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S. A. OAKLEY

2,677,172

METHOD OF MAKING SHEATHED ELECTRIC HEATING UNITS

Filed Oct. 16, 1948

FIG. 6

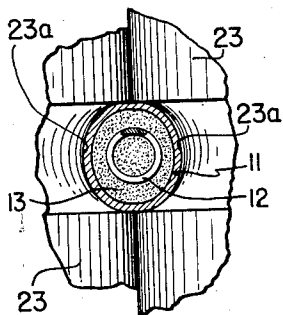


FIG. 5

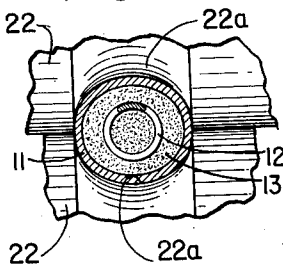


FIG. 4

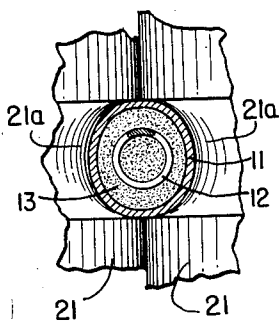


FIG. 3

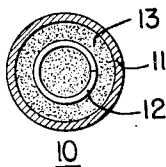


FIG. 2

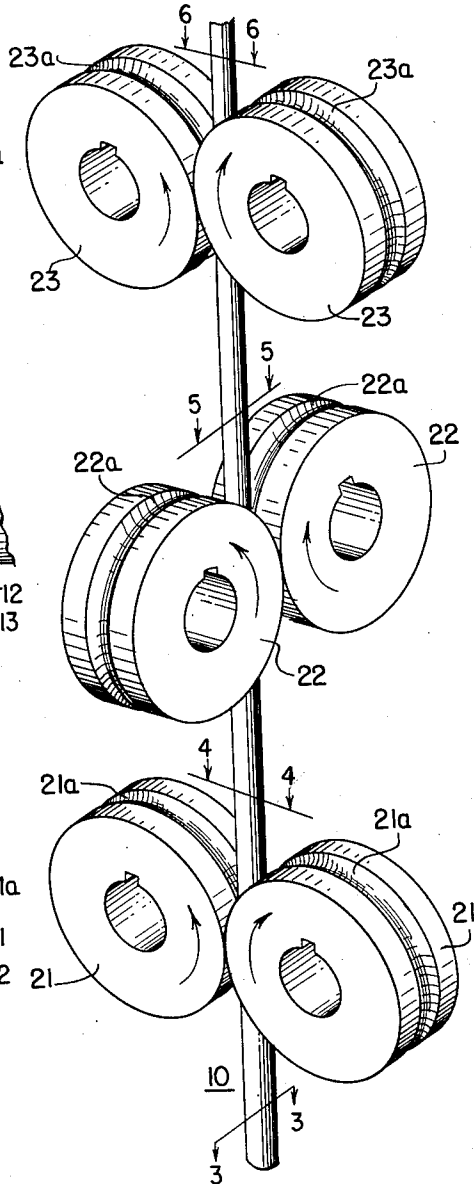
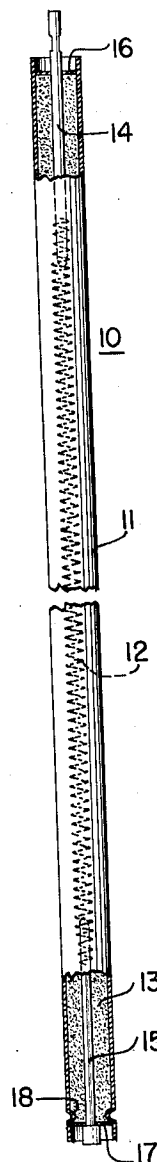


FIG. 1



INVENTOR.
Sterling A. Oakley

BY
Smith, Olsen & Baird
Attys

UNITED STATES PATENT OFFICE

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METHOD OF MAKING SHEATHED ELECTRIC HEATING UNITS

Sterling A. Oakley, Lincolnwood, Ill., assignor to
General Electric Company, a corporation of
New York

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9 Claims. (Cl. 29—155.5)

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The present invention relates to methods of making sheathed electric heating units and more particularly to improved cold rolling steps that are employed in such methods. This application comprises a continuation in part of the copending application of Sterling A. Oakley, Serial No. 483,699, filed April 19, 1943, now abandoned.

An electric heating unit of the sheathed type usually comprises an electric resistance conductor or element having a helical form, an enclosing tubular metal sheath, and a body of compressible heat-conducting and electrical-insulating material embedding the resistance conductor and holding it in a substantially central location within the sheath. Ordinarily, the opposite ends of the resistance conductor are welded or otherwise secured to electrical terminals that are also embedded in the insulating material and respectively project from the opposite ends of the sheath. Finally, the opposite ends of the sheath may be sealed by glass or other suitable plugs respectively surrounding the projecting terminals. One electric heating unit of this type is disclosed in U. S. Patent No. 1,367,341, granted on February 1, 1921 to C. C. Abbott. Ordinarily, the resistance conductor is formed of a suitable nickel-chromium alloy, the sheath is formed of a suitable nickel-chromium-iron alloy that is sufficiently plastic to permit cold working thereof, and the resistance material essentially comprises finely divided or granulated magnesia.

In methods heretofore employed in making an electric heating unit of the type noted the parts mentioned have been assembled and then the sheath has been worked so as to reduce the cross sectional area thereof in order firmly to compact the insulating material in the resulting space between the resistance conductor and the wall of the sheath. This working of the sheath has been performed by swaging or hammering and has always been performed while the assembly occupied a horizontal position, since commercially available swaging machinery is designed to operate in this manner.

Applicant in his endeavor to improve the performance and to extend the useful life of heating units of this type observed that one of the principal factors causing ultimate failure of these units was lack of symmetry of the resistance conductors with respect to the sheaths and concluded that this defect was resulting from sagging of the resistance conductors from their assembled substantially central positions during the working of the sheaths in accordance with the prior

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methods that were employed in the manufacture of the heating units.

Accordingly, it is a general object of the present invention to provide an improved method of making an electric heating unit of the type noted that insures that in the finished heating unit the resistance conductor occupies a substantially central location within the sheath.

Another object of the invention is to provide an improved method of making an electric heating unit of the type noted, wherein the elements of the heating unit are assembled in a substantially upright position and then the sheath is cold worked in a substantially upright position, without permitting the sheath to assume an appreciable horizontal position following assembly of the elements therein and until after working thereof, so as to prevent any substantial sagging of the resistance conductor from its substantially central location within the sheath.

A further object of the invention is to provide an improved method of rolling an electric heating unit assembly of the type noted, wherein the assembly is subjected to successive gradual cold rolling passes while it occupies a substantially upright position and wherein the rolling passes are sufficiently gradual to prevent any substantial lateral displacement of the resistance conductor from its substantially central location within the sheath as the sheath is elongated and as the insulating material therein is compacted.

Further features of the invention pertain to the particular arrangement of the steps of the method, whereby the above-outlined and additional operating features thereof are attained.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification taken in connection with the accompanying drawings, in which Figure 1 is a side elevational view, partly broken away, of a loaded sheathed heating unit assembly that is prepared for rolling in accordance with the method of the present invention; Fig. 2 is a reduced fragmentary perspective view of the heating unit assembly undergoing cold rolling in accordance with the present method, and illustrating schematically the first three rolling stages of a cold rolling machine that may be employed in carrying out the present method; Fig. 3 is an enlarged transverse sectional view, taken along the line 3—3 in Fig. 2, of the heating unit assembly preceding the first rolling stage of the rolling machine; Fig. 4 is an

enlarged transverse sectional view, taken along the line 4-4 in Fig. 2, of the heating unit assembly following the first rolling stage of the rolling machine, as well as a fragmentary plan view of the rolls incorporated in the first rolling stage; Fig. 5 is an enlarged transverse sectional view, taken along the line 5-5 in Fig. 2, of the heating unit assembly following the second rolling stage of the rolling machine, as well as a fragmentary plan view of the rolls incorporated in the second rolling stage; and Fig. 6 is an enlarged transverse sectional view, taken along the line 6-6 in Fig. 2, of the heating unit assembly following the third rolling stage of the rolling machine, as well as a fragmentary plan view of the rolls incorporated in the third rolling stage.

Referring now to the drawing, in Fig. 1 there is illustrated a sheathed electric heating unit assembly 10 that has been prepared for the rolling operations. This assembly 10 comprises an outer metallic tubular sheath 11 that may be formed of a suitable nickel-chromium-iron alloy and having a substantially circular cross-section, and an electrical resistance conductor or element 12 that may be formed of a suitable nickel-chromium alloy and located substantially centrally within the sheath 11 and embedded in a body of heat-conducting and electrical-insulating material 13. The insulating material 13 is in finely divided or granulated form and holds the resistance conductor 12 in its substantially central location. Preferably the insulating material 13 essentially comprises magnesia and has been charged into the sheath 11 and tamped in place. Preferably the opposite ends of the resistance conductor 12 are welded or otherwise suitably secured to two electrical terminals 14 and 15 that respectively project from the opposite ends of the sheath 11, the inner ends of the terminals 14 and 15 being also embedded in the insulating material 13. Finally, the opposite ends of the sheath 11 are closed by suitable washers 16 and 17 respectively surrounding the terminals 14 and 15 and retaining the insulating material 13 in place.

In producing the assembly 10 the loading machine disclosed in U. S. Patent No. 2,316,659, granted on April 13, 1943 to John L. Andrews, may be employed. More particularly, after the inner ends of the terminals 14 and 15 are secured to the opposite ends of the resistance conductor 12, the lower washer 17 is secured to the terminal 15 and these elements are threaded through the lower end of the sheath 11, the washer 17 engaging a locating bead 18 formed adjacent to the lower end of the sheath 11. At this time the terminal 14 is held in a substantially central location in the upper end of the sheath 11, and the body of insulating material 13 is charged into the sheath 11 while the sheath 11 and the elements mentioned occupy a substantially upright or vertical position. As the finely divided insulating material 13 is charged into the sheath 11 it embeds first the terminal 15, then the resistance conductor 12, and ultimately the terminal 14 restraining or holding these elements in their substantially central location within the sheath 11. During charging of the insulating material 13 into the sheath 11, the sheath 11 may be vibrated or jarred slightly in order to insure tamping or packing of the insulating material in the space between the terminals 14 and 15 and the resistance conductor 12 and the wall of the sheath 11 and between the convolutions of the resistance conductor 12 and into the core of the

resistance conductor 12 defined by the convolutions thereof. After the insulating material 13 has been charged into the sheath 11 and tamped in place filling the spaces mentioned, the upper washer 16 is secured in place within the upper end of the sheath 11 in order to prevent any possible escape of the insulating material 13 from the sheath 11. At this time the assembly 10 is removed from the loading machine to be subsequently finished in a cold rolling machine as described below. In removing the assembly 10 from the loading machine and in storing the assembly 10 prior to inserting it in the rolling machine as described below, the assembly 10 is retained in its substantially upright position in order positively to prevent sagging of the resistance conductor 12 prior to inserting the assembly 10 into the rolling machine.

At this time the assembly 10 is subjected to a plurality of successive gradual cold rolling passes, and in carrying out this operation the cold rolling machine disclosed in the previously mentioned Oakley application may be employed. As schematically illustrated in Fig. 2, this cold rolling machine comprises a plurality of successive gradual oval rolling stages arranged in substantially vertical alignment and alternately angularly disposed approximately ninety degrees. Specifically, this machine comprises a first rolling stage including the pair of individual forming rolls 21, a second rolling stage including the pair of individual forming rolls 22, a third rolling stage including the pair of individual forming rolls 23, and other successive and similar rolling stages, not shown. The first, second, third, etc., rolling stages are arranged in substantially vertical alignment, as previously noted, the first rolling stage being lowermost in the rolling machine and associated with guide structure, not shown, for the purpose of introducing the upper end of the assembly 10 between the rolls 21 thereof. The rolls 21 of the first rolling stage, the rolls 23 of the third rolling stage and the other rolls of the other odd rolling stages are arranged in a first substantially vertically disposed plane; while the rolls 22 of the second rolling stage, and the other rolls of the other even rolling stages are arranged in a second substantially vertically disposed plane; wherein the first and second planes mentioned are angularly displaced approximately ninety degrees with respect to each other. The rolls 21 in the first rolling stage have complementary substantially semi-elliptical forming grooves 21a arranged therein and cooperating to define a first pass having a generally elliptical cross-section; the rolls 22 in the second rolling stage have complementary substantially semi-elliptical forming grooves 22a arranged therein and cooperating to define a second pass having a generally elliptical cross-section; the rolls 23 in the third rolling stage have complementary substantially semi-elliptical forming grooves 23a arranged therein and cooperating to define a third pass having a generally elliptical cross-section. Thus the first, second, third, etc., passes are productive of ellipses of gradually reduced cross sectional areas and angularly rotated approximately ninety degrees with respect to each other. The final rolling stage, or stages, not shown, incorporating in the rolling machine may be productive of a substantially cylindrical pass, although any other desired configuration may be produced by providing appropriate complementary forming grooves in the cooperating rolls thereof.

In this rolling machine each rolling stage is

provided with an individual adjustable speed drive, not shown, whereby the second, third, etc., rolling stages may be operated at successively slightly increased speeds with respect to the speed of the first rolling stage in order to accommodate elongation of the assembly 10 as the cross sectional area thereof is successively reduced without buckling of the assembly 10 between the successive rolling stages. Also the individual rolls of each rolling stage are rotated in opposite directions and in such directions as to propel or feed the assembly 10 upwardly through the rolling machine after the upper end of the assembly 10 has been inserted between the rolls 21 of the first rolling stage.

Accordingly, in the operation of this rolling machine it will be understood that after the upper end of the assembly 10 is inserted by the guide structure, not shown, between the complementary forming grooves 21a formed in the rolls 21 of the first rolling stage that the assembly 10 is moved or fed upwardly through the rolling machine and ultimately discharged from the upper end thereof. The passes incorporated in the rolling machine are sufficiently gradual to prevent appreciable flowing of the insulating material 13 ahead of the individual rolling stages and the consequent longitudinal distortion of the convolutions of the resistance conductor 12. Moreover, the passes incorporated in the rolling machine are sufficiently gradual in order successively to reduce the cross sectional area of the assembly 10 without appreciable lateral distortion of the convolutions of the resistance conductor 12 or lateral displacement of the resistance conductor 12 from its substantially central location within the sheath 11. As clearly indicated in Figs. 4, 5, and 6, the orientation of the major axes of the successive elliptical cross-sections produced in the assembly 10 at the respective first, second and third rolling stages are alternately rotated by approximately ninety degrees, which arrangement is very advantageous in that the two rolling stages respectively disposed below and above a given rolling stage constitute vises for holding the respective upper and lower ends of the section of the assembly 10 that is being rolled in the given rolling stage. Moreover, this arrangement prevents the production of fins or ridges on the sheath 11 at the junctions between the cooperating forming grooves provided in the different pairs of rolls in the various rolling stages. Finally, in order positively to insure that the outer surface of the sheath 11 is not damaged incident to performing the rolling operations described the outer surface of the sheath 11 may be given a preliminary thin coating of oil, graphite or other suitable drawing compound.

During the operation of the machine the sheath 11 is elongated and the cross sectional area thereof is reduced so as to compact the insulating material 13 into a dense mass and firmly into engagement with the resistance conductor 12 and the terminals 14 and 15 and firmly in the resulting space between these elements and the wall of the sheath 11 and between the convolutions of the resistance conductor 12. After the assembly 10 has been discharged from the cold rolling machine it is annealed and may then be stored in a horizontal or any desired position until it is ultimately finished for use. In the finishing operations the opposite ends of the sheath 11 are stripped back in order to remove the washers 16 and 17. Thereafter the opposite ends of the compacted dense mass of insulating material 13 may

be cored in order to provide cavities respectively adjacent to the opposite ends of the sheath 11 and respectively surrounding the terminals 14 and 15. Then these cavities may be filled with glass plugs in order to seal the opposite ends of the sheath 11 and to support the terminals 14 and 15 in their substantially central locations projecting from the opposite ends of the sheath 11. Finally, the sheath 11 of the finished assembly 10 may be flattened and otherwise formed to provide the required configuration of the completed heating unit.

For example, in rolling one standard heating unit assembly 10 the sheath 11 is formed of "Inconel," an alloy comprising approximately 78% nickel, 13% chromium and 9% iron; and the cold rolling machine comprises eight rolling and forming stages. The sheath 11 is initially substantially cylindrical having an outside diameter of approximately 0.373". The first rolling stage is substantially elliptical, whereby the first oval in the sheath 11 has major and minor outside dimensions of approximately 0.379" and 0.355", respectively. The second rolling stage is substantially elliptical, whereby the second oval in the sheath 11 has major and minor outside dimensions of approximately 0.369" and 0.346", respectively. The third rolling stage is substantially elliptical, whereby the third oval in the sheath 11 has major and minor outside dimensions of approximately 0.359" and 0.337", respectively. The fourth rolling stage is substantially elliptical, whereby the fourth oval in the sheath 11 has major and minor outside dimensions of approximately 0.349" and 0.327", respectively. The fifth rolling stage is substantially elliptical, whereby the fifth oval in the sheath 11 has major and minor outside dimensions of approximately 0.339" and 0.318", respectively. The sixth rolling stage is substantially elliptical and identical to the fifth rolling stage and is provided primarily to take up any wear in the preceding rolling stages, whereby the sixth oval in the sheath 11 again has major and minor outside dimensions of approximately 0.339" and 0.318", respectively. The seventh and eighth rolling stages are substantially circular and identical and insure that the finished sheath 11 is smooth and round and of an outside diameter of approximately 0.333". Thus the outside diameter of the sheath 11 is reduced from 0.373" to 0.333" in the several cold rolling passes effecting a corresponding reduction in the cross sectional area thereof, this reduction in the initial cross sectional area of the sheath 11 being in excess of 21% in the present example. By employing the alloy mentioned in the sheath 11 and the gradual rolling passes described, not only are the previously mentioned characteristics attained in the finished heating unit, but it is pointed out that annealing between the successive cold rolling passes is not required in working the metal sheath 11.

The utilization of the cold rolling machine disclosed in the previously mentioned Oakley application for the purpose of carrying out the rolling steps described is very advantageous in view of the fact that the successive gradual oval passes are accomplished by a single feeding of the assembly 10 in an upright position therethrough; however, it will be understood that it is not imperative that this rolling machine be employed, as the assembly 10 may be passed successively in an upright position through a cold rolling machine provided with a single rolling stage, with

appropriate orientation of the assembly 10 between successive passes. In employing a single stage cold rolling machine the assembly 10 is rotated through an angle of approximately ninety degrees between successive passes and the co-operating rolls are successively changed in order to obtain both the required orientation of the oval rolling passes and the gradual reduction of the cross sectional area of the sheath 11.

However, in any case and regardless of the type of cold rolling machine or other apparatus that may be utilized for the purpose of cold working the sheath 11, the assembly 10 is always maintained in a substantially upright position following the charging of the insulating material 13 into the sheath 11 and the tamping of the insulating material 13 in place and until after completion of the cold working of the sheath 11 in order positively to prevent any substantial sagging of the resistance conductor 12 from its assembled substantially central location within the sheath 11.

In view of the foregoing it will be understood that in accordance with the present method the component elements of the assembly 10 are not only assembled while the sheath 11 occupies a substantially upright position, but the sheath 11 is cold worked in the substantially upright position, and the assembly 10 is never permitted to assume an appreciable horizontal position at any time following the production of the assembly 10 and until after the cold working of the sheath 11.

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be understood that various modifications may be made therein, and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. The method of making a sheathed electric heating unit including a tubular metal sheath, an electrical resistance conductor substantially centrally located within said sheath, and a body of compressible heat-conducting and electrical-insulating material embedding said resistance conductor and holding it in its substantially central location within said sheath, comprising the steps of inserting said resistance conductor into said sheath, charging said material in finely divided form into said sheath about said resistance conductor while said sheath is arranged in a substantially upright position and tamping said material in place between said sheath and said resistance conductor while said sheath is arranged in a substantially upright position in order substantially centrally to locate said resistance conductor within said sheath, and then cold working said sheath while said sheath is arranged in a substantially upright position so as substantially to reduce the cross sectional area of said sheath in order firmly to compact said material into a dense mass in engagement with said sheath and said resistance conductor without substantial displacement of said resistance conductor from its substantially central location within said sheath, wherein said charging and tamping steps and then said cold working step are carried out successively without permitting said sheath to depart appreciably from its substantially upright position following said charging and tamping steps and until after said cold working step so as to prevent any substantial interim sagging of said resistance conductor from

its substantially central location within said sheath.

2. The method of making a sheathed electric heating unit comprising the steps of inserting an electrical resistance conductor into a tubular metal sheath, charging a finely divided compressible heat-conducting and electrical-insulating material into said sheath about said resistance conductor while said sheath is arranged in a substantially upright position and tamping said material in place between said sheath and said resistance conductor while said sheath is arranged in a substantially upright position so as to locate said resistance conductor substantially centrally within said sheath and in spaced relation with the wall of said sheath, and then subjecting said sheath to a plurality of successive gradual cold rolling passes while said sheath is arranged in a substantially upright position so as substantially to reduce successively and gradually the cross sectional area of said sheath in order to compact said material into a dense mass in the resulting space between said resistance conductor and the wall of said sheath without appreciable lateral displacement of said resistance conductor from its substantially central location within said sheath, wherein said charging and tamping steps and then said cold rolling steps are carried out successively without permitting said sheath to depart appreciably from its substantially upright position following said charging and tamping steps and until after said cold rolling steps so as to prevent any substantial interim sagging of said resistance conductor from its substantially central location within said sheath.

3. The method of making a sheathed electric heating unit comprising the steps of inserting a helical electrical resistance conductor into a tubular metal sheath, charging a finely divided compressible heat-conducting and electrical-insulating material into said sheath about said resistance conductor while said sheath is arranged in a substantially upright position and tamping said material in place between said sheath and said resistance conductor while said sheath is arranged in a substantially upright position so as to locate said resistance conductor substantially centrally within said sheath and in spaced relation with the wall of said sheath and to preserve the spacing between the convolutions of said resistance conductor, and then subjecting said sheath to a plurality of successive gradual cold rolling passes while said sheath is arranged in a substantially upright position so as substantially to reduce successively and gradually the cross sectional area of said sheath in order to compact said material into a dense mass in the resulting space between said resistance conductor and the wall of said sheath and between the convolutions of said resistance conductor without appreciable lateral displacement of said resistance conductor from its substantially central location within said sheath and without appreciable distortion of the convolutions of said resistance conductor, wherein said charging and tamping steps and then said cold rolling steps are carried out successively without permitting said sheath to depart appreciably from its substantially upright position following said charging and tamping steps and until after said cold rolling steps so as to prevent any substantial interim sagging of said resistance conductor from its substantially central location within said sheath.

4. In the method of making a sheathed electric

9 heating unit including a tubular metal sheath, an electrical resistance conductor substantially centrally located within said sheath, and a body of finely divided compressible heat-conducting and electrical-insulating material embedding said resistance conductor and filling the space between said resistance conductor and the wall of said sheath; the steps comprising producing an assembly of said elements named, and then subjecting said sheath to a plurality of successive gradual cold rolling passes while said assembly is arranged in a substantially upright position so as to reduce successively and gradually the initial cross sectional area of said sheath by at least 10% in order to compact said material into a dense mass in the resulting space between said resistance conductor and the wall of said sheath without appreciable lateral displacement of said resistance conductor from its substantially central location within said sheath.

5. In the method of making a sheathed electric heating unit including a tubular metal sheath, a helical electrical resistance conductor substantially centrally located within said sheath, and a body of finely divided compressible heat-conducting and electrical-insulating material embedding said resistance conductor and filling the space between said resistance conductor and the wall of said sheath and the space between the convolutions of said resistance conductor; the steps comprising producing an assembly of said elements named, and then subjecting said sheath to a plurality of successive gradual cold rolling passes while said assembly is arranged in a substantially upright position so as to reduce successively and gradually the initial cross sectional area of said sheath by at least 10% in order to compact said material into a dense mass in the resulting space between said resistance conductor and the wall of said sheath and between the convolutions of said resistance conductor without appreciable lateral displacement of said resistance conductor from its substantially central location within said sheath and without appreciable distortion of the convolutions of said resistance conductor.

6. In the method of making a sheathed electric heating unit including a tubular metal sheath, an electrical resistance conductor substantially centrally located within said sheath, and a body of finely divided compressible heat-conducting and electrical-insulating material embedding said resistance conductor and filling the space between said resistance conductor and the wall of said sheath; the steps comprising producing an assembly of said elements named, and then cold rolling said sheath in successive gradual oval passes while said assembly is arranged in a substantially upright position so as to reduce successively and gradually the initial cross sectional area of said sheath by at least 10%, and changing the relative orientation of said sheath and said oval passes between successive ones of said oval passes in order alternately to rotate the major axis of the oval cross section of said sheath through a substantial angle between successive ones of said oval passes, thereby to compact said material into a dense mass in the resulting space between said resistance conductor and the wall of said sheath.

7. In the method of making a sheathed electric heating unit including a tubular metal sheath, a helical electrical resistance conductor substantially centrally located within said sheath, and a body of finely divided compressible heat-con-

ducting and electrical-insulating material embedding said resistance conductor and filling the space between said resistance conductor and the wall of said sheath and the space between the convolutions of said resistance conductor; the steps comprising producing an assembly of said elements named, and then cold rolling said sheath in successive gradual oval passes while said assembly is arranged in a substantially upright position so as to reduce successively and gradually the initial cross sectional area of said sheath by at least 10%, and changing the relative orientation of said sheath and said oval passes between successive ones of said oval passes in order alternately to rotate the major axis of the oval cross section of said sheath through an angle of approximately 90° between successive ones of said oval passes, thereby to compact said material into a dense mass in the resulting space between said resistance conductor and the wall of said sheath and between the convolutions of said resistance conductor.

8. In the method of making a sheathed electric heating unit including a tubular metal sheath, a helical electrical resistance conductor substantially centrally located within said sheath, and a body of finely divided compressible heat-conducting and electrical-insulating material embedding said resistance conductor and filling the space between said resistance conductor and the wall of said sheath and the space between the convolutions of said resistance conductor; the steps comprising producing an assembly of said elements named, and then moving said assembly upwardly while arranged in a substantially upright position and simultaneously subjecting said sheath to a plurality of successive gradual angularly rotated cold rolling passes so as to reduce successively and gradually the initial cross sectional area of said sheath by at least 10% in order to compact said material into a dense mass in the resulting space between said resistance conductor and the wall of said sheath and between the convolutions of said resistance conductor without appreciable lateral displacement of said resistance conductor from its substantially central location within said sheath and without appreciable flowing of said material ahead of said rolling passes and the consequent longitudinal distortion of the convolutions of said resistance conductor.

9. The method of making a sheathed electric heating unit including a tubular metal sheath, a helical electrical resistance conductor substantially centrally located within said sheath, and a body of compressible heat-conducting-electrical-insulating material embedding said resistance conductor and holding it in its substantially central location within said sheath, comprising the steps of producing an assembly of said resistance conductor within said sheath, placing said assembly in a substantially vertical position in a vertical material charging and tamping machine, operating said machine to charge said material in finely divided form into said sheath about said resistance conductor and to tamp said material in place between said sheath and said resistance conductor in order substantially centrally to locate said resistance conductor within said sheath, transferring said assembly in a substantially vertical position from said machine to a vertical plural stage cold rolling mill, and then operating said mill to move said assembly in the vertical direction and simultaneously to subject said sheath to a plurality of successive gradual

cold rolling passes so as to reduce successively and gradually the initial cross sectional area of said sheath by at least 10% in order to compact said material into a dense mass in the resulting space between said resistance conductor and the wall of said sheath without appreciable lateral displacement of said resistance conductor from its substantially central location within said sheath and without appreciable distortion of the convolutions of said resistance conductor.

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