Aug. 12, 1958 S. G. ESKIN 2,846,829

METHOD OF MAKING A THERMALLY RESPONSIVE ELEMENT

Filed March 10, 1954 2 Sheets-Sheet 1

Fig 1

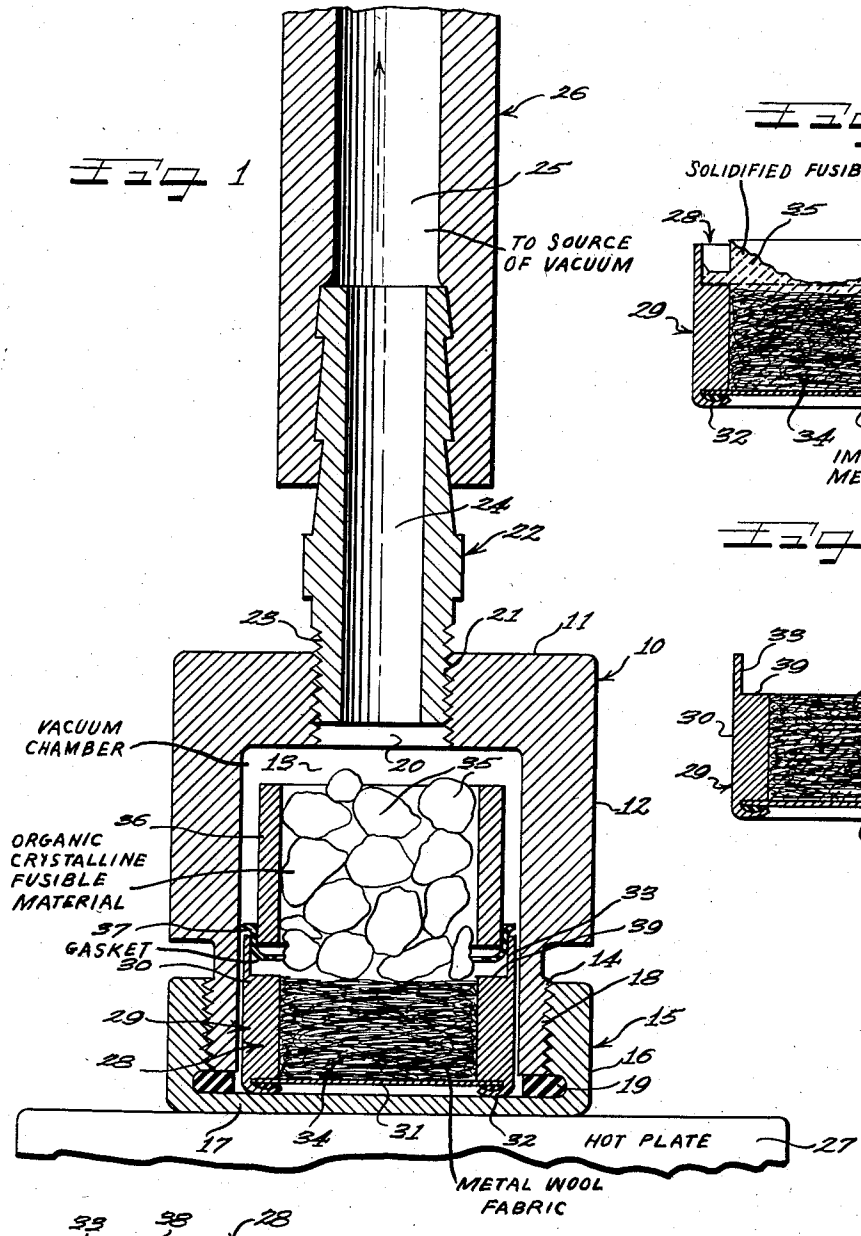


Fig 2

Fig 3

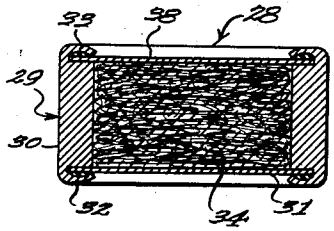


Fig 4

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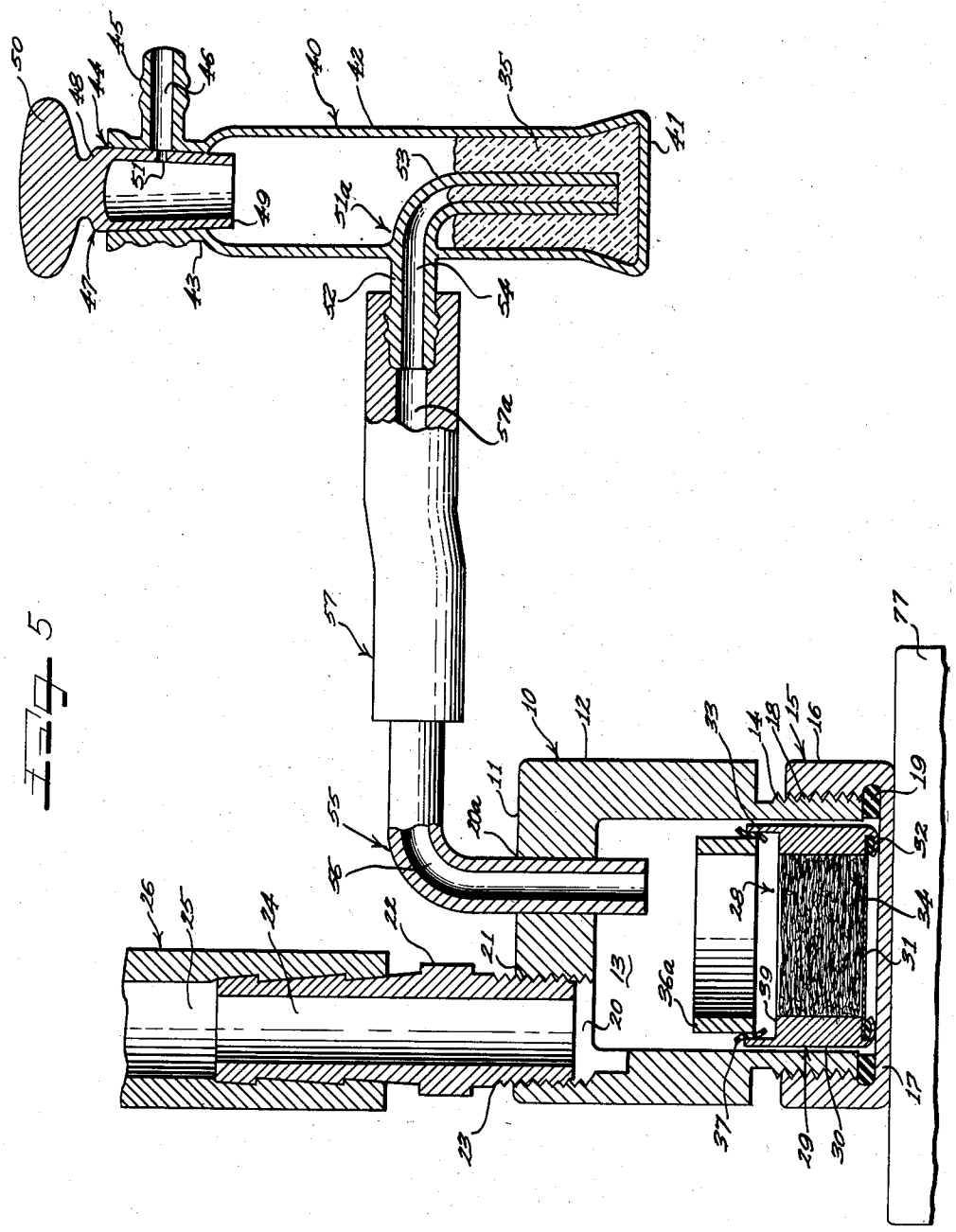


FIG. 5

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METHOD OF MAKING A THERMALLY RESPONSIVE ELEMENT

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Application March 10, 1954, Serial No. 415,351

6 Claims. (Cl. 53—22)

The present invention relates to a new and improved method of making thermally responsive elements.

The thermally responsive elements of this invention consist essentially of a heat expansible substance imbedded in a heat conducting material. The heat expansible material to which I refer comprises an organic crystalline substance having a fusing point within a predetermined range; for example waxes, such as paraffin and/or microcrystalline waxes. These crystalline organic substances have the property of expanding upon melting or fusing. That is, they occupy a greater volume in a liquid or fused state than in a solid state. This property supplies the actuating or power generating force in the thermally responsive elements of the instant invention.

In the present thermally responsive element a crystalline organic substance having a melting point within a predetermined range is embedded in and intimately engaged with a compressible metal fabric of intermeshing or interlocking, elongated strands, such as a metal wool mat. The element preferably has a disk-like or cylindrical configuration and is enclosed in a suitable housing. The flat end portions of the disk-like element are tightly enclosed by a circular diaphragm or disk formed of thin metal or similar material. When the thermally responsive element thus produced is subjected to temperature conditions in a range at or near the fusing point of the crystalline organic substance, said organic substance will expand and force the diaphragms or disks on the outer faces of the element outwardly. This outward movement of the diaphragms or disks, in turn actuates a suitable mechanism or control device for creating conditions which will modify or change the temperature of a system in a predetermined manner.

The fusible material, that is, the one that serves as the power agent in the element due to its expansion and contraction upon change in temperature, may be of a single type of organic crystalline substance having a fusing point within a predetermined range, such as a wax. If desired, however, it may be a mixture of one or more of such materials having the desired expansion characteristics upon fusion, alone or in admixture with some other material with which the fusible material is miscible and which increases the viscosity, cohesiveness and plastic or elastic properties of the fusible material.

In the case of a wax, a paraffin wax is preferred as the heat fusible material for use in low temperature operations, while a microcrystalline wax is preferred in high temperature operations. The waxes can be used by themselves or additives such as hydrogenated rosin, ester gum, or other natural or synthetic resins or another wax may be incorporated with the waxes to increase their viscosity, cohesiveness, elasticity or otherwise alter their fusing point properties.

Paraffin wax is commercially available in a number of grades having a melting or fusing point which will operate within a temperature range of from about 92 to 145° F. The exact fusing point, of course, will depend on the grade or fraction of paraffin employed. Certain grades

or fractions of paraffin are available having melting point ranges as narrow as 5° to 10° F.

Microcrystalline waxes are also available in various grades and fractions having melting points ranging from about 145 to 195° F. Particular grades or fractions of microcrystalline waxes are available having melting point ranges as narrow as 10° F. in changing from a solid state to a state of complete fusion. Indeed, some sources offer microcrystalline waxes having a melting point range as small as 5° F.

In place of the waxes or wax mixtures other materials may be employed including mixtures of such crystalline organic substances as diphenyl, p-dibromobenzene and p-dichlorobenzene, together with a resin or polymer such as vinyl polymer, as a binder for the principal fusible substance. Such mixtures are not preferred, however, since they are, in general, more expensive than the suitable grades of microcrystalline or paraffin waxes and their presence reduces the sharpness of the fusion temperatures.

The material having good heat conductive properties, as noted above, preferably comprises a compressible fabric of interlocking or intermeshing elongated metal strands, such as a metal wool mat formed, for example, from a metal such as copper, aluminum or similar metals. The use of this form of heat conducting material is far superior to the heat conducting materials which have been previously employed in producing thermally responsive elements similar to those of the instant invention.

Thermally responsive elements produced heretofore, using a heat expandable, fusible crystalline organic material, such as wax, have invariably employed finely divided material, such as powdered metals, as the heat conducting medium for transmitting temperature changes throughout the entire mass of the organic crystalline substance. While such elements are generally satisfactory, a binder is required to prevent the finely divided heat conductive material from separating out from the fusible organic crystalline material. These binders, however, tend to react with the fusible material and reduce the temperature sensitivity of the element.

In the thermally responsive element produced in accordance with the method of the instant invention, however, this shortcoming is eliminated. For by my use of a compressive metal fabric consisting of elongated intermeshing strands, such as a metal wool mat, I am able to get rapid conduction of heat through the entire mass of the heat fusible material without the use of binders as was hitherto necessary. Further since I do not employ finely divided powdered metals the problem of such material settling out is eliminated.

Heretofore, the vast majority of the present form of thermally responsive elements have been produced by pressure molding techniques. That is, a heat conducting material is admixed which a suitable molten organic crystalline substance, such as wax, and the entire mass is subjected to compression or pressure molding to form the composite thermally responsive element. Although these prior pressure molding methods produce operable elements, the techniques and procedures used, are nevertheless, relatively expensive; for costly machinery is required and the methods themselves are time-consuming.

I have found that it is now possible to produce thermally responsive elements in a new and more rapid manner and at lower costs than was heretofore possible. In the instant invention, I have eliminated the step of compressing the heat conducting materials after it has been impregnated with the heat fusible material. With the instant method it is no longer necessary to provide a dwell period under pressure in order to assure intimate engagement of the organic crystalline substance with the heat conducting material.

In the present invention I impregnate metal wool with a crystalline organic material by introducing the fusible organic crystalline substance into the fabric or metal wool in a molten state at reduced pressures. That is, rather then employing a compression technique as was done previously I now place the compressible fabric in a zone which is capable of being evacuated and heated, such as a vacuum oven, and then impregnate the compressible fabric with the molten crystalline material while the zone is at reduced pressures and elevated temperatures.

By this novel in vacuo process I am able to realize a thermally responsive element which is at least as operably effective as ones produced by compression techniques. Further, the instant method produces thermally responsive elements in a much more rapid, efficient and economical manner than was hitherto possible.

In accordance with the foregoing it is therefore an object of the present invention to provide a method for producing a thermally responsive element having superior advantages over similar elements heretofore available.

Another object is to provide a method for making a thermally responsive element wherein a compressible fabric of intermeshing metal strands is impregnated at reduced pressures with a molten organic crystalline substance having a fusing point within a predetermined range.

A further object is to provide a new and unique method by which thermally responsive elements comprising a metal wool mat and a fusible organic crystalline substance may be produced in a manner more rapid than was heretofore possible.

Other objects and advantages of this invention will become apparent to those skilled in the art from the following description of the annexed sheets of drawings wherein:

Figure 1 is a transverse sectional view of a structure of an apparatus which may be employed in producing a thermally responsive element in accordance with the method of the instant invention;

Figure 2 is a transverse sectional view of a partially formed thermally responsive element produced in accordance with the method of the instant invention;

Figure 3 is a view similar to Figure 2 showing a thermally responsive element in a further stage of completion;

Figure 4 is a transverse sectional view similar to Figures 2 and 3 showing a completed thermally responsive element made in accordance with the method of the instant invention; and

Figure 5 is a transverse sectional view partly in section and partly in elevation showing another embodiment of an apparatus which can be employed in producing the novel thermally responsive elements in accordance with the method of the instant invention.

Referring now to the drawings, as seen in Figure 1 a metal housing shown generally at 10 comprises a circular top wall 11 having an integral annular depending side wall or skirt portion 12, said top and side walls 11 and 12 of the housing 10 defining a hollow vacuum zone or chamber 13. The outer periphery of the bottom portion of the depending side wall or skirt 12 has threads 14 formed thereon. A housing base member or housing nut 15 having an annular upstanding side wall portion 16 and an integral circular bottom portion 17 is threadedly engaged on the bottom portion of the depending side wall 12 of the housing 10 by means of threads 18 formed on the inner periphery of the side wall 16. An annular, resilient gasket or washer 19 is compressibly deformed by the pressure exerted between the bottom face of the depending side wall 12 of the housing 10 and the bottom portion 17 of the housing nut 15 and thereby forms an effective vacuum seal hermetically closing the vacuum zone or chamber 13 to the ingress of air.

A centrally disposed aperture 20 having threads 21 formed therein is provided in the top wall 11 of the housing 10. A tapered, stepped nozzle 22 having threads 23 formed on the outer periphery of the bottom portion thereof is threadedly engaged into the aperture 20. The nozzle 22 has a lumen 24 communicating between the vacuum chamber 13 and the lumen 25 of a resilient tubing or conduit 26. The tubing 26, which is of a sufficient strength to be capable of withstanding a vacuum without collapsing, is connected to and in communication with a source of vacuum (not shown).

The housing 10 and housing nut 15, which are threadedly engaged to provide the vacuum chamber or zone 13, rest upon a suitable source of heat 27, such as, for example, an electric hotplate.

A generally disk-shaped thermally responsive element-unit shown generally at 28 is centrally positioned in the vacuum chamber 13 and rests upon the inner surface of the bottom portion 17 of the housing nut 15. This thermally responsive element-unit comprises (Figures 1–4) a cylindrical heat conducting element retaining member 29 having an annular side wall portion 30 and a lower retaining disk 31 supported by an upturned annular flange 32. An annular upstanding retaining flange 33 is provided integral with the cylindrical side wall 30, for a purpose to be described later.

A mass of a compressible fabric of intermeshing metal strands, such as, for example, copper, aluminum or other metal wool 34, which has been compressibly formed into a mat of the proper cylindrical shape is retained within the cylindrical side walls 30 of the retaining member 29 and rests upon the lower retaining disk 31. For optimum results the compressible fabric mass or mat 34 should be highly compacted and fit tightly within the confines of the cylindrical side walls 30.

A predetermined quantity of wax 35 or other organic crystalline substance having a fusing point within a predetermined range is positioned directly above the metal wool mat 34 by means of a cylindrical wax retaining member 36, comprising a tubular section of sheet metal or similar material. The wax retaining member 36 is held in position above the metal wool mat 34 by means of a washer or gasket 37 preferably formed of a resilient material such as rubber or the like. The gasket 37, upon which the wax retaining member 36 rests, makes contacts with and is supported by the upper edge of the upstanding retaining flange 33 of the cylindrical element retaining member 29.

The exact amount of the organic crystalline substance used to impregnate the heat conducting metal wool mat will, of course, vary with the size of the metal wool mat employed. In general, the proportions by weight of the wax 35, or similar substance and the heat-conductive metal wool mat 34 will run between 25 and 60% of the metal wool 34 by total weight of the element; the wax 35, or similar material constituting the remaining 75 to 40%.

For example, I have found that a mixture of about 75% of a microcrystalline wax having a melting point between 160° and 180° F. will give very satisfactory thermal characteristics within a temperature range of 185° to 205° F. when said wax is imbedded in about 25% of aluminum wool by weight.

While 25% of metal wool or the like by weight of the element has been found entirely satisfactory from both an operating and an economical standpoint, the percentage can be increased to as high as about 80% or even slightly higher with denser metals such as copper and silver. The range of 25 to 50%, however, is preferred. The fusible organic crystalline substance, of course, constitutes the balance of the element.

In accordance with the method of the instant invention the thermally responsive element unit 28 having the metal wool mat 34 retained within the cylindrical retaining member 29 is centrally positioned on the inner surface of the bottom portion 17 of the housing nut 15. The gasket 37 is then placed atop the annular retaining

flange 33 and the wax retaining cylindrical member 36 is positioned on the gasket 37. A predetermined quantity of an organic crystalline substance 35 having a fusing point within a predetermined range is then placed within the cylindrical wax retaining member 36. Thereafter, the housing 10 is placed over the thermally responsive element unit 28 and the housing 10 is threadedly engaged with the housing nut 15 to form a hermetically sealed vacuum zone or chamber 13. The tubing 26 is then introduced over the nozzle 22 and by means of a source of vacuum (not shown) the chamber 13 is evacuated to reduce the pressure therein. After the vacuum chamber 13 has been initially evacuated the entire housing unit is heated by suitable means such as by energizing the electric hotplate 27 upon which the housing unit rests. The vacuum is applied throughout the entire heating process and the chamber 13 is evacuated to as great an extent as possible.

The use of in vacuo conditions just prior to and during the impregnating of the metal wool mat 34 with the wax 35 is essential in the instant invention. By applying a vacuum to the chamber 13 I am able to eliminate substantially all of the air or other gases occluded within the network of strands in the metal wool 34. When such air and gases have been removed, it is possible for the molten wax to completely impregnate the metal wool and assure intimate engagement of the wax therewith. In the more time-consuming and expensive methods employed heretofore, as noted previously, the air was forced from the heat conducting material and the wax simultaneously brought into engagement therewith by means of heavy pressure molding techniques.

As heat is applied to the vacuum chamber 13 the fusible organic crystalline substance 35 reaches its fusing point and melts. Under the influence of gravity the molten material 35 runs down through the metal wool mat 34, impregnating the same and becoming intimately embedded therein.

After a sufficient amount of heating time has ensued to assure complete impregnation of the metal wool mat 34 by the liquefied fusible material 35, the application of heat is discontinued and the entire structure is allowed to cool to room temperature, or to a temperature below the fusing point of the organic crystalline material employed. When the unit has been sufficiently cooled to assure solidification of the fusible material, the vacuum is broken and air is bled or vented into the vacuum chamber 13 by removing the tubing 26 from the tapered nozzle 22. The housing member 10 is then disengaged from the housing nut 15 and the thermally responsive element unit 28 is removed therefrom.

The thermally responsive element unit 28 having the heat conducting metal wool mat portion 34 thereof completely impregnated by and intimately engaged with the fusible organic crystalline substance 35, is not complete and requires several small finishing steps. In practice it is not possible nor practicable to ascertain with any degree of certainty the exact amount of wax or similar material 35 which is required to completely impregnate the metal wool mat 34. Consequently, to assure complete impregnation a slight excess of wax over that theoretically required is used. Accordingly there is always a slight surplus or excess of the solidified wax formed on the top surface of the metal wool mat 34 as shown in Figure 2. In order to finish the thermally responsive element 28 this excess wax or similar material 35 is removed by machining down to the level of the top surface of the metal wool mat 34 as shown in Figure 3.

An upper retaining disk or diaphragm 38 which may or may not be identical to the lower retaining disk 31 is placed on top of the upper surface of the wax impregnated metal wool mat 34 and rests upon retaining shoulders 39 formed on the top surface of the cylindrical wall 30. To produce the finished thermally responsive element 28 the upper retaining disk 38 is then anchored permanently in place by turning down the annular retaining flange 33 which holds the disk 38 in a tight gripping relation as shown in Figure 4.

Another embodiment of an apparatus which may be employed in forming the novel thermally responsive elements in accordance with the method of the instant invention is shown in Figure 5, wherein similar parts have the same numbers as employed in Figures 1–4 and, accordingly, need no further clarification. In this embodiment the wax or similar material which is used to impregnate the metal wool mat 34 is not positioned above the thermally responsive element unit 28 in the vacunum chamber 13 is a particulate or solid state as done in the embodiment shown in Figure 1. Rather, the wax 35 is introduced into the vacuum chamber 13 in a molten state and impregnates the metal wool mat 34 at reduced pressures. This is accomplished by providing a suitable supply of molten wax or similar organic crystalline fusible material adjacent the vacuum chamber 13 and in hermetically sealed communication therewith.

In the embodiment shown in Figure 5 this is facilitated by providing a wax retaining vessel or container 40 adjacent the housing unit 10. A quantity of wax 35 contained within the container 40 is maintained in a molten state by means of a suitable source of heat (not shown). The molten wax container 40 comprises a bottle or similar structure having a circular bottom member 41, an integral, annular, upstanding wall portion 42 and a narrowed down or constricted neck portion 43 providing an opening 44 for filling the bottle. A transversely extending tubular air inlet portion 45 having air passage or lumen 46 extending therethrough is integrally formed with the neck portion 43. A drum-type stop cock 47 having a top portion 48, a dependent integral annular body portion 49 and a suitable handle 50 is slidably engaged in the opening 44 and is rotatable therein. An air vent 51 formed in the depending wall portion 49 of the stop cock 47 is rotatably engageable into communication with the lumen 46 of the air intake 45. A delivery tube 51*a* comprising an external transversely extending tubular member 52 and a downwardly bent interior member 53 is formed integrally with the annular side wall member 42 of the wax container 40. A common lumen or passage 54 extends the entire length of the delivery tube 51*a* and provides open communication between the inside and outside of the container 40.

An L-shaped filling tube 55 is mounted in the top wall 11, of the housing 10 in an aperture 20*a*. The filling tube 55 is hermetically sealed in the aperture 20*a* by means of a suitable cement or sealing compound. The lumen 56 of the filling tube 55 is connected to the delivery tube of the wax container 40 by means of a nipple or length of resilient tubing or conduit 57 having a passage or lumen 57*a* extending the length thereof. In this fashion, the lumen 54 of the delivery tube 51*a* of the container 40, and the lumen 56 of the filling tube 55 are in communication via the lumen 57*a* of the nipple 57, forming a continuous hermetically sealed conduit from the interior of the container 40 to the vacuum chamber 13.

In accordance with this embodiment of the instant invention the wax or similar fusible organic crystalline material impregnates the metal wool mat 34 and is intimately engaged therewith as follows:

An annular wax directing or guiding member 36*a* (which is the physical analogue of the wax retaining member 36 of Figure 1) is supported atop the annular flange 33 of the thermally responsive element unit 28 by means of a gasket or washer 37. The thermally responsive element unit 28 having the wax directing member 36*a* thus positioned thereover is then positioned on the inner surface of the bottom portion 17 of the housing nut 15, so as to be generally centered under the lumen 56 of the filling tube 55. The housing nut 15 is then threadedly engaged with the housing 10 forming a her-

metically sealed vacuum chamber **13**. The vacuum chamber **13** is then connected to a source of vacuum (not shown) by means of the tube **26** and the stepped nozzle **22** in the same fashion as described previously. The stop cock **47** is then rotated to disengage the air vent **51** from the air passage **46** of the air inlet **45**. This precludes any influx of air into the system. The wax container **40** is then tilted so that the bottom end portion of the interior tube **53** of the delivery tube **51***a*, which is normally disposed below the surface of the molten wax, is exposed to the vacuum system in order to completely evacuate the air from the bottle and the delivery line. The container is then returned to its normal upright position. After the entire system has been evacuated and the pressure therein properly reduced, the housing unit and vacuum chamber **13** are then heated by any suitable source of heat such as, for example, the electric hotplate **27**. When the housing unit has reached a temperature at least equal to the fusing point of the wax employed, the stop cock **47** of the container **40** is rotated to bring the air vent **51** into engagement with the air passage **46**. The air pressure differential thus resulting causes the molten wax **35** to be forced up through the lumen **54** of the delivery tube, through the lumen **57***a* of the nipple **57**, into the lumen **56** of the filling tube **55** and into the vacuum chamber **13**. The molten wax **35** which thus enters the vacuum chamber **13** is directed by the wax directing member **36***a* into direct contact with the metal wool mat **34**. When a sufficient amount of molten wax **35** has been transferred from the bottle **40** to the vacuum chamber **13**, the stop cock **47** is rotated to disengage the air vent **51** from the air inlet **46** thereby stopping the flow of wax. The quantity of wax delivered may be easily determined by having the container **40** calibrated in convenient volume units. The application of heat is discontinued and when the temperature has dropped sufficiently for the wax to solidify, the vacuum is broken and the thermally responsive element removed from the housing **10**.

The thermally responsive element **28** is then finished in the same manner as discussed above in describing Figures 2, 3 and 4.

It will be apparent to those skilled in the art that I have now provided a simple and rapid method for making thermally responsive elements in an economical manner.

It will, of course, also be understood that various details of the invention may be varied through a wide range without departing from the principles of this invention, and it is, therefore, not the purpose to limit the patent granted hereon otherwise than necessitated by the scope of the appended claims.

I claim as my invention:

1. A method of making a thermally responsive element which comprises providing a vacuum chamber, confining a predetermined amount of metal wool fabric within a casing, placing an open ended container on the casing and sealing the container thereto, placing a predetermined quantity of a solid organic crystalline substance having a fusing point within a predetermined temperature range within the open ended container in close juxtaposed relation to the metal wool fabric, placing the casing and container with the metal wool fabric and solid organic crystalline substance within the vacuum chamber, evacuating said chamber to reduce the pressure therein, maintaining the reduced pressure in said chamber and applying heat thereto to cause said solid organic crystalline substance to fuse and impregnate said metal wool fabric, cooling said chamber and restoring normal air pressure therein, and removing any excess organic crystalline substance adhering to the surface of said compressible fabric.

2. A method of making a thermally responsive element which comprises providing a vacuum chamber, confining a predetermined amount of metal wool fabric

within a casing, placing an open ended container on said casing in communication with the metal wool fabric therein and sealing the container thereto, placing in said container in juxtaposed relation to the metal wool fabric in said casing a quantity of a solid organic crystalline substance having a fusing point within a predetermined temperature range, said quantity of solid organic crystalline substance comprising from about 75 to 40% by weight of the thermally responsive element to be produced, evacuating said vacuum chamber to reduce the pressure therein, maintaining said vacuum chamber at a reduced pressure and applying heat thereto to cause said organic crystalline substance to fuse and impregnate said compressible fabric under the influence of gravity, cooling said chamber and restoring normal air pressure therein, removing any excess organic crystalline substance adhering to the surface of said compressible fabric, then sealing said casing with a metallic diaphragm deflectable upon fusion of said thermally expansible material.

3. A method of making a thermally responsive element comprising the steps of providing a cup-shaped casing having a shoulder adjacent the top and an upstanding flange extending from said shoulder, inserting a predetermined amount by weight of metallic wool in said casing, providing and confining above said metallic wool an amount slightly in excess of a predetermined amount by weight of a thermally expansible material fusible within a predetermined temperature range, placing said casing and metallic wool and fusible thermally expansible material in a vacuum chamber, producing a substantial vacuum in said vacuum chamber and heating the vacuum chamber and its contents until said thermally expansible material fuses and impregnates the metallic wool in said casing, cooling said vacuum chamber and its contents to solidify the fused thermally expansible material, removing said casing and metallic wool and thermally expansible material from said vacuum chamber, removing from said casing only the thermally expansible material in excess of said predetermined amount, while leaving said predetermined amount of thermally expansible material in said casing impregnated in said metallic wool, placing a metallic diaphragm on said shoulder, and spinning said upstanding flange over said metallic diaphragm to seal said thermally expansible material in said casing, said predetermined amount by weight of thermally expansible material in said casing being an amount determined to produce a predetermined amount of deflection of said metallic diaphragm upon fusion of said thermally expansible material.

4. The method of claim 3 including the step of predetermining the volumetric capacity of said casing from the predetermined amounts by weight of metallic wool and thermally expansible material to be placed therein.

5. A method of making a thermally responsive element comprising the steps of providing a cylindrical casing having a shoulder at each end and a flange extending from each shoulder axially of said casing, placing a metallic diaphragm on one of said shoulders and spinning the respective flange over said diaphragm to maintain said diaphragm tightly in engagement with said one shoulder to form a bottom for said casing, inserting a predetermined amount by weight of metallic wool in said casing, providing and confining above said metallic wool an amount slightly in excess of a predetermined amount by weight of a thermally expansible material fusible within a predetermined temperature range, placing said casing and metallic wool and thermally expansible material in a vacuum chamber, vacuumizing said vacuum chamber and heating the vacuum chamber and its contents until said thermally expansible material fuses and impregnates the metalic wool in said casing, cooling said vacuum chamber and its contents to solidify the fused thermally expansible material, removing said casing and metallic wool and thermally expansible material from said vacuum chamber, removing from said casing only

the thermally expansible material in excess of said predetermined amount while leaving said predetermined amount of thermally expansible material in said casing impregnated in said metallic wool, placing a second metallic diaphragm on the other of said shoulders, and spinning the respective flange over said second metallic diaphragm to seal said thermally expansible material in said casing, said predetermined amount by weight of thermally expansible material being an amount determined to produce a predetermined amount of deflection of said metallic diaphragms upon fusion of said thermally expansible material.

6. The method of claim 3 including the step of predetermining the volumetric capacity of said casing from the predetermined amounts by weight of metallic wool and thermally expansible material to be placed therein.

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