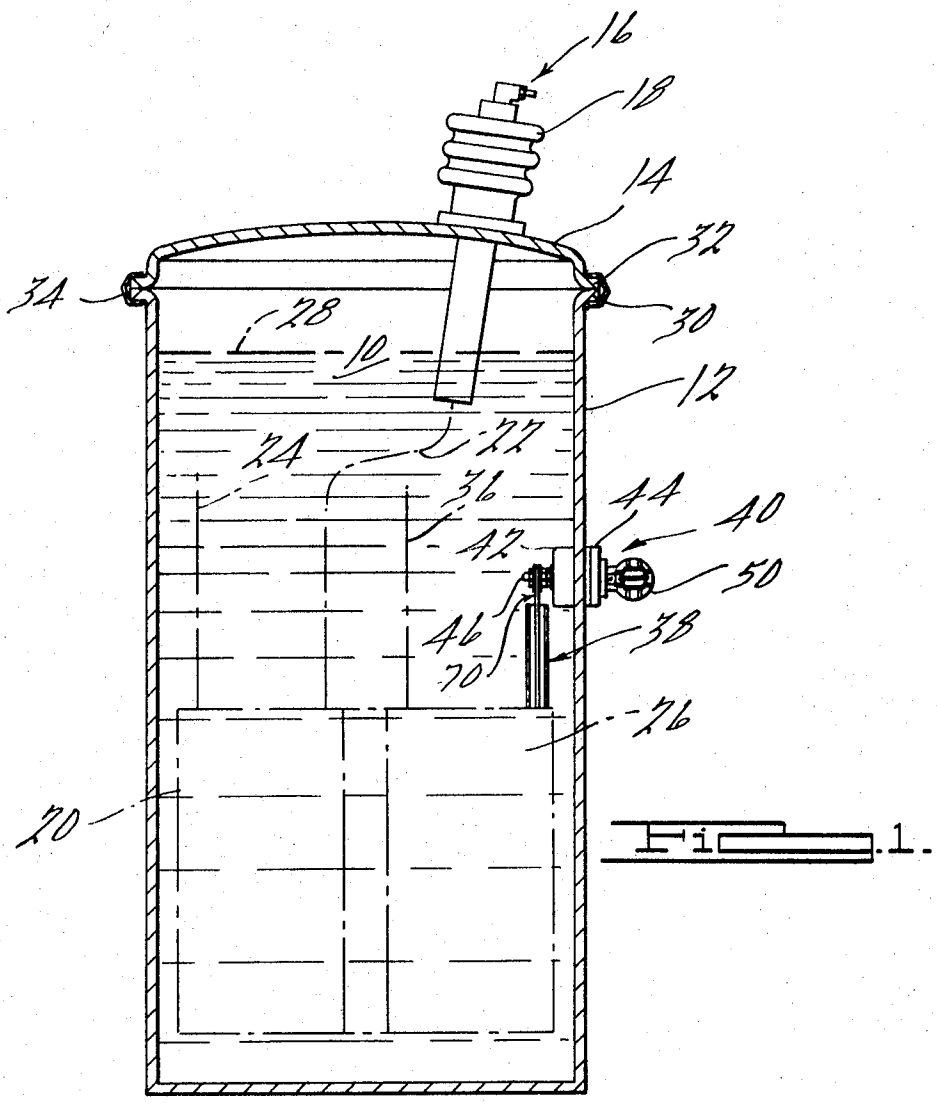


Fig. 1.

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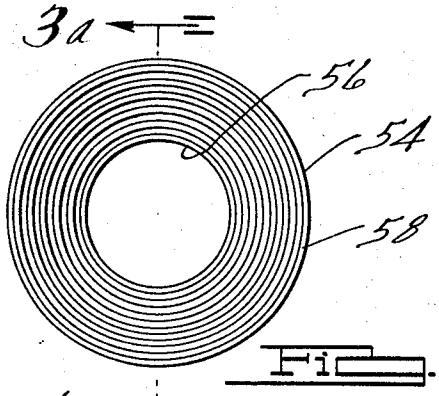


Fig. 2.

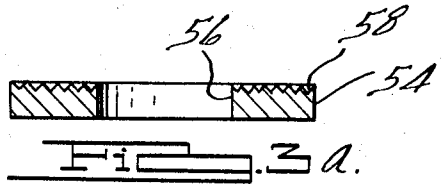


Fig. 3a.

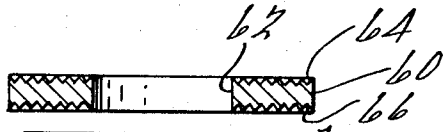


Fig. 3b.

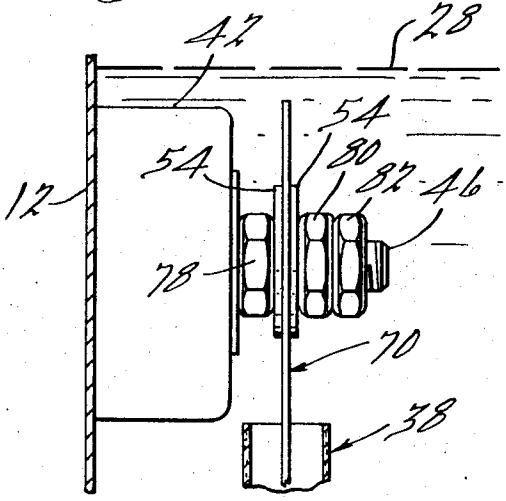


Fig. 4.

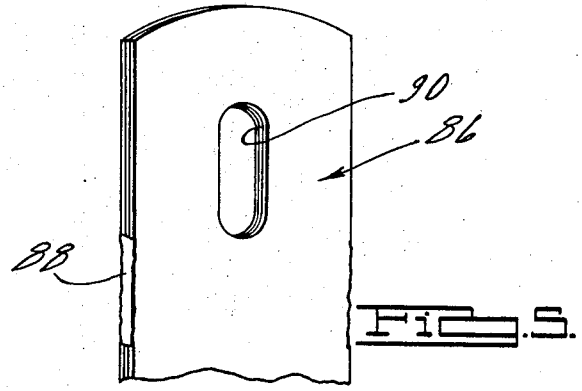


Fig. 5.

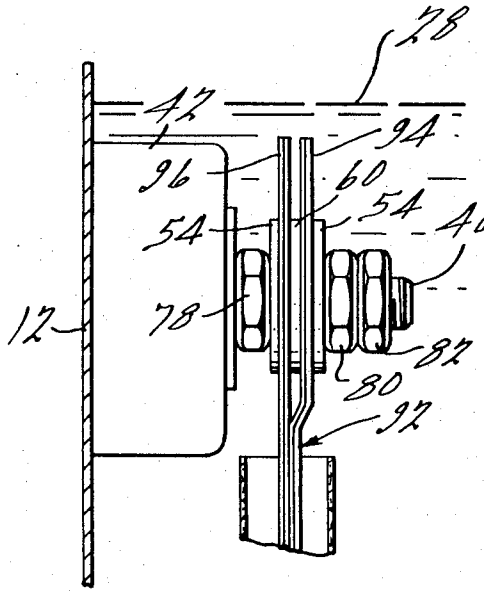


Fig. 7.

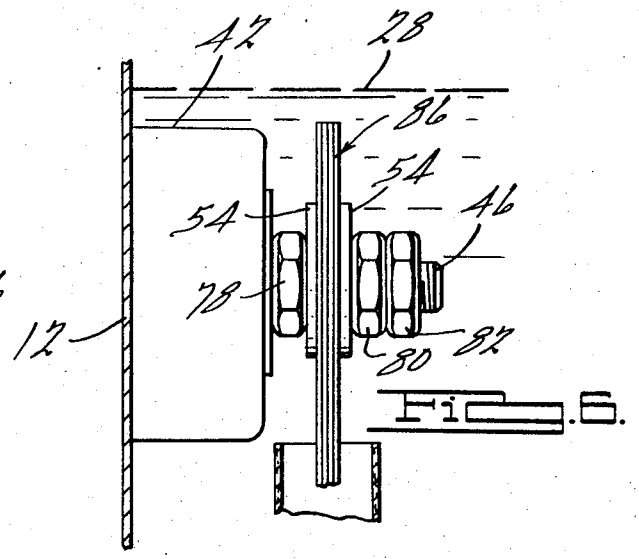


Fig. 6.

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TRANSFORMER WITH CONNECTOR AND METHOD OF ASSEMBLY

BACKGROUND AND SUMMARY OF THE DEVELOPMENT

This invention relates generally to a connector assembly for connecting aluminum strip conductors to a stud and more particularly to a connector assembly which includes a concentrically grooved washer made of material which is sufficiently hard relative to the aluminum conductor that the aluminum conductor will flow into the voids created by the concentric grooves thereby eliminating poor connections inherent in thermally cycled connectors for aluminum strips.

In the past, copper was the common material utilized for transformer secondary coil leads or busses, the copper being typically formed in a relatively flat strip. However, with the unusual increase in cost of copper, other materials have been sought which have the proper electrical and mechanical characteristics for use in connection with the leads of the secondary winding of a transformer.

One material which has been found to have the desirable electrical characteristics is aluminum. Typically, electrical grade aluminum is extremely soft and attains its highest conductivity in the dead-soft, annealed state. However, certain problems have arisen in the use of aluminum for the secondary strip lead, these problems having been present form some period of time.

For example, one problem which has existed with the use of dead-soft aluminum is the tendency for the aluminum to cold flow out of the connector assembly when any compressive force is applied. This problem particularly arises when it is desired to clamp the aluminum strip to a connector assembly for providing either a termination of the electrical conductor or the connection of the conductor to an external connector outside of the transformer casing.

The problem becomes particularly acute when the phenomenon of thermal cycling occurs wherein the thermal expansion of the various components of the connector assembly are different, thus creating an extremely high compressive force on the strip aluminum. For example, aluminum expands at a rate which is approximately 1.3 to 1.5 times the rate of expansion of copper. This causes the aluminum to cold flow out of the joint or connector thereby decreasing the cross-sectional area of the conductor strip. Also, the cooling down of the conductor due to a reduced current flow or due to the reduction of the environmental temperature causes the aluminum to retract from the connector thereby increasing the electrical resistance of the connection. Once the joint has loosened as a result of cold flow, surface contact resistance between the various components of the electrical joint increases both due to a lack of joint pressure and formation of non-conductive oxides, the oxides developing on the aluminum as a result of the relatively loose fit of the joints or connector assembly. This increased electrical resistance increases the contact heating during subsequent electrical loading and the thermal cycling becomes more destructive until a thermal runaway condition occurs. When this runaway condition occurs the connection fails.

Another phenomenon occurs with certain connections heretofore used in connection with the termination of secondary conductors of a transformer, this

phenomenon being the formation of aluminum oxide on the strip conductors. This problem was solved by removing the aluminum oxide and using a clamp type connector. However, the clamp type connector failed if the joint was thermally cycled due to the fact that the aluminum would flow to the exterior of the connection, thereby destroying the contact pressure at the joint. Thus, some system was needed to shield the interior portion of the connection or joint from oxide causing oxygen after the joint or connection was thermally cycled.

With the connector assembly of the present invention, all of the problems described above are substantially reduced plus adding other desirable features to the connection of an aluminum terminal strip of the secondary transformer to an external connector. The assembly of the present invention includes the provision of a concentrically grooved washer, either grooved on one or both faces, the washer being extremely flat relative to its diameter, and a clamping mechanism is provided for initially slightly deforming or cold flowing the aluminum by forcing the concentrically grooved face of the washer slightly into the surface of the aluminum buss bar strip. In this way, any aluminum oxide crust that may be present on the face of the aluminum buss bar is broken thereby providing intimate contact between the exposed clean surfaces of the aluminum and the sharp ridges of the washer face. Also, the aluminum is slightly cold flowed into the grooves of the concentrically grooved washer leaving small voids or spaces at the apex of the void area formed by the grooves in the washer. Thus, when the joint is thermally cycled, the aluminum tends to flow into the voids formed by the concentric grooves rather than out of the joint to substantially limit clamping pressures on the aluminum buss strip. Further, when the joint cools, and the aluminum shrinks at a rate greater than other components in the system, the aluminum is restricted to movement along the angular faces of the grooves of the concentrically grooved washer effectively maintaining intimate contact of clean electrically conductive surfaces of the aluminum and the washer and also essentially maintaining clamping pressure on the joint. Thus, a good electrical connection is maintained and the formation of additional aluminum oxide is precluded.

Accordingly, it is one object of the present invention to provide an improved connector assembly for use in connecting low voltage aluminum strip conductors to the through connection in a transformer.

It is another object of the present invention to provide an improved connector assembly for a transformer which has improved thermal cycling characteristics.

It is a further object of the present invention to provide an improved connector assembly for a transformer which precludes oxides from forming in the strip buss connector joint which would be detrimental to the performance of the connection.

It is still a further object of the present invention to provide an improved connector assembly which enables the effective use of aluminum strip conductors in the secondary circuit of a transformer.

It is still a further object of the present invention to provide an improved connector assembly for the secondary circuit of a transformer which minimizes the resistance of the of the connection throughout the life of the transformer.

It is still a further object of the present invention to provide an improved connector assembly which is particularly adaptable for use in connection with interconnecting the secondary winding of a transformer with the transformer tank exterior conductor.

It is still a further object of the present invention to provide an improved connector assembly for use in conjunction with interconnecting conductors fabricated of materials which have widely varied thermal expansion characteristics.

It is a further object of the present invention to provide improved connector assembly for a transformer which is inexpensive to manufacture, reliable in use and substantially reduces problems heretofore encountered in connector assemblies of this type.

Further objects, features and advantages of this invention will become more apparent from a consideration of the following description, the appended claims and the accompanying drawings in which:

FIG. 1 is a sectional view of a transformer assembly, illustrating the primary and secondary windings in symbolic form, and particularly illustrating the connector assembly of the present invention;

FIG. 2 is a plan view of a grooved washer of the present invention;

FIG. 3*a* is a cross-sectional view of the washer of FIG. 2 taken along lines 3*a*—3*a* thereof;

FIG. 3*b* is a cross-sectional view of a modified form of washer of FIGS. 2 and 3*a* and particularly illustrating grooving on both faces of the washer;

FIG. 4 is a detail view of a connector assembly of the present invention and particularly illustrating two single faced grooved washers on either side of a buss bar;

FIG. 5 is a perspective view of a laminated buss bar and particularly illustrating the edge welding thereof;

FIG. 6 is a side view of the connector assembly of FIG. 4 and particularly illustrating the use thereof in connection with the laminated buss bar of FIG. 5; and

FIG. 7 is a side view of a modified connector assembly and particularly illustrating the use of two single face groove washers on the outboard sides of laminated buss bars and further including a double faced grooved washer between selected laminations of the buss bars or between two laminated buss bars terminating to one threaded stud connection assembly.

Referring now to the drawings, and particularly to FIG. 1 thereof, there is illustrated a transformer assembly **10** which is formed generally of an outer casing **12** and a cover member **14**, as is typical in the art. The primary conductors of the transformer are fed a high voltage by means of an input conductor assembly **16** which includes an insulating member **18** to insure that the high voltage is isolated from the tank. The high voltage is fed to the primary winding, symbolically illustrated at **20**, by means of conductors **22,24** and the primary is magnetically coupled with a secondary winding, symbolically illustrated at **26**.

The interior of the transformer tank **12** is filled with oil generally to a level indicated at **28** to provide a cooling and insulating fluid for the transformer windings **20,26**. The cover member **14** is joined to the main tank at a lip section, a lip being formed on both the tank and the cover at **30,32**, respectively. The two lips are joined by means of a clip **34** or other similar type of fastening member commonly used in transformers of this type.

The secondary winding **26** includes a pair of output conductors, one of which is symbolically illustrated at **36**, and the other of which is illustrated as a strip or bar conductor assembly **38**. It is to be understood that both the output conductors **36,38** are identical. The conductor **38** is fed through the transformer tank wall **12** by means of a connector assembly **40**, forming at least a portion of the subject matter of the present invention.

The connector assembly **40** includes means for hermetically sealing the interior of the connector assembly **40** such that the oil **28** does not leak to the exterior of the tank **12**. Typically, a pair of cup elements **42,44** form this seal and the connection is made through the interior of the cup members **42,44**. In the case of the present invention, the buss element **38** is connected to a stud member **46** by means of a plurality of locknuts and washers to be more fully explained in conjunction with the description of FIGS. **2** through **7**. The stud member **46** extends through the interior of the cup elements **42,44** to an exterior connector **50** to which the service conductors are connected.

As was stated above, it has been found that aluminum conductors, formed as is conductor **38**, may be effectively used in conjunction with the secondary windings of a transformer if the problems of oxidation and thermal cycling at the lead terminations are solved. It has been found that both of these problems may be substantially reduced by the use of a concentrically grooved washer interposed between the strip conductor and a fastening member, as for example a nut. Such a washer element is illustrated at **54** in FIG. **2**. The washer element includes a centrally located aperture **56** and a plurality of grooves **58** formed therein. It has been found that the grooves may be easily formed in the washer **54** by mounting the washer on a mandrel and rotating the washer in a position adjacent a sharp cutting tool thereby cutting the grooves in the washer rather than applying the grooves by means of a stamping process. It has been found that the grooves could best be applied by the use of a tap tool, the tap being positioned with the axis of the tool parallel to the face of the washer, for simultaneous cutting of plural grooves. The operating edge of the flute of the tap actually machines the grooves.

FIGS. 3*a* and 3*b* illustrate a cross-sectional view of washers which may be typically used in connection with connector assemblies incorporating features of the present invention. Particularly, FIG. 3*a* is a cross-sectional view of a washer having a grooved area on a single face such as that illustrated in FIG. **2**. FIG. 3*b* is a modified form of a washer **60** having the identical inner aperture **62** as was described in conjunction with FIGS. **2** and 3*a* and a plurality of grooves **64** on one face of the washer **60**. Additionally, the washer **60** is provided with a second set of concentric grooves **66** on the opposite face of the washer **60**. Thus, the washer **60** may be utilized in conjunction with two aluminum conductor strips, the washer being positioned between the two strips such as will be described in conjunction with FIG. **7**.

Referring now to FIG. **4**, there is illustrated a typical connector assembly utilizing the principles of the present invention. Particularly, the connector assembly is associated with a transformer tank **12** including the cup member **42** described in conjunction with FIG. **1**. A buss bar assembly is illustrated at **38** and includes an insulating tube and central conductor **70**. The buss strip **70** is inserted on the stud **46** after a nut **78** and a single faced washer **54** is inserted on the stud **46**.

Thereafter, a second single faced concentric washer **54** is applied with the grooves in the case of both washers facing the buss conductor **70**. Finally, a compression nut **80** and a locknut **82** are applied, the compression nut **80** compressing the assembly, including the washers **54** and conductor **70**, to cause the aluminum conductor **70** to cold-flow so that aluminum is forced into the grooves **58** to a certain extent. However, the grooves are not completely filled and a void is provided. The nut **82** is then applied to lock the assembly in the position shown.

Referring now to FIGS. **5** and **6**, there is illustrated a modified form of the conductor **70**, the modified form being fabricated as a laminated buss assembly **86**. The conductor **86** of FIG. **6** is fabricated as illustrated in FIG. **5**. Particularly, the conductor **86** is fabricated of aluminum strips which are placed in face abutting relation and tig welded, as at **88**, to insure that all the individual conductors are provided with a good electrically conductive path to the faces of the concentric grooved washer connectors. The weld **88** is made close to an aperture **90** to reduce the electrical path. The aperture **90** is utilized to permit insertion of the stud member **46**. The assembly of FIG. **6** is seen to be substantially identical to that described in conjunction with FIG. **4** with the exception of the type of conductor **86** being connected to the stud **46**. As was the case above, the connector assembly includes a nut **78**, a single face grooved washer **54**, a second single face grooved washer **54**, a compression nut **80** and a locknut **82**. The connector assembly is put together identically to that described in conjunction with FIG. **4**.

Referring now to FIG. **7**, there is illustrated a further modified form of conductor assembly **92**, this assembly being formed of a first and second laminated conductor assemblies **94,96**, each laminated conductor **94,96** being tig welded as was the case with conductor **86**. Again, the exterior assembly of the conductor assemblies **92** is identical to that described in conjunction with FIGS. **4** and **6** and includes a nut **78**, a pair of single face grooved washers **54**, a compression nut **80** and a locknut **82** to fasten the entire assembly on a stud **46**. However, a space is provided between conductor assemblies **94,96** into which is inserted a double face grooved washer **60** such as was described in conjunction with the description of FIG. **3***b*. The washer **60** includes the two grooved faces into which the aluminum of the conductors **94,96** are cold-flowed as a result of the turning of the compression nut **80**. The washer **60** is provided to increase the electrical contact between conductors **94,96**, and thus maintain good electrical conductivity between conductor assemblies **94** and **96**.

Accordingly, when any of the connections illustrated in FIGS. **4**, **6** or **7** are thermally cycled, the difference in expansion and contraction of the various materials used in the connector assembly, for example copper, brass and aluminum, will cause a differential expansion and an increase in the compressive force on the washer and conductor assembly. This will cause the aluminum to flow into the grooves or the voids created by the grooves and subsequent reduction in temperature will permit the aluminum to remain in contact with the grooved faces of the washer thereby maintaining the electrical contact. It is preferable to fabricate the washers such that the grooved washer faces will have quite sharp ridges to allow ready penetration into the aluminum strip surface. It has been found that the thermal cycling characteristics are improved with a sharper washer.

While it will be apparent that the preferred embodiments of the invention disclosed are well calculated to fulfill the objects above stated, it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope or fair meaning of the subjoined claims.

What is claimed is:

1. In a transformer assembly having an enclosure tank, a primary winding and a secondary winding in the tank, and a connector assembly for leading the ends of at least one of the windings to the exterior of the tank including a stud element and compression elements, the improvement comprising the ends of at least one of the windings being fabricated of a soft, cold-flowable material, and means for maintaining the electrical resistance of the connector assembly after the connector assembly has been thermally cycled including a washer having a plurality of concentric grooves formed on at least one fact thereof, said washer being positioned on the stud adjacent the said soft material between two compression elements with the said grooves being contiguous with the soft material, the compression elements being operated to force soft material at least partially into said grooves.

2. The improvement of claim **1** wherein said at least one of the windings is the secondary winding and said ends are fabricated of aluminum, said grooves being formed with sharp ridges and are continuous.

3. The improvement of claim **2** wherein the circuit to the exterior of the transformer tank includes said aluminum ends, said washer, said compression element and the stud.

4. In the transformer assembly of claim **2** further including cooling fluid contained within the tank, the improvement further comprising said connector assembly having at least a portion thereof within the tank and below the level of said cooling fluid and further including means for providing a fluid-tight seal with the tank.

5. The improvement of claim **3** wherein said ends are fabricated of a plurality of aluminum strips, said aluminum strips including an aperture formed adjacent one end thereof.

6. The improvement of claim **5** wherein said aluminum strips are positioned in face to face abutting relation and a weld is provided at the edges of said strips closely adjacent said aperture to maintain the electrical resistance characteristics of said welded strips.

7. The improvement of claim **6** wherein said connector assembly includes a second washer having a concentrically grooved face, said second washer being positioned adjacent said aluminum strips with said grooved face contiguous with said aluminum strips.

8 The improvement of claim **7** wherein said compression element operates to force soft material at least partially into the said grooves of said second washer.

9. The improvement of claim **8** wherein said weld is discontinuous across the edges of said aluminum strips, at least two of said strips being spaced at said discontinuity to provide a space between said strips.

10. The improvement of claim **9** wherein said connector assembly further includes a third washer positioned in said space between said strips, said third washer having concentrically grooved faces on opposite sides of said washer, said compression element op-

erating to force soft material at least partially into said grooves of said third washer.

11. The method of forming a transformer assembly comprising the steps of assembling a primary winding and a secondary winding in a tank, assembling a connector assembly including a stud associated with at least one of said windings, the ends of the at least one of the windings being fabricated of a soft, cold-flowable material, and maintaining the electrical resistance of the connector assembly after the assembly has been thermally cycled including assembling a washer with a plurality of concentric grooves on at least one face of said washer, positioning at least two compression elements and the said washer on the stud adjacent the soft material, said washer being between the two compression elements with said groove being positioned contiguous with said soft material, and operating at least one compression element to force said soft material at least partially into said grooves.

12. In the transformer assembly of claim 11 wherein at least one of the said windings is the secondary winding and said ends are fabricated of aluminum.

13. In the transformer assembly of claim 12 wherein the circuit to the exterior of the transformer tank includes said aluminum ends, said washer, said compression elements and the stud.

14. In the transformer assembly of claim 12 further including cooling fluid contained within the tank, the method further comprising said connector assembly having at least a portion thereof within the tank and below the level of said cooling fluid and further providing a fluid-tight seal with the tank.

15. The method of claim 13 further including fabricating said ends of a plurality of aluminum strips, and forming an aperture in said aluminum strips adjacent one end thereof.

16. The method of claim 15 further including positioning said strips in face to face abutting relation and welding the edges of said strips closely adjacent said aperture to maintain the electrical resistance characteristics of said welded strips.

17. The method of claim 16 further including providing a second washer having a concentrically grooved face, and positioning said second washer adjacent said aluminum strips with said grooved face contiguous with said aluminum strips.

18. The method of claim 17 further including operating said compression element to force soft material at least partially into the said grooves of said second washer.

19. The method of claim 18 further including providing a discontinuity across the edges of said aluminum strips, and spacing at least two of said strips at said discontinuity to provide a space therebetween.

20. The method of claim 19 further including providing a third washer in said space between said strips, said third washer having concentrically grooved faces on opposite sides of said washer and operating said compression element to force soft material at least partially into said grooves of said third washer.

21. The improvement of claim 11 wherein at least two of said washer, stud and compression elements are of differing coefficients of thermal expansion.

22. The method of claim 11 wherein said washer is formed by steps including mounting blank washer stock on a mandrel, mounting a cutting tool adjacent a face of the washer stock, rotating one of said stock and tool relative to the other, and advancing one of said stock and tool relative to the other.

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