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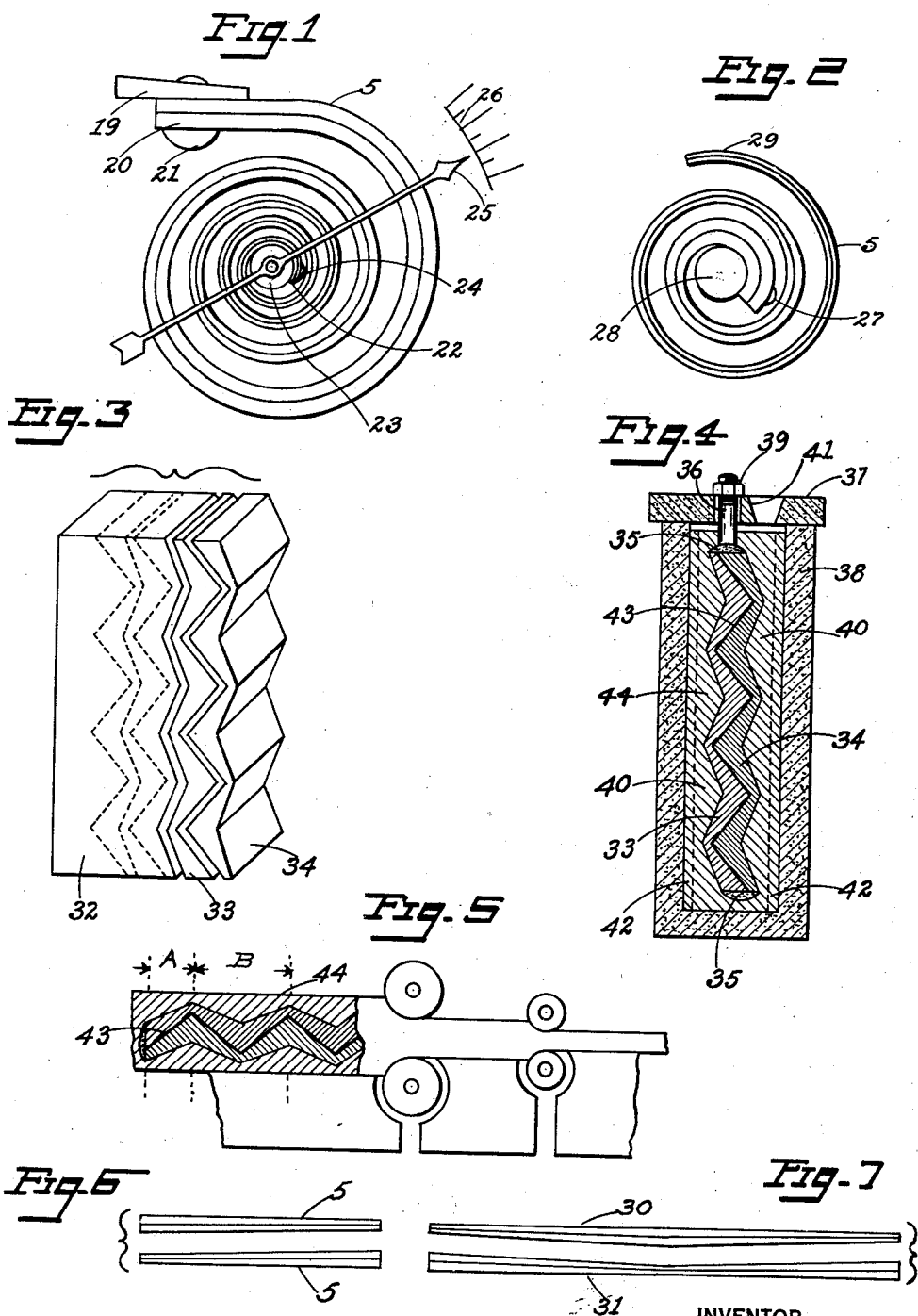
N. L. DERBY

2,144,915

TAPERED THERMOSTATIC ELEMENT

Filed March 10, 1937

2 Sheets-Sheet 1



INVENTOR
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Jan. 24, 1939.

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TAPERED THERMOSTATIC ELEMENT

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2 Sheets-Sheet 2

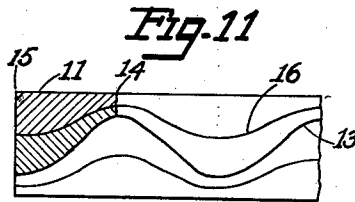
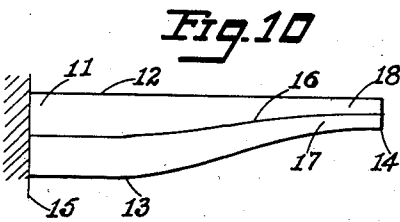
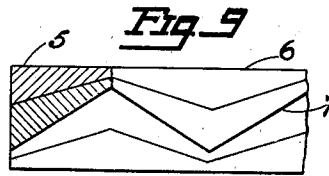
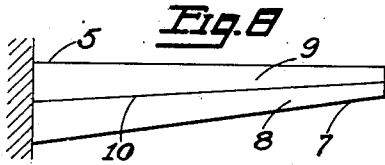


Fig. 12

Fig. 13

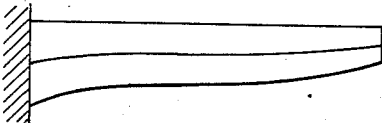


Fig. 14

Fig. 15

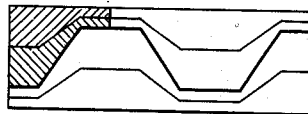


Fig. 16

Fig. 17

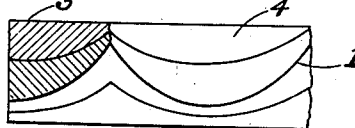
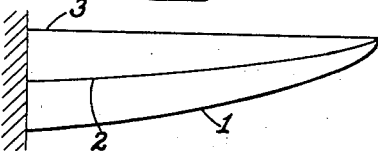


Fig. 18

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UNITED STATES PATENT OFFICE

2,144,915

TAPERED THERMOSTATIC ELEMENT

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Application March 10, 1937, Serial No. 130,046

11 Claims. (Cl. 297—16)

This invention relates to improvements in thermostatic elements and principally to a device of this type consisting of a bimetallic strip tapering in thickness to improve the characteristics of the element.

When a bimetallic thermal strip of constant width and thickness is spirally coiled it is noticed that the turns closest to the center of the coil are very rigid or stiff and are difficult to form. However, as the diameter of the turns become greater and greater they are progressively easier to form and have progressively less stiffness.

It is apparent that the stiffness or rigidity is some function of the curvature of the turns of the coil. The less the curvature the less the stiffness of a turn. From this it may also be stated that the smaller the overall diameter of the spiral coil the greater the stiffness.

By stiffness as herein used is meant the ability to resist mechanical distorting forces such as a force tending to crowd the various turns of the coil together at certain sections, or forces tending to cause the coil to vibrate or quiver.

Usually, in a dial type thermometer a spirally coiled bimetallic thermal element is rigidly fixed to a supporting member at the outer end while the inner end is attached to the pointer axle and is free to move the pointer through an angle in response to a change in temperature.

The most desirable features in a spirally coiled bimetallic thermal element for use in a dial type thermometer are: (a) Stiffness to resist forces tending to cause vibrations and crowding of the turns in certain sections. (b) A very high rate of response or great sensitivity to temperature changes. (c) The ability to move the pointer over equal increments of the dial for equal changes in temperature (this will hereinafter be referred to as accuracy). (d) Economy in the cost of production. (e) Compactness to fit available space in modern instruments.

In the above particular use strength of the element is not of great importance because the load carried is light.

Heretofore these spirally coiled bimetallic thermal elements for devices such as dial type thermometers have been very delicate and exceedingly sensitive to vibrating and distorting forces in general.

As the rate of response to temperature changes of similar thermal elements is inversely proportional to the thickness and independent of the width within certain limits, the tendency has been to make the element quite thin and to increase the stiffness by increasing the width.

Unfortunately, increasing the width of a thin element, especially a coiled bimetallic element, tends to cause bending of the strip at right angles to the usual direction of bending in response to temperature changes. This crosswise bending interferes with the normal deflection of the free end and the pointer will not give accurate readings of temperature.

Another alternative is to use a narrow element of constant width and thickness and then increase the thickness to increase the stiffness. It is found, however, that when the outer turns of the coil are made sufficiently thick to give the required stiffness, the inner turns have considerably greater stiffness than necessary, with the general conclusion that expensive excess metal is used in the inner turns. More important, however, than the waste of expensive material is the decreased rate of response to temperature changes of the element, and the difficulty of winding turns close to the center of the coil.

To overcome some of the objections to wide and thin, or narrow and thick composite metal elements for dial thermometers it has been proposed to use thin elements uniformly tapered in width. These are relatively wide at the fixed end and tapered transversely towards the free end. This design is a step in the right direction. It provides economy in the use of expensive bimetals, and permits winding turns close to the center of the coil. However, it eliminates only a small part of the objectional crosswise bending and does not facilitate accuracy or compactness in spirally coiled elements.

The principal object of my invention is to provide an improved bimetallic thermal element in which the distribution of the materials of which the element is made is such as to provide adequate stiffness, strength, high rate of response to temperature changes, accuracy and compactness, together with economy in the use of expensive materials.

Another object is to provide an improved thermostat comprising a work hardened bimetallic thermal element having a prearranged tapered thickness to improve its characteristics, and supporting means for the element.

Another object is to provide a tapered bimetallic thermal element that may be economically produced in various sizes and tapers by the use of standard rolling mill equipment.

Other objects will appear hereinafter.

In the drawings:—

Fig. 1 is a front elevation of a dial type ther-

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mometer utilizing a tapered bimetallic thermal element, embodying my improvements.

Fig. 2 is the front elevation of a thermostat having an improved tapered thermal element designed for greater strength than the element of Fig. 1.

Fig. 3 is a view of a slab of metal and a pair of complementary inserts cut therefrom.

Fig. 4 is a sectional elevation of a refractory mold holding a two high partable composite ingot produced by pouring a molten metal around the two inserts shown in Fig. 3.

Fig. 5 is a longitudinal elevation, partly in section of the two high ingot being reduced by rolling.

Fig. 6 shows a longitudinal elevation of a complementary pair of bimetallic elements produced by rolling down the portion (A) of the ingot in Fig. 5.

Fig. 7 shows a longitudinal elevation of a complementary pair of bimetallic elements produced by rolling down the portion (B) of the ingot in Fig. 5.

Fig. 8 is the longitudinal side elevation of a uniformly tapered bimetallic thermal element mounted as a cantilever.

Fig. 9 is a two high ingot from which a plurality of elements all equal and similar to Fig. 8 may be produced by rolling.

Fig. 10 is a longitudinal side elevation of a bimetallic element in which one face is represented by a portion of a sine curve.

Fig. 11 is a side elevation of a two high ingot used to produce a plurality of elements all equal and similar to Fig. 10.

Figs. 12 and 14 are views of elements that are modifications of the element shown in Fig. 10, and Figs. 13 and 15 are the corresponding ingots from which a plurality of elements all equal and similar respectively to the elements of Figs. 12 and 14 may be produced by rolling.

Fig. 16 is a longitudinal side elevation of a bimetallic element designed as a true cantilever of uniform strength, in which one face of the element is represented as a portion of a parabola.

Fig. 17 is a longitudinal side elevation of a two high ingot used to produce the element in Fig. 16.

Fig. 18 is a plan view of any one of the elements of Figs. 8, 10, 12, 14 and 16 showing that the width is constant throughout the length in each case.

It is found that a bimetallic thermal element tapering in thickness and of constant width, when designed as a true cantilever of uniform strength, is the most economical in the use of materials for a given strength, rate of response to temperature changes and accuracy. The rate of response to temperature changes is approximately twice as great as for another element of the same length and dimensions at the fixed end, but of constant width and thickness.

The above also applies to spirally coiled elements with the end of major thickness closest to the center of the coil.

It is further found that in elements where strength is not an important consideration, an element tapered in thickness and originally designed as a cantilever of uniform strength has a remarkable stiffness when spirally coiled with the end of minor thickness closest to the center of the coil, the end of major thickness being fixed at the outer end of the coil.

The above coiled element, furthermore, has approximately twice the rate of response to tem-

perature changes, compared with and considerably less weight than another coil of the same length and the same dimensions at the fixed end, but of constant width and thickness.

A cantilever of uniform strength is one in which the unit stress is constant at all sections along the length, and herein is confined to cantilevers designed for carrying a concentrated load at the free end.

It may be said that a thermal element originally designed as a cantilever of uniform strength, tapering in thickness and of constant width is the ideal element for most temperature responsive devices.

Unfortunately, it is not possible to economically produce tapered elements of uniform strength by the use of standard rolling mill equipment, as will be shown below.

A tapered cantilever of uniform strength and constant width, with a concentrated load at the free end may be represented as follows:—

$$d_x = d_1 \sqrt{\frac{x}{L}}$$

In which—

(d_1) = the thickness of the cantilever at the fixed end.

(L) = the length of the cantilever.

(d_x) = the thickness at any point (x) measured from the free end of the cantilever towards the fixed end.

with (d_1) and (L) known it is an easy matter to find the thickness (d_x) at any point (x).

The above is the equation of a parabola and is represented graphically by the curved base line 1, and the weld line 2, in the composite thermal element 3, in Fig. 16. At 4, in Fig. 17, is shown a side elevation of a two high ingot, parted on line 1. When this ingot is reduced by rolling, the portion 3, shown in section becomes the bimetallic element in Fig. 16. As the parting line 1, is a group of parabolas, it is not possible to produce from this ingot a plurality of elements all equal and similar to Fig. 16, since the two parts of this ingot are unlike. Therefore, it is not possible to produce true cantilevers of uniform strength economically by rolling down a two high ingot.

However, close approximations or modifications of true cantilevers of uniform strength may readily be produced by rolling down a two high ingot with standard rolling mill equipment. Such an element is represented by the uniformly tapered element 5, in Fig. 8. It may be produced by rolling down the two high partable ingot 6, in Fig. 9, having a parting line 7. The ratio of the thickness of the two different metals 8, and 9, fused together along the line 10, is substantially constant at all points along the surface of the element, and for best results the two different metals have equal thicknesses at all corresponding sections. If the ratio between the thickness at the two ends is about 3 to 1, the element becomes a modified cantilever of uniform strength.

When the above mentioned ingot Fig. 9 is rolled down, the portion 5, shown in section becomes the element in Fig. 8 and a plurality of such elements all equal and similar may be produced by rolling down this two high ingot.

Fig. 10, shows a side elevation of a thermal element 11, the area of which is confined between a horizontal line 12, and the portion of a sine curve 13, measured from the center of a crest 14, to the center of an adjacent trough 15. The line 16, which is also a sine curve, represents the weld

joint between the two different component metals 17, and 18, of the element. The ratio of the thickness of the two component metals is approximately constant and equal at all points along the surface of the element.

Fig. 11, is a side elevation of the two high ingot from which the bimetallic element of Fig. 10, was produced by rolling. The portion of the ingot 11, shown in section becomes the element 11, in Fig. 10, and the parting line 13, which also is a sine curve divides the ingot into two separable parts.

It will be noticed that a plurality of thermal elements all equal and similar may be produced by rolling down this ingot and properly shearing the rolled strips.

The thermal elements in Figs. 8, 12, and 14 are all modifications of the element in Fig. 10, and the corresponding two high ingots in Figs. 9, 13, and 15, from which the above elements were produced are modifications of the ingot in Fig. 11. A plurality of tapered bimetallic thermal elements all equal and similar may be produced from any of the above ingots by rolling.

In general, it may be stated that when the area in a side elevation of an element is confined between a horizontal line and a portion of a sine curve or a modification thereof extending from the center of a crest to the center of an adjacent trough, a plurality of bimetallic thermal elements all equal and similar may be produced by rolling down a properly designed two high, partable ingot by the use of standard rolling mill equipment.

Conversely, when one surface of a tapered element is represented in the side elevation by a portion of a parabola, a circle or an ellipse, then it is not possible to produce a plurality of elements all equal and similar by rolling down a two high ingot. The element 3, in Fig. 16, is in this class.

Bimetallic thermal elements may be produced having approximately any desired prearranged length or taper or ratio between the thicknesses of the component metals by rolling down a two high ingot having the proper prearranged proportions.

When the ingot is longitudinally rolled, the length increases in direct proportion to the decrease in thickness and the width remains substantially unaltered. The ratio between the thickness at the ends remains constant and the ratio between the thickness of the component metals at any section remains constant in the element when constant in the ingot.

It is important to note that the length of all these tapered thermal elements is definite and prearranged in the two high partable ingot. The ingot, after rolling must be sheared crosswise into sections of a definite length in order to produce a plurality of elements all equal and similar. The portion of the sine curve or modification thereof representing the parting line in the side elevation of a pair of complementary tapered thermal elements must be capable of dividing a rectangular area into two equal and similar parts.

The only portion of a sine curve or modified sine curve that meets the above limitations is that portion extending from the center of a crest to the center of an adjacent trough of a wave of the curve.

The thermostat shown in Fig. 1 of the drawings was designed, principally for applications where the work performed is relatively light, such as in dial type thermometers. It may also be used to advantage in automatic choke controls and

intake manifold heat controls on automobile engines.

It comprises a spirally coiled, work hardened bimetallic strip 5, tapering in thickness in the direction of its length and rigidly fixed to a stationary supporting member 19, at a point adjacent the end of major thickness or outer end 20, by means of the rivet 21. The inner end or the end of minor thickness 22, is attached to the shaft 23, by means of the screw 24. The pointer or hand 25, is rigidly attached to the end of the shaft and moves over the fixed dial 26.

In response to a change in temperature the inner end of the coiled element, the shaft, and the pointer deflect as a unit about the center of the coil, causing the pointer to move over the dial.

The terminal element in the above thermostat is uniformly tapered in thickness in the direction of its length with the end of minor thickness closest to the center to give all the turns of the coil substantially the same stiffness to resist vibrations and other mechanical distorting forces that tend to cause the pointer to quiver and which tend to crowd the various turns together at certain sections.

In this construction the turns of the element remain substantially concentric about the center of the coil under all load and temperature conditions when the proper ratio exists between the thickness at the two ends of the strip.

The ideal arrangement of the materials of the element for effecting the greatest response to temperature changes, accuracy and compactness, together with economy in the use of expensive materials for a given stiffness, is when the thermal element is made from a composite strip, designed to approach as near as possible a cantilever of uniform strength.

Furthermore, in the above construction the ability to wind turns close to the center of the coil makes it unnecessary to provide a bearing in the frame or dial of the instrument to hold the pointer shaft concentric, thus eliminating friction and avoiding error in readings from this source.

It is found that when the ratio between the thickness at the two ends of the uniformly tapered element is about 3 to 1, the strip is a modified cantilever of uniform strength and is well suited for dial thermometers. However, while the element is formed of an initially uniformly tapered, straight strip of substantially cantilever form, when coiled and mounted in this particular construction of Fig. 1 the tapered strip is no longer a modified cantilever of uniform strength.

In Fig. 2 is illustrated a thermostat which is the reverse of that shown in Fig. 1, and is designed principally for great strength, with maximum response in use and economy in the employment of materials.

The flat bimetallic strip before coiling is designed as a modified cantilever of uniform strength having a ratio between the thickness at the two ends of about 3 to 1.

The thermostat comprises a spirally coiled, work hardened bimetallic strip 5, uniformly tapering in thickness with its end of major thickness or inner end attached by screw 27, to the stationary shaft 28, positioned in the center of the coil. The end of minor thickness, which in this case is the outer end, is free to deflect in response to temperature changes.

This thermostat is used principally in heat re-

sponsive devices where the element is required to carry a load at the free end, such, for instance, where the thermostat is to be used for tripping a latch, and for water temperature controls in automobile engines. It further finds use in automatic electric switches where only a small portion of the free end of the thermal element, because of its reduced area, is heated by the resistance of an electric current passing through the element. The heat from the free end is transmitted by conduction to the other portions of the element. The time necessary to heat the entire thermal element in the above manner makes this type of thermostat ideal for delayed operation of a switch in response to over-loads.

To produce bimetallic metal thermal elements tapered in thickness, such in accordance with this invention, as elements 5, in Fig. 6, or the elements 30, and 31, in Fig. 7, I first form a two high partable ingot 44, in Fig. 5. This is separated or parted on line 43, into two distinct ingots, one on top of the other.

To produce the two high ingot, I preferably take a slab 32 of low expansion metal, such as Invar, see Fig. 3, and scribe guide lines thereon, and then cut out the complementary sections or inserts 33, and 34, by means of a narrow band saw.

The contacting surfaces of the two Invar sections are then coated with a refractory material, such as powdered magnesium oxide, mixed in sodium silicate to keep these surfaces from sticking together during later rolling operations.

The two Invar sections are then held together in proper alignment and the contacting surfaces, with the refractory therebetween, are sealed by arc welding a layer of metal along the outer edges thereof. Portions of the weld metal are shown at 35, in Fig. 4. A small vent is left open in the weld metal and the Invar sections are heated to around 500° F. to drive off gases, after which the vent is sealed. The threaded steel rod 36, is then welded to the top of the sections. After this, all the exposed Invar surfaces are thoroughly cleaned and then pickled electrolytically in a strong hydrochloric acid solution.

The surfaces are then preferably coated with an easily fusible flux, such as 60 to 80% KHF with the balance boric acid.

On top of the flux is placed a fabric covering, such as canvas. Then on top of the canvas is wrapped several layers of thin sheet copper, which will melt and fuse with the molten bronze later to be poured around the Invar inserts in the mold.

Finally the protected Invar inserts are placed centrally in the refractory mold 38, of Fig. 4, and spaced from the bottom and sides of the mold by a coarse layer of porous wood charcoal. The inserts are then attached to the mold cover 37, by means of the steel rod 36, and the nut 39.

Molten high expansion metal 40, such as bronze known by the trade name of "Barronia metal", heated to about 2200° F., is then rapidly poured around the Invar inserts, through the opening 41 in the mold cover.

The flux, when molten removes the highly refractory oxide from the Invar. The outer wrapping of copper melts into the bronze and the canvas decomposes to produce charcoal carbon and a reducing gas, which prevent new oxides

from forming on the Invar and also reduce the oxides in the molten bronze.

The mold and its contents are then reheated to around 2100° F., or slightly above the melting point of the Barronia metal. This reheating causes all the remaining oxides to be reduced by the carbon, and the bronze will then readily wet and fuse to the clean surfaces of the Invar.

The two high composite ingot thus produced is rapidly cooled to around 1400° F. at which temperature it is removed from the mold and first hot then cold rolled as shown in Fig. 5.

After the hot rolling operation the ingot is allowed to cool down to room temperature. The excess bronze indicated by the dotted lines 42, in Fig. 4, is machined off and the slab is then cold rolled or cold drawn down to the finished size of the two high tapered strips it is desired to be produced. The cold rolling or drawing work hardens the strips, and thereby increases the strength, the toughness and resiliency of the finished tapered elements.

The elements 5 in Fig. 6 correspond to the section (A) of the ingot in Fig. 5, after reduction by rolling, and likewise, the elements 30 and 31 in Fig. 7 correspond to the reduced section (B) of Fig. 5.

The bimetallic metal element 5, in Fig. 6, represents diagrammatically the tapered thermal element 5, in the thermostats of Figs. 1 and 2.

In producing the tapered bimetallic thermal elements various low and high expansion alloys may be substituted for the Invar-bronze combination. As an illustration, for high temperatures I prefer to substitute 42% nickel steel for Invar, as the low expansion metal, and for the high expansion metal I prefer to use a ferrous alloy, comprising 12% Ni, 5% Mn, 3.5% Cr, 0.6% C, with the balance iron.

To obtain a corrosion resistant bimetallic element, I prefer to use for the low expansion member an alloy comprising 16% Cr, 1% Mn, 0.5% Cu, 0.1% C, and balance iron. For the high expansion member I use an alloy comprising 18% Cr, 4 to 6% Mn, 2 to 3% Cu, 0.1% C, 2 to 4% Ni, with balance iron.

When the poured metal is a ferrous alloy I prefer to substitute a protective wrapping of ingot iron for the sheet copper, and to use ferric oxalate instead of the canvas cover. The reheating of the composite ingot for rolling is to the welding temperature around 2200° F.

Furthermore, when using the bronze-Invar combination, the solid inserts 33, and 34, Fig. 4, may be the bronze and the poured molten metal, Invar. In this case a properly shaped thin strip of austenitic steel will act as the separating material between the two bronze insert sections.

The bronze inserts will be joined together with the sheet steel therebetween by welding a layer of bronze around the outer edges. The outer bronze surfaces will be protected, first by the flux, then by a layer of ferric oxalate, and finally by several layers of ingot iron that will melt into the Invar being poured around the inserts.

In the above arrangement no reheating of the ingot before rolling is necessary, as the molten Invar will cause a film of the bronze to melt so that the ferrous metal will be fused to the surface of the bronze without reheating the mass. The first rolling temperature is around 1400° F., with later cold rolling down to finished size.

Finally, as another alternative method of producing the two high ingots, the Invar inserts 33

and 34 are welded together along the edges with a refractory therebetween as before.

The Invar inserts are then sandwiched between a pair of properly shaped sections, corresponding to the metal 40 in Fig. 4, but cut from a solid slab of high expansion ferrous alloy.

Between each section of Invar and a section of high expansion metal is placed a heavy layer of powdered ferric oxalate.

10 Three or four thin layers of ingot iron are then wrapped around the assembly. The longitudinal seam and the two ends are then sealed by welding.

15 The package thus produced is heated to about 2200° F. and rolled at this temperature.

The oxalate decomposes, giving off a reducing atmosphere, and leaving a cemented layer of iron between each Invar section and a section of high expansion metal. The iron acts as a flux to weld 20 the two metals together face to face during the hot rolling. After rolling, the procedure is the same as the previous methods outlined.

What I claim and desire to secure by Letters Patent is:—

25 1. A uniformly work hardened, solid, thermostatic bimetal element comprising strips of different metals each of which is uniformly tapered in thickness in a lengthwise direction, said strips being secured together in superposed face to face 30 relation, and having their ends of major thickness at one end of said element and their ends of minor thickness at the other.

2. A thermostatic bimetal element formed of layers of different metals joined face to face, 35 said element having a portion thereof of prearranged uniformly and progressively tapered crosswise thickness in a lengthwise direction.

3. A thermostatic bimetal strip in the form of a solid beam of uniform strength, with the 40 thickness at one end of said strip approximately three times the thickness at the opposite end of said strip to economize in the use of materials and to increase the rate of response of said strip to temperature changes, as compared to another 45 thermal strip of the same materials, of equal length, and of equal strength at the section of greatest stress, but of constant width and thickness.

4. A solid, thermostatic bimetal element uniformly tapered in thickness from end to end, the 50 thickness at the end of major thickness being at least two times, and less than four times the thickness at the end of minor thickness.

5. A solid, thermostatic bimetal element having a portion thereof of prearranged lengthwise 55 tapering thickness, the area in a longitudinal side elevation of said element being confined between a straight line and another line extending

generally in the same direction and capable of dividing a rectangular area formed between said first line and another straight line parallel there- into two equal and similar parts.

6. A spirally coiled thermostatic bimetal element tapering in thickness, substantially from 5 end to end, with the end of major thickness adjacent the center of the coil, said element having a greater strength at the section of greatest stress than another similarly coiled element of the same materials of the same length and width, 10 but of a thickness approximately equal to the mean, intermediate thickness of said tapered element, such as would allow the same ultimate movement for a given temperature change. 15

7. A spirally thermostatic bimetal element tapering in thickness, substantially from end to end, with the end of minor thickness adjacent 20 the center of the coil, said element having a correspondingly greater stiffness than another similarly coiled element of the same length and width, but of a thickness approximately equal to the mean, intermediate thickness of said tapered 25 element, such as would allow the same ultimate movement for a given temperature change.

8. A thermostatic bimetal element having a 25 given cross-sectional thickness at one point and a different cross-sectional thickness at another point spaced lengthwise of and remote from said first mentioned point, the intermediate portion 30 between said points having a prearranged lengthwise tapered thickness.

9. A thermostat comprising a spirally coiled 35 thermostatic bimetal thermal element of prearranged tapering thickness in a lengthwise direction, and having its ends of major and minor thickness respectively, and means to support said element adjacent the end of major thickness, 40 the end of minor thickness being free to deflect in response to a temperature change.

10. A thermostat comprising a spirally coiled 40 bimetallic thermal element of prearranged tapering thickness in a lengthwise direction, and having its ends of major and minor thickness respectively, and means to support said element adja- 45 cent the end of major thickness, the end of minor thickness being arranged adjacent the center of the coil and free to deflect in response to a temperature change.

11. In a heat responsive device, a bimetallic 50 thermal element having spaced sections of minor and major crosswise thickness and having a portion of prearranged, longitudinally tapered thickness extending between said sections, and supporting means for said element adjacent one 55 of said first mentioned sections.

NORMAN L. DERBY.

CERTIFICATE OF CORRECTION.

Patent No. 2,144,915.

January 24, 1939.

NORMAN L. DERBY.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, second column, line 18, for the word "terminal" read thermal; page 5, second column, line 16, claim 7, after the word "spirally" insert coiled; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 4th day of April, A. D. 1939.

(Seal)

Henry Van Arsdale
Acting Commissioner of Patents.