

Oct. 14, 1947.

E. L. WIEGAND

2,428,899

ELECTRICAL HEATING ELEMENT

Filed Oct. 21, 1940

2 Sheets-Sheet 1

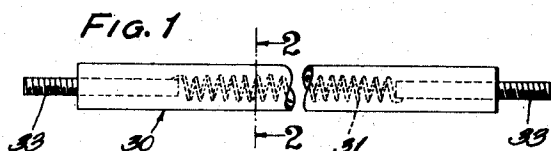


FIG. 2

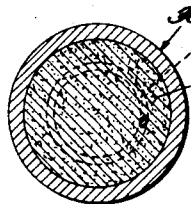


FIG. 5

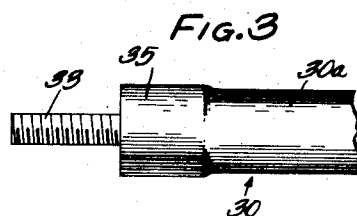
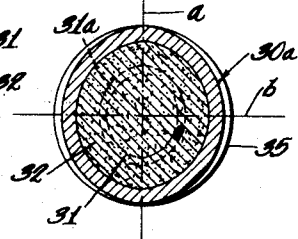


FIG. 4

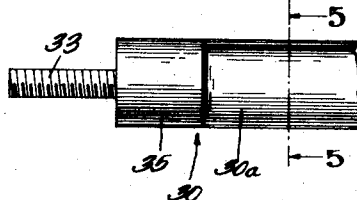


FIG. 6

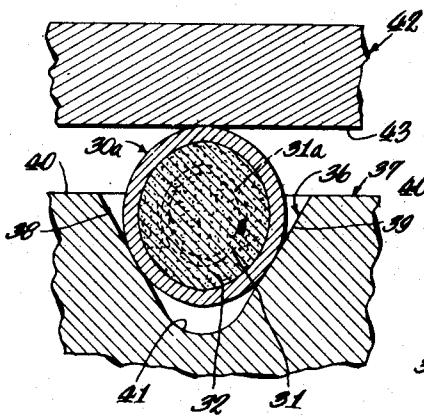


FIG. 7

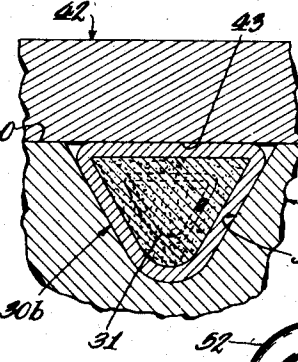


FIG. 8

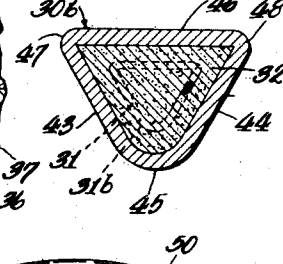


FIG. 9

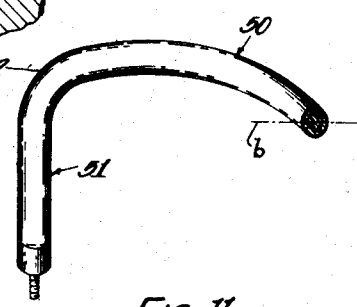


FIG. 10

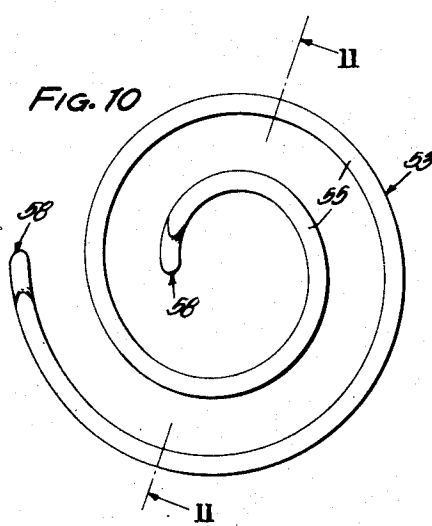
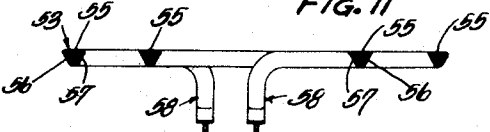


FIG. 11



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2 Sheets-Sheet 2

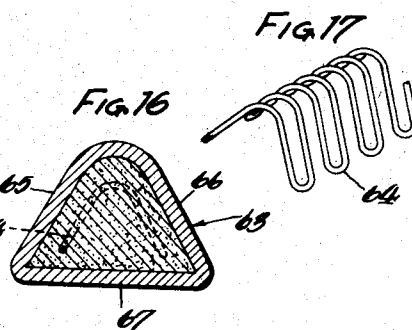
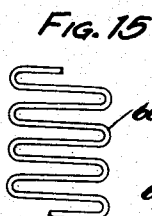
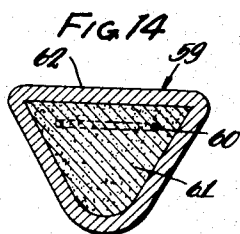
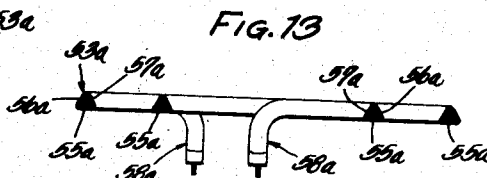
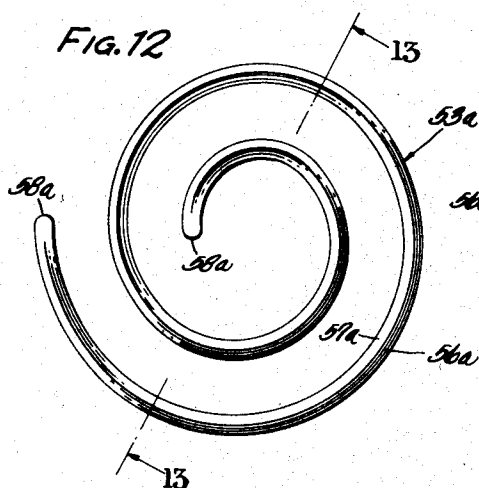
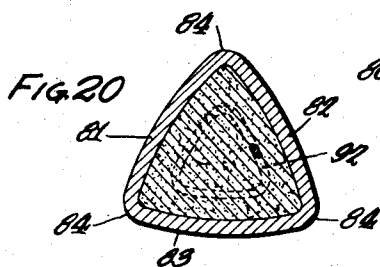
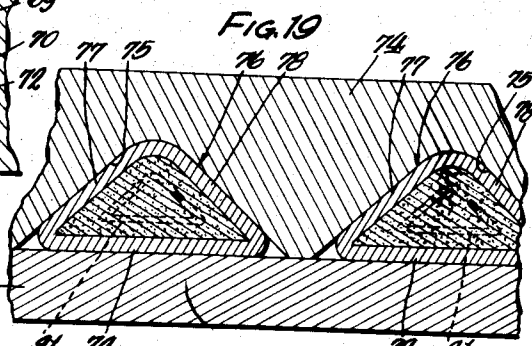
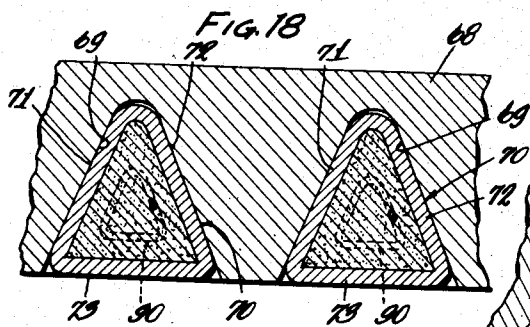
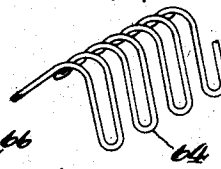


FIG. 17



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UNITED STATES PATENT OFFICE

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ELECTRICAL HEATING ELEMENT

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Edwin L. Wiegand Company, Pittsburgh, Pa.,
a corporation of Pennsylvania

Application October 21, 1940, Serial No. 361,997

10 Claims. (Cl. 201—67)

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My invention relates to electrical resistance heating units or elements of various types comprising a resistor disposed within and insulated from a metal sheath. The principal object of my invention is to provide new and improved electrical heating elements or units of these types, and to provide new and improved processes of making heating elements or units of these types. This application is a continuation in part of my application Serial Number 236,847, filed October 25, 1938.

In the drawings accompanying this specification, and forming a part of this application, I have shown, for purposes of illustration, several forms which my invention may assume, and in these drawings:

Figure 1 is a fragmentary side view of an electrical heating element in an intermediate stage of a process of making an element in accordance with my invention,

Figure 2 is an enlarged cross-sectional view taken on the line 2—2 of Figure 1,

Figure 3 is an enlarged fragmentary view of a side of an element in a later stage of a process of making an element in accordance with my invention,

Figure 4 is an enlarged fragmentary side view of an element in the stage shown in Figure 3, but looking in a direction at right angles to the direction in which the element is viewed in Figure 3,

Figure 5 is an enlarged cross-sectional view taken on the line 5—5 of Figure 4, looking in the direction of the arrows,

Figure 6 is a cross-sectional view showing dies ready to press-forg an element to its final cross-sectional form, the element in this instance having a cross-sectional form such as shown in Figure 5,

Figure 7 is a cross-sectional view showing the dies and element after the dies have been brought together,

Figure 8 is a cross-sectional view of an electrical heating element embodying my invention,

Figure 9 is a fragmentary perspective view of an electrical heating element in an intermediate stage of a process of making another embodiment of an element in accordance with my invention,

Figure 10 is a plan view of another element embodying my invention,

Figure 11 is a section taken on the line 11—11 of Figure 10,

Figure 12 is a plan view of another element embodying my invention,

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Figure 13 is a section taken along the line 13—13 of Figure 12,

Figure 14 is a cross-sectional view of another element embodying my invention,

Figure 15 is a fragmentary plan view of the resistor of the element shown in Figure 14,

Figure 16 is a cross-sectional view of another element embodying my invention,

Figure 17 is a fragmentary perspective view of the resistor of the element shown in Figure 16,

Figure 18 is a cross-sectional view of a hot plate showing associated therewith another element or elements embodying my invention,

Figure 19 is a cross-sectional view of a press platen or the like showing associated therewith another element or elements embodying my invention, and

Figure 20 is a cross-sectional view of another element embodying my invention.

The element shown in Figures 1 and 2 comprises a rectilinear tubular metal sheath 30 of circular cross-sectional outline, within which is disposed a resistor 31 of desired form, in this instance a helix of resistance wire. The resistor 31

is embedded in refractory electrical-insulating heat-conducting material and desirably uniformly spaced from the inside wall of the sheath 30. Projecting from the ends of the sheath 30 and extending into the insulating material 32 within

the sheath a desired distance are terminals 33, these being suitably connected to the ends of the resistor 31. One way in which a metal-sheathed insulated resistor such as shown in Figures 1 and 2 may be produced is to dispose a resistor in a

tubular metal sheath so that the resistor is spaced from the inside walls of the sheath, and then introduce refractory insulating material in a granular, or comminuted, or powdered state into the sheath, the insulating material being com-

pressed to any desired degree and in any desired manner. However, my invention is not limited to any particular way of producing such a metal-sheathed insulated resistor. The sheath may be made in any desired and suitable way and assembled with the resistor and insulating material in any desired and suitable manner and in any desired sequence, and the insulating material may be compacted in any desired and suitable manner.

While I prefer not to compact the insulating material 32 by swaging the sheath 30 to a smaller circular outline because this operation draws and elongates the sheath and has other objections, as will appear, my invention is also applicable in case a metal-sheathed resistor such as shown in Figures 1 and 2 has involved swaging and elonga-

tion of the sheath. I prefer to use any method of preliminarily compacting the insulating material which will not elongate the sheath. I then prefer next to side-press the sheath 30 so that its cross-sectional outline is generally elliptical or oval, or, in general, of oblong form. This step is particularly desirable if in its final form the element is to have a non-rectilinear longitudinal axis, but is also useful and desirable even if the element is to remain rectilinear, as will appear. The element shown in Figures 1 and 2 is placed between dies (not shown) having similar matrix portions which when brought together will produce the desired oblong cross-sectional outline. When the element is so side-pressed it may assume an oblong cross-sectional form 30a such as shown in Figure 5, the resistor also assuming a corresponding oblong cross-sectional aspect as shown at 31a. When the element is viewed from the side and in the plane of the major axis a of the cross-section 30a it appears as in Figure 3, and when viewed in the plane of the minor axis b of the cross-section 30a, it appears as in Figure 4. It will be understood that when the element is in the form shown in Figures 3, 4, and 5, the longitudinal axis thereof still is rectilinear, and as shown in these figures, the sheath is not side-pressed to an oblong cross-sectional outline throughout its entire length but an end portion 35 at each end may be left of circular cross-section. The portion 30a of oblong cross-sectional outline desirably overlaps a portion of that part of a terminal 33 which is disposed within the sheath 30. The side-pressing operation just described serves to compact the insulating material 32 to a sufficient degree, if it is not already so compacted, to maintain the resistor 31 in a central position within the sheath 30 when the element is subsequently bent to non-rectilinear form or when it is otherwise worked, or both.

I prefer that the oval or oblong cross-section 30a have a major axis approximately the same as, or at least not materially greater than, the diameter of the original circular section of the sheath. Dies which bring the sheath to such oval form will of course confine the sheath against free elongation in the direction of the major axis, the oval or oblong shape being secured instead by reduction of the diameter of the sheath in the direction of the minor axis.

Whether or not the element shown in Figures 3, 4, and 5 is bent to non-rectilinear form, that portion thereof which is of oblong cross-sectional outline 30a, or a desired longitudinal part thereof, is placed in the matrix 36 of a die 37 as shown in Figure 6. The matrix 36 is of generally V-shape cross-section having straight sides 38, 39 making between them an angle of 60°, the bisecting line of the angle being normal to the upper flat face 40 of the die. The apex of the triangle formed by the sides 38, 39 is here shown as rounded off by a fillet 41. The element preferably is so placed in the matrix 36 that the major axis of the oblong cross-sectional outline 30a coincides approximately with the line bisecting the angle between the lines 38, 39. Another die 42 having a flat operating face 43 is then brought down against the element until the dies 37, 42 contact as in Figure 7, thereby press-forging the element so that its cross-sectional outline 30b is generally triangular. Thus, the sheath now has two walls 43, 44, (Figure 8), the major portions of which are flat and make between them an angle of 60°, these walls merging in a rounded apex 45 formed by the fillet 41 of the matrix 36. The third wall 46 is

substantially entirely flat and makes with the walls 43, 44 angles of 60° respectively. Thus in this particular element the flat portions of the walls 43, 44 are respectively of less cross-sectional extent than the substantially entirely flat wall 46. This is of advantage under some circumstances of use and is the reason the fillet 45 is provided. The radius of the fillet may be as desired, or the matrix may be V-shaped with no fillet at the apex.

The cross-sectional perimeter of the cavity formed by the matrix portion 36 of the die 37 and the face 43 of the die 42 when the faces 40 and 43 of these dies are in contact as in Figure 7, is preferably such that the perimeter of the generally triangular cross-sectional outline 30b of the element is less than the cross-sectional perimeter of the original circular section sheath 30. However, even if the perimeter of the final cross-section shown in Figure 8 is substantially the same as the perimeter of the original sheath, the press-forging of the element to a generally triangular cross-sectional outline results in a very large reduction in cross-sectional area and hence in compaction of the insulating material 32 to very great density. The corners 47, 48 of the cross-section are slightly rounded, the amount of this rounding depending on the relation between the original section of the element and the cavity between the matrix 36 of the die 37 and the face 43 of the die 42.

By pressing the element to generally triangular cross-sectional outline the resistor 31 is reformed so that its cross-sectional aspect 31b is generally triangular as shown in Figure 8, the outline of the resistor being substantially similar to and substantially uniformly spaced from the outline of the inner wall of the sheath, and more nearly so if, as in this instance, the sides of the sheath define a triangle the adjacent sides of which are at 60° to each other. In general, however, in an element triangularly pressed, even if the angles are not all 60°, there is a minimum of undesirable flowing or displacement of the insulating material so that there is a minimum of displacement of the resistor from a symmetrical and uniform position with respect to the walls of the sheath. In the finally pressed element, as shown in Figure 8, the resistor is uniformly spaced from the flat walls 43, 44, 46 but is closer to these walls than it is to the inner wall of the sheath when the sheath is of either the original circular or oblong cross-sectional outlines as in Figures 2 and 5 respectively.

The pressures which I prefer to use to press the element to triangular cross-sectional outline are so high that the element is to be regarded as not merely deformed or pressed to generally triangular cross-section but as press-forged. I prefer to use pressures of 25 tons per square inch or more. For example, I use a press capable of exerting a pressure such that when the die 42 reaches the end of its stroke the pressure on the surface of the wall 46 of the element is approximately 40 tons per square inch, or more. These pressures are so high that the material is "upset." This is evidenced, for example, by the fact that the resistor 31 is upset and shortened, that is, in effect forged. For instance in the case of a resistor in an initially circular section tubular sheath about $\frac{1}{8}$ of an inch to $\frac{1}{4}$ of an inch in outside diameter and having a wall thickness of .030 of an inch, the resistor is upset and shortened to such an extent that its electrical resistance is decreased approximately 8 to 10%, when the element has been subjected to approximately 40 tons per

square inch as hereinbefore described. The amount of upsetting and decrease will of course depend upon the pressure used and I give the foregoing as an illustration that a press-forging action does take place, and not by way of limitation to particular dimensions or other values.

For any given density or compaction of the insulating material, a triangular section element will contain less insulating material, and hence the sheath will become heated more quickly. Also, for a given initial amount of insulating material, the insulating material in an element embodying my invention is compacted to a super-density, thereby further improving its heat conducting properties. In general, a triangular section element provides the optimum combination of rigidity and strength with a greater ratio of sheath area to element volume and weight. Or stated in another way, it provides a greater ratio of perimeter to sectional area and what is more important, a much larger percentage of perimeter and sheath area may be brought into contact with an object to be heated, and the path of conduction from the opposite extreme point on the sheath is considerably reduced from what it is in, for example, a round section merely pressed somewhat flat on one or both sides. For any one or more of these reasons, heat is more quickly conducted from the resistor to the sheath.

Furthermore, I have made comparative tests on tubular heating elements of circular section and tubular heating elements of triangular section made in accordance with my invention from tubular sheath the same size as the circular section elements and have found that the watts input per square inch of external active surface of the heating element required to fuse the resistor is approximately 15 to 25% higher in the case of the triangular section elements than it is in the case of the circular section elements. Referring to an element of the size hereinbefore mentioned, the resistor fusing point is raised to about 225 watts per square inch of active resistor area. This is because the temperature gradient from the very center of the element section to the outer surface of the sheath is considerably reduced over other constructions. Obviously this feature permits material increase in the maximum normal operating capacity or temperature or both. By way of example, an element of the size hereinbefore mentioned may be normally operated at about 50 to 60 watts per square inch of active surface, in open air at room temperature. By active surface of the sheath I mean the surface of the sheath surrounding and longitudinally co-

extensive with the resistor. I prefer first to side-press the element to an oval or oblong cross-section before placing it in the die 37, even if the longitudinal axis of the finished element is to be rectilinear, but I may also place an element of circular section in the die 37 and press-forg it to triangular cross-section.

An element in accordance with my invention may be made of non-rectilinear form in which case I prefer first to provide an element of rectilinear form as shown in Figures 1 and 2, then to side-press it to an oblong cross-sectional outline as shown in Figures 3, 4, and 5 and then to bend an active portion 50 thereof as shown in Figure 9. In bending the active portion 50 I prefer to bend it in the plane defined by the minor axis b of the oblong section. If desired an end portion 51, or both end portions, of the element may be bent out of the plane defined by the bent active

portion 50, this end portion 51 being joined to the active portion 50 by a bent portion 52 bent in the plane of the major axis of the oblong section, or the terminal zone between the active portion and the extremity of the element may be further pressed round before bending or to any other desirable shape for optimum bending conditions and to secure maximum compactness at this zone. The active portion 50 may be bent in the form of a spiral, or in any other desired form. In any case the bent active portion 50 is placed in a die having a triangular matrix portion, similar to the matrix portion 36, this matrix portion of course having a longitudinal axis corresponding to the longitudinal axis of the bent active portion 50. The active portion 50 is then press-forged to triangular section as hereinbefore described.

An element in accordance with my invention is extremely rigid, though it be long, or have a non-rectilinear longitudinal axis, or both.

Figures 10 and 11 show an element embodying my invention, which has an active portion 53 of spiral form and of triangular cross-section, having wall portions 55, 56, 57, the wall portion 55 defining a plane corresponding to the general plane of the spiral. The element has end portions 58, similar to the end portion 51 of Figure 9, which extend transversely of the plane of the spiral and, in this instance, are disposed at that side of the element opposite from the plane of the wall 55.

Figures 12 and 13 show an element embodying my invention, which is similar to the element shown in Figures 10 and 11 except that the element of Figures 12 and 13 has end portions 58a which, while they extend transversely of the general plane of the spiral active portion 53a of the element, are disposed at the same side of the element as the plane defined by the wall 55a corresponding to the wall 55 of the element of Figures 10 and 11.

One use for heating elements such as shown in Figures 10 through 13 is in electric ranges but their use is not limited to that purpose.

It will be noted that if an object to be heated and having a generally plane surface is placed against the wall 55 of the element shown in Figures 10 and 11, there will be a comparatively large area of contact between the object and the element so that under these conditions the object is heated largely by conduction. On the other hand, if such an object is placed against the upper defining surface, as viewed in Figure 13, of the element shown in Figures 12 and 13, the object will be in contact with the apexes of the triangular sections and will be heated mainly by radiation from the walls 56a and 57a of the element. It will be noted that due to the triangular section of the element the bulk of the radiation from the element is directed upwardly. The bulk of the radiation from the walls 56a, 57a is directed diagonally upwardly in respectively opposite directions considering any given portion of the element. By reason of the diagonally upward direction of the radiation, the opposed surfaces 56a and 57a of adjacent portions of the spiral do not inter-radiate to any great extent, and inter-radiate much less than if the walls 56a, 57a were not beveled or inclined with respect to the general plane of the element. In general, the amount of downward radiation from the wall 55a is much less than the upward radiation from the walls 56a, 57a. By decreasing the width of the wall

55a with respect to the walls 56a, 57a the downward radiation may be made still less if desired.

It will of course be apparent that what has been hereinbefore stated with respect to reduced inter-radiation between adjacent portions of a spirally formed element applies also to adjacent portions of separate elements and whether the longitudinal axes of the elements are spiral, rectilinear, or of any other form.

The resistor may be constructed and arranged so that it is non-symmetrical with respect to the cross-section of the heating element in any desired cross-sectional form, either in connection with the forms herein illustrated or in connection with any desired form. Figure 14 is an example of such a construction, and shows a cross-section of an element having a metal sheath 59 similar to the sheath shown in Figure 8, a resistor 60 being embedded in insulating material 61 within the sheath. In this instance the resistor 60 is of sinusously formed wire as shown in the plan view of Figure 15 and defines a surface collateral with the inside surface of the wall 62 of the sheath as shown in Figure 14, the wall 62 corresponding in this instance to the wall 46 of the element of Figure 8. This construction may be utilized if it is desired that the wall 62 be directly heated more than the other walls.

A further example is shown in Figure 16. A heating element is here shown in cross-section, this element comprising a sheath 63 similar to that of the element shown in Figure 8, but including a resistor 64 so constructed and arranged that its principal heating effect will be on the sides 65, 66 of the sheath, less heat being supplied toward or to the side 67. A fragmentary portion of the resistor 64 is shown in perspective in Figure 17. The resistor 64 is here shown as in the form of a wire bent back and forth in zig-zag or serpentine manner, the so-bent wire being further bent as a whole so that it defines a dihedral angle, the defining sides of which are adapted to be disposed adjacent the inside walls of the sides 65, 66 of the sheath, with the apex of the dihedral angle adjacent the inter-section of the sides 65, 66. It will be understood that the resistor 64 initially may be of a form different from that shown in Figures 16 and 17 and may assume the form there shown by reason of the side-pressing of the heating element. On the other hand, as far as the feature of unsymmetrical heating is concerned the sheath initially may have the general cross-sectional shape of the finished heating element in which case the resistor 64 ordinarily will be formed initially to be complementary to the desired surface of the inside of the sheath. Accordingly, it will be understood that the use of an unsymmetrical resistor is not limited to the forms of elements herein shown, nor to the processes of making them herein disclosed.

The construction shown in Figure 14 may if desired be embodied in an element such as shown in Figures 10 and 11 the wall 62 then corresponding to the wall 55. The construction shown in Figure 16 may, if desired, be embodied in an element such as shown in Figures 12 and 13 the walls 65 and 66 then corresponding to the walls 56a and 57a.

In Figure 18 is shown a hot plate, which may be used for cooking purposes or the like, this comprising a metal plate 68 having triangular grooves 69 in which are disposed the active sheath portions 70 of a triangular section heating element or elements, it being understood that the

grooves 69 are of any desired axial configuration to accommodate the element or elements. The cross-section of the active portions 70 is substantially complementary to the cross-section of the grooves 69. Press-forging of the element results in the resistor 90 of the element assuming triangular form substantially similar to the sheath 70. A triangular section heating element is exceedingly well adapted for cooperation with a hot plate or the like because of the ease with which triangular grooves, complementary to the heating element, may be formed in the plate 68.

In the particular instance shown in Figure 18 the sheath 70 is of isosceles section having walls 71, 72, 73, the walls 71, 72 making an angle of less than 60° so that of course the angles between these walls respectively and the other wall 73 are each greater than 60°. This construction is of advantage when it is desired that a larger part of the perimeter of the section shall be in contact with a device to be heated.

Figure 19 shows a press platen comprising a metal plate 74 having triangular section grooves 75 in which are disposed the active sheath portions 76 of a triangular section heating element or elements, similarly to the case of the hot plate of Figure 18. An active portion 76 comprises walls 77, 78, 79, the walls 77, 78 being here shown as making an angle greater than 90°, and fitting complementarily in the groove 75, the walls 77, 78 of course making angles of less than 60° respectively with the wall 79. The resistor 81 of the element of course also has a cross-section substantially similar to the sheath 76. The platen includes a metal plate 80 which bears against the wall 79.

Figure 20 shows a section of a heating element having a sheath the walls 81, 82, 83 of which define an equilateral triangle, the apexes 84 of which are slightly rounded. Under some circumstances it may be desirable, irrespective of the form of the triangle, to have the walls 81, 82, 83 of the sheath slightly cambered as shown in Figure 20, that is, the walls bulge outwardly slightly with respect to the interior of the sheath. In this case the resistor 92 of the element will assume the form of an equilateral triangle the sides of which are cambered. It will be understood that if the element has cambered walls they are so formed by reason of the shape of the dies between which the element is press-forged.

It will be evident from the foregoing that the shape of the triangular section may be varied and that for one purpose a given shape will be best adapted and that for another purpose another shape will be best adapted. Furthermore, the shape of the triangular section may result in different typical cross-sectional aspects of the resistor one of which may be better for one purpose and another of which may be better for another purpose. For example, if it is desired that the resistor shall be most nearly centrally located and uniformly spaced from the walls of the sheath, an equilateral triangular form, or a triangular form in which the defining lines define a triangle all of the angles of which are 60°, are the best forms. These forms also result in the greatest uniformity of density of insulating material. However, in general, the triangular form is superior to other forms because, among other reasons, there is a minimum of displacement of the resistor and of the insulating material; more uniform density of the insulating material; and circumferential tensile stresses in any portion of the sheath which result from other methods of

side-pressing, are minimized or entirely eliminated.

Side-pressing in accordance with my invention, has the advantage that the tubular sheath may be cut to specified length, assembled with resistor, insulating material, and terminals, and then processed as hereinbefore set forth, the predetermined length of the element being unaltered. Furthermore, the elimination of tensile stresses in the sheath avoids any tendency to burst open a tubular sheath, particularly at a welded seam. A seam may be present in a tubular sheath for a heating element designed to operate at very high temperature since it has not been found feasible to manufacture seamless tubing from high temperature alloys such as nickel-chrome. Tubing made from such alloys is rolled from ribbon to tubular form and seam-welded, which of course tends to affect the strength of the metal adjacent the weld.

An element such as shown in Figures 1 and 2, or an element such as shown in Figures 3, 4, and 5 may have discontinuities or voids in the insulating material, or such discontinuities and voids may be produced by bending an element of either of these forms to a non-rectilinear form. These discontinuities and voids are in themselves objectionable, and furthermore, gases in these discontinuities or voids are apt to be ionized, thereby further reducing the insulating value of the insulation, this being particularly true where the elements are designed so that the energy input is such that the units operate at a desired external temperature of from 1200° or 1400° F. to 1600° F. or higher, temperatures at which these elements are capable of operation. Accompanying the reduction in insulating value of the insulation is also a reduction in the life of the elements. This will be true even if the sheath is made of nickel, or a metal alloy, for example, nickel chrome, or "inconel," capable of withstanding such temperatures, and it is of course understood that a sheath made of a material capable of operation at such temperatures may be used. However, the shaping and press-forging of the elements as described, redistributes, recompacts and further densifies the insulating material so as to close up any discontinuities or voids which may be present therein either due to the bending of the elements, or due to any other cause. Thus, the side press-forging of the elements to a more efficient cross-section at the same time increases the life of the elements.

It will be evident that the sheath may be of other desired and suitable initial and intermediate forms before it is brought to triangular cross-section; that the sheath may be of any desired suitable metal or alloy; that the resistor may be of any desired suitable composition, and of any desired suitable form; that the refractory insulating material may be, or may include, for example, silica, or silicates, or magnesium oxide, or aluminum oxide, or any refractory oxide or combination of refractory oxides, or any other suitable refractory material, desirably of a mineral character; that such refractory material may be mixed, if desired, with a bonding or cementing material, or mixed with a clay, or with any other suitable binder; and that the initial form or state of the insulating material, in which it is introduced into or assembled with the sheath, may be varied, and, if necessary, varied to suit the form of the sheath and the method of making it, and to suit any desired method of introducing the

insulating material into the sheath or of assembling it with the sheath.

From the foregoing it will be apparent to those skilled in the art that the disclosed embodiments of my invention provide new and improved electrical heating elements, and new and improved processes for making the same, and accordingly, each accomplishes the principal object of my invention. On the other hand, it also will be obvious to those skilled in the art that the disclosed embodiments of my invention may be variously changed and modified, or features thereof, singly or collectively, embodied in other combinations than those disclosed, without departing from the spirit of my invention, or sacrificing all of the advantages thereof, and that accordingly, the disclosure herein is illustrative only, and my invention is not limited thereto.

I claim:

1. An electrical heating element, comprising: a metal sheath, having a generally triangular cross-sectional outline; resistor means disposed within and insulated from said sheath, said resistor means being substantially continuously distributed approximately in a plane longitudinally of one side only of said sheath.

2. An electrical heating element, comprising: a metal sheath, having a generally triangular cross-sectional outline; and a resistor disposed within and insulated from said sheath, said resistor being so constructed and arranged that it is generally V-shaped in cross-sectional aspect and is so disposed within said sheath that said V-shape is generally complementary to one of the angles defined by the triangular cross-sectional outline of said sheath.

3. An electrical heating element, comprising: a metallic sheath; resistor means within and insulated from said sheath, said resistor means being substantially continuously distributed longitudinally of a portion of said sheath, said resistor means defining a surface unsymmetrical with respect to the cross-sectional outline of the inside surface of said sheath so that the sheath portion nearest said resistor means is directly heated to a substantially greater extent than the remainder of said sheath, said surface defined by said resistor means being circumferentially discontinuous in cross-sectional aspect, extending circumferentially along a part only of the cross-sectional outline of said inside surface.

4. An electrical heating element, comprising: a metallic sheath; resistor means within and insulated from said sheath, said resistor means being substantially continuously distributed longitudinally of a portion of said sheath, said resistor means defining a surface unsymmetrical with respect to the cross-sectional outline of the inside surface of said sheath so that the sheath portion nearest said resistor means is directly heated to a substantially greater extent than the remainder of said sheath, said surface defined by said resistor means being approximately uniformly spaced from said inside surface longitudinally and circumferentially and extending circumferentially along a part only of the cross-sectional outline of said inside surface.

5. An electrical heating element, comprising: a metallic sheath having wall portions defining a closed generally triangular cross-sectional outline; compacted refractory heat-conducting electrical-insulating material disposed within said sheath and in heat-transfer contact with the inside surface of said sheath at said wall portions, the cross-sectional outline of said in-

side surface and the cross-sectional outline of said insulating material conforming to each other; and resistor means embedded in said compacted insulating material and insulated from said sheath by said insulating material, said resistor means being so distributed as to define a surface similar to and extending collaterally with respect to the inside surface of only one of said wall portions.

6. A tubular, sheathed, embedded-resistor electric heating element, having an active section comprising a tubular sheath formed to a generally triangular cross-sectional outline, a helical resistor extending approximately axially of said sheath and formed approximately to a corresponding cross-sectional outline, and laterally compacted granular refractory material within said sheath, of correspondingly uniform thickness between said resistor and said sheath, embedding said resistor and serving to insulate said resistor and to conduct the heat from said resistor to said sheath, at least a portion of said active section being bent so that the longitudinal axis is non-rectilinear.

7. A tubular, sheathed, embedded-resistor electric heating element, having an active section comprising a tubular sheath formed to a generally triangular cross-sectional outline, a helical resistor extending approximately axially of said sheath and formed approximately to a corresponding cross-sectional outline, and laterally compacted granular refractory material within said sheath, of correspondingly uniform thickness between said resistor and said sheath, embedding said resistor and serving to insulate said resistor and to conduct the heat from said resistor to said sheath, at least a portion of said active section being bent so that the longitudinal axis is non-rectilinear and one side of the generally triangular cross-sectional outline is disposed approximately in a plane.

8. A tubular, sheathed, embedded-resistor electric heating element, having an active section comprising a tubular sheath formed to a generally triangular cross-sectional outline, a helical resistor extending approximately axially of said sheath and formed approximately to a corresponding cross-sectional outline, and laterally compacted granular refractory material within said sheath, of correspondingly uniform thickness between said resistor and said sheath, embedding said resistor and serving to insulate said resistor and to conduct the heat from said resistor to said sheath, at least a portion of said

active section being bent so that the longitudinal axis is non-rectilinear and one side of the generally triangular cross-sectional outline is disposed approximately in a plane, and the terminal ends of said element being bent out of said plane.

9. An electrical heating element, comprising: a metallic sheath having wall portions defining a closed generally triangular cross-sectional outline; compacted refractory heat-conducting electrical-insulating material disposed within said sheath and in heat-transfer contact with the inside surface of said sheath at said wall portions, the cross-sectional outline of said inside surface and the cross-sectional outline of said insulating material conforming to each other; and resistor means embedded in said compacted insulating material and insulated from said sheath by said insulating material, said resistor means being so distributed as to define approximately a V similar to and extending collaterally with respect to the inside surface of two of said wall portions.

10. An electrical heating element, comprising: a metal sheath, having a generally triangular cross-sectional outline; resistor means disposed within and insulated from said sheath, said resistor means being substantially continuously distributed approximately in a V longitudinally of two sides of said sheath.

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