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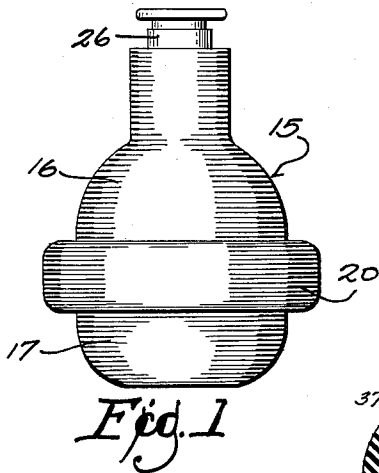
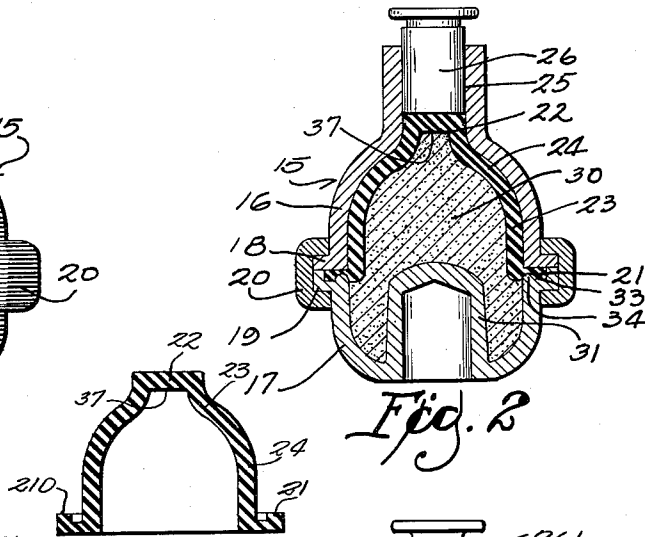
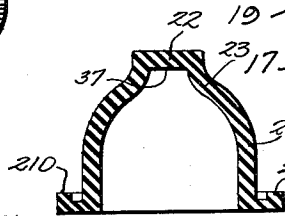
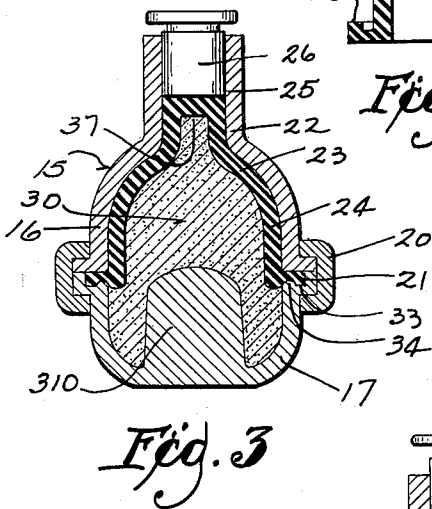
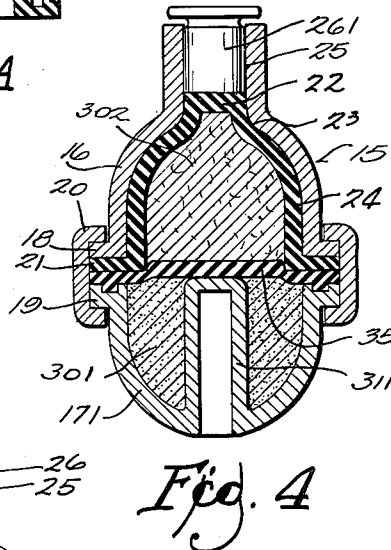
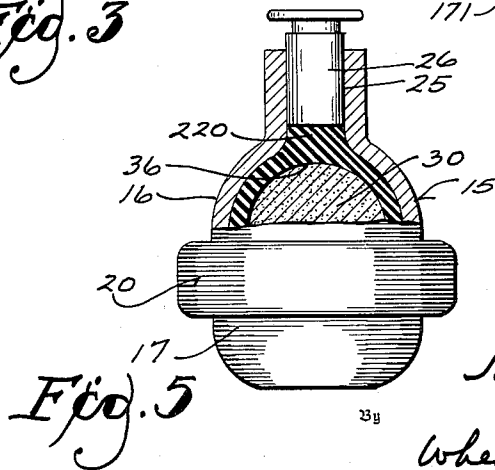
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2,736,604

THERMALLY RESPONSIVE DEVICE

Filed May 15, 1950

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

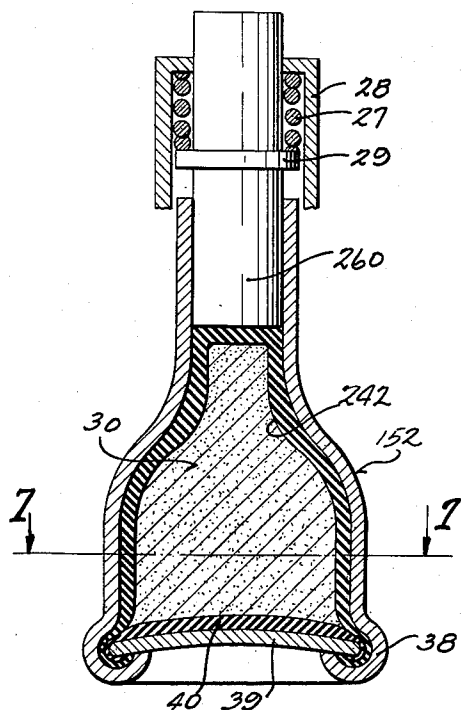


Fig. 6

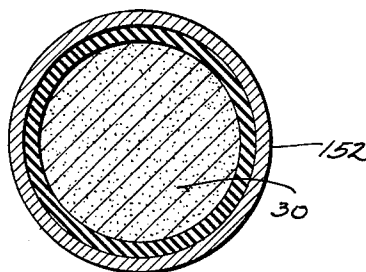


Fig. 7

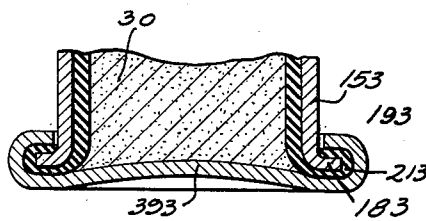


Fig. 8

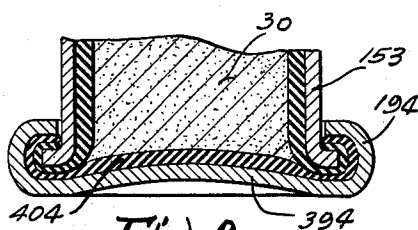


Fig. 9

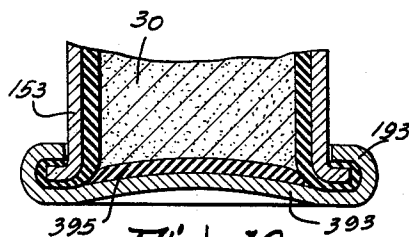


Fig. 10

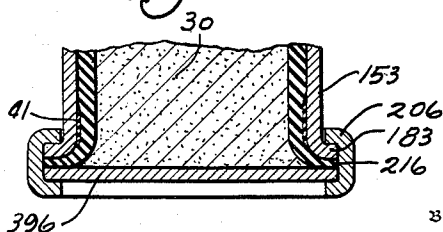


Fig. 11

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2,736,604

THERMALLY RESPONSIVE DEVICE

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13 Claims. (Cl. 297—6)

This invention relates to a thermally responsive device. The present application is a continuation in part of application 55,797, filed October 21, 1948, now Patent No. 2,593,238. Claims divided from the said parent application have been transferred hereto.

As in the said parent application, it is broadly the object of the invention to provide improved means for concentrating the pressure of a substantial body of thermally expansible material on a plunger of relatively small cross sectional area to produce relatively large axial response of the plunger. This application also has in common with its parent application the objective of protecting the diaphragm against destruction which usually follows when a diaphragm is repeatedly subject to bending stress.

In the present case as well as in the parent application above identified, it is sought to prolong the life of the diaphragm by making it in one piece with a deformable liner for at least a portion of the chamber which contains the thermally responsive material, the said chamber having surfaces which taper curvilinearly and reversely from the large diameter of the chamber to the small diameter of the cylinder and the liner being extended from the diaphragm in the cylinder smoothly along the curvilinear surfaces and to a remote anchorage in the chamber.

Objects specific to the present invention include the provision of a skirted diaphragm which desirably extends upwardly into the cylinder and preferably depends primarily upon attenuation rather than deformation to accommodate expansive movement resulting from the expansion of the crystalline material; the provision of a chamber construction in which bridging of the crystalline expansion material in the course of the cooling thereof is prevented and cooling from the center of the mass outwardly is promoted; and the provision of a composition in which the expansion material is distributed throughout a mass of inert material which not only separates but lubricates the crystals as they form to minimize any bridging tendency.

In the drawings:

Fig. 1 is a view in side elevation on a greatly enlarged scale of a device embodying the invention.

Fig. 2 is a view in vertical axial section through the device of Fig. 1.

Fig. 2a is a view in axial section through the combined diaphragm and skirt used in the devices of Fig. 1.

Fig. 3 is a view similar to Fig. 2 showing a slightly modified embodiment of the invention.

Fig. 4 is a view in axial section through another modified embodiment of the invention.

Fig. 5 is a fragmentary detail view partially in side elevation and partially in axial section showing a modified diaphragm and skirt arrangement usable in any of the embodiments herein disclosed.

Fig. 6 is a view in vertical axial section through another modified embodiment of the invention.

Fig. 7 is a view taken in cross section on the line 7—7 of Fig. 6.

Fig. 8 is a fragmentary detail view in axial section

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showing a further modified embodiment of the invention.

Figs. 9, 10 and 11 are views similar to Fig. 8 showing further modified embodiments.

The devices disclosed are not equivalents except in a generic sense, since specifically each has advantages and for most purposes the construction shown in Figs. 1 and 2 is preferred.

The container 15 is made in two parts 16 and 17 having complementary radial flanges at 18 and 19, respectively, these being encircled by a ring 20 of channel-shaped cross section which holds the flanges together under pressure on the intervening flange 21 of a liner for a chamber portion 16 which includes, desirably in one piece, a diaphragm and plug element 22 in the skirt 23 and an intervening portion 24 which is reversely curved in axial section to connect the relatively large diameter of the skirt 23 with the relatively small diameter of the diaphragm or plug 22. This liner is complementary to the inner surface of the chamber element 16, to which it conforms exactly. At the upper end of the chamber portion is a cylinder 25 for plunger 26. The diaphragm of plug portion 22 of the liner is disposed in, and fits the cross section of, the cylinder 25 and abuts the lower end of the plunger 26. In use, the plunger will be subject to the bias of a compression spring such as that shown at 27 in Fig. 6 to be confined between the spring seat cup 28 and a flange 29 on the plunger 26 which is there illustrated. The showing of such a spring has been omitted from the device of Figs. 1 and 2 because the thermostatic unit may be sold without any such spring and derive a return bias for its plunger from the organization in which it is used.

The space within the container 15, and within the liner thereof is completely filled with a thermally expansible material 30. While it is broadly immaterial what the composition of this substance is, various examples being given in the companion application above identified, it is preferred to use, as the active ingredient, a material which is crystalline at atmospheric temperature and which melts at approximately the temperature at which thermostatic response is desired, the melting being accompanied by a substantial increase in volume. Such a material may conveniently comprise paradichlorobenzene. For reasons hereinafter explained, it is desired first, to separate and, secondly, to lubricate or reduce friction between the crystals of the active thermostatic material. For this reason, I prefer to use with the material some inert substance such as powdered chalk plasticized with some oil which in no manner interacts with the paradichlorobenzene or other thermally responsive active ingredients. The amount and character of the inert powder and the oil are not critical. I have used successfully the identical composition of chalk and linseed oil which is used as putty in glazing windows and in which, at a temperature of 130° F. I have stirred paradichlorobenzene until a thorough mixture was effected. In preparing the putty, any other inert powder such as clay or rouge or silica flour may be substituted for the chalk, and such oils as glycerin, any of the polyglycols and any of the lighter silicones may be substituted for the linseed oil.

In practice, I have found the most desirable proportions to be 40% of crystals of paradichlorobenzene or the like and 60% of putty by weight. As above indicated, any other inert material and plasticizer are comprehended within the term "putty." I may use as low as 40% of the selected crystals and 60% of the putty. There is no sharply defined limit, but the length of travel is reduced as the percentage of crystals in the composition is reduced. If I use greatly in excess of 60% of the crystals, I do not obtain full relief from the bridging phenomenon as hereinafter described.

The composition is non-homogeneous, since the crys-

tals may be disposed anywhere in the inert putty. They tend, however, to be quite uniformly distributed throughout the composition when the proportions are within the indicated range.

In the assembly of the parts, the composition is packed into the chamber and inside of the liner under sufficient pressure to eliminate voids.

A thermally conductive post which may be tubular as shown at 31 in Fig. 2, or solid as shown at 310 in Fig. 3, is integral with the base member of the chamber and projects centrally up into the chamber as shown. The purpose of this is to conduct to the outside of the chamber the heat from the body of composition at 30 which fills the chamber. I have found this to be very important in promoting the initial crystallization of the acting thermostatically responsive ingredient at points remote from the upper end of the chamber. I have found that the action in this regard can be slightly enhanced if the surfaces of the post which are exposed to the composition are left somewhat rough instead of being smoothly finished.

Another desirable, though not strictly essential, feature consists in the provision within the flange 19 of the lower chamber element 17 of a channel 33 lying between the outer head of the flange and an annular rib 34 which encircles its inner head. In practice, there is provided between the rib 34 and the opposing flange 18 a clearance of approximately half the thickness of the flange 21 of the rubber liner. Assuming the flange to be .02 inch in thickness, the clearance would be approximately .01 inch in thickness, this spacing being maintained despite actual metal engagement of the flanges at their outer peripheries to prevent the pressure used in closing the chamber from completely severing the flange of the rubber liner. The initial form of the flange 21 of the rubber liner may be such that it also has a marginal rib at 210 (Fig. 2a) which, however, is merely to provide additional stock without necessarily registering with channel 33.

It is not necessary that all of the semi-fluid material within the device comprise the active ingredient or the composition as above described. Fig. 4 shows an organization closely comparable to that of Fig. 2 with the exception that the chamber in Fig. 4 is subdivided by a flexible partition at 35, the margins of which are clamped, along with the flange 21 of the liner 23, between the flange 18 of the upper portion of the shell and the flange 19 of the lower portion thereof. The central conductor post 331 is made tubular, like that of Fig. 2, but has a flat top against which the partition diaphragm 35 is normally seated. The entire lower portion 171 of the shell is filled with the thermally responsive crystalline composition 301 while the upper portion 16 of the shell, above the partition, is filled with an inert semi-fluid material at 302, which may comprise putty or the like, and the function of which is simply to transmit to the plunger 261 the pressure developed by the crystalline powder, and, during contraction, to transmit to the crystalline material the compression to which the plunger 261 may be subject in use. As before, the device is highly sensitive because of the fact that the crystalline thermally responsive material lies in an annular zone having both inner and outer metallic walls through which heat transfer is very rapid.

The operation of the device as thus far described will be summarized in order that the advantages of the construction disclosed may be more fully apparent.

The thermostatic capsule as shown in Fig. 1 may be assumed to be in operation for thermostatically controlling a water valve to effect movement thereof at approximately 130° F. At this temperature, the melting of the crystals of the active thermostatic ingredient of the composition 30 will cause rapid expansion which will attenuate the liner in the upper part of container 15 throughout substantially its entire height from its point

of anchorage at flange 21 to its diaphragm or plug portion 22.

The movement of the plug or diaphragm 22 is communicated to the plunger 26 to effect axial movement thereof. Because a relatively large body of material is expanding into the relatively small cross section of the piston cylinder 25, the plunger will have relatively great movement. Yet it will be observed that the movement of the liner skirt and diaphragm does not involve any flexion across a shoulder or edge, but only flow along curvilinear surfaces. The increase in length of the lining material from the larger cross section of the chamber 16 into the cylinder 25 results in considerable attenuation, but the movement from a large cross section into a smaller cross section involves lateral compression, so that the net result is a deformation or flow of the lining material under circumstances which do not tend to cause fatigue or wear or breakage.

While the form of the chamber 15 is ideal for the protection of the combination liner and diaphragm, and the organization is also ideal in positively precluding any leakage of the thermostatic material outwardly through the cylinder 25, I found unexpected difficulties in the use of some organizations of this kind if such organizations lack means for overcoming a tendency for recrystallization to occur along the wall of the liner while the central core of the composition remains soft. In other words, after the relief of temperatures which have occasioned thermostatic response, the liner and plunger may not tend to return to their original positions, even when subjected to considerable bias, until very substantial drops in temperature have occurred, this being due to the fact that the crystals used tend to form a bridge or dome within the liner, which bridge has considerable strength to reduce further inward movement of the liner and plunger.

The two separate means herein disclosed for meeting the problem have proved entirely successful and both are desirably used, although either one alone is sufficiently successful to be practical. Reference is made, first, to the use of an inert filler or putty as above described, which prevents the crystals from bridging and which facilitates their movement with respect to another when they form, and, secondly, to the provision of the heat conductive post at 31 or 310 which takes the heat out of the center of the body of composition 30 at a rate more rapid than the rate at which heat escapes from the upper portion of the body (which is relatively insulated by the liner). Thus, when the fluid environment of the device becomes cooler, the first formation of crystals tends to be along the inner surface of the uninsulated chamber section 17 and along the surfaces of the post 31 (or 310). Recrystallization of the active thermostatic material at these points results in contraction of such material as has crystallized and this happens while the rest of the active material is still liquid and uncrystallized and, therefore, freely movable downwardly. Recrystallization proceeds from the bottom up and from the center outwardly and thus all portions of the liner remain in contact with liquid material or inert material until recrystallization is complete, the portion of the material nearest the liner being the last to crystallize because the liner has an appreciable thermally insulating effect.

A device of this character has an appreciably greater thermostatic response than devices of the same size which have previously been known or used for this purpose and yet, despite its greater response, its action and reaction curves are as sharp or sharper, the speed of retraction upon recrystallization being particularly great and being complete within a ten degree drop in temperature below the temperature at which expansion occurs.

The device of Fig. 5 differs from that already described only in the fact that the interior of the liner is smoothly dome-shaped at 36, the curvilinear throat portion of the chamber being completely filled with the rubber plug 220, and the cavity extending upwardly throughout the throat

at 37 of Figs. 2, 3 and 4 being completely eliminated. In this construction, there is more rubber to be displaced in the deformation which accomplishes the thermostatic action and the resilience of the rubber provides inherently a strong reactive pressure tending to restore the parts to the original form shown in Fig. 5. In this respect, the construction is similar to that shown in Fig. 1 of the companion application above identified.

Figs. 6 and 7 not only disclose the biasing spring as already described, but also disclose other features which are independently usable:

First, the chamber 152 is lined throughout its height and has an integral bottom flange 38 rolled about a bottom closure 39 which may also be covered by a lining disk 40.

Secondly, the anchorage provided by the rolled flange 38 may, if desired, be supplemented or substituted by an adhesive connection of the liner to the casing in a limited zone at the remote end of the casing, as at 41.

Thirdly, the chamber liner may, as a separate feature, have its throat portion 242 materially thickened as compared with the throat portion 24 of the liner in Figs. 2, 3 and 4.

Fig. 8 differs from the device of Fig. 7 only in that the chamber 153 has an outwardly turned flange at 183 about which the liner flange 213 extends and is anchored by an upwardly rolled flange 193 on the bottom closure 393, the bottom lining 40 being also omitted.

The device of Fig. 9 is identical with that of Fig. 8 except that a liner 404 has been added, the liner being extended outwardly to be clamped by the flange 194 of the bottom closure 394.

The device of Fig. 10 is identical as to its bottom closure with the device of Fig. 8, but it has a liner at 395 which is similar to that shown at Fig. 6 except that it terminates short of the clamping engagement of the flange 193.

In the device of Fig. 11, the bottom closure 396 comprises a disk in clamping engagement with the outturned flange 216 of the liner, the bottom closure and the flange 183 of the receptacle being anchored under clamping pressure of the encircling channeled ring 206. The various forms of closures of the means of clamping and forms of liners are interchangeably usable where their respective advantages may be desired and their respective disadvantages are immaterial. For general purposes, the construction of Figs. 1, 2 and 4 is a preferred construction.

Where reference has been made to rubber, it will be understood that the liner may be made of natural or synthetic rubber, the latter term being intended to include a silicone.

In all forms of the device as hereinafter disclosed, the chamber and liner not only provides a diaphragm which makes a gasket unnecessary, but also provides a seal in the closing of the thermostatic chamber. Where the upper section of the chamber is made of material which may be corroded or otherwise affected by the thermostatic composition used at 30, the liner further protects the metal from such composition. Since the diaphragm portion of the liner is form-sustaining and provides a movable wall confining the composition 30, it will be obvious that any movable part contacting the diaphragm portion of the liner will receive motion therefrom, reference to the plunger being merely illustrative in this regard. It is unnecessary that the plunger be tightly fitted to the cylinder in the sense that a piston is fitted to its cylinder.

I claim:

1. In a thermally responsive device of the character described, the combination with a receptacle having communicating first and second chamber portions with means for securing said chamber portions in abutting relation with respect to each other, the first chamber portion having a cylinder with a plunger guided for extensible move-

ment therealong, said cylinder terminating into a uniformly diverging throat extending into said first chamber portion and diverging into a curvilinear wall portion extending from said throat and forming a curved wall uniformly converging into said cylinder, of an integral form sustaining diaphragm and skirt, the diaphragm extending across said cylinder and being movable therealong and the skirt extending along said throat and wall and preformed to conform to the form thereof and forming a liner therefor, said skirt terminating into an outwardly turned flange extending at substantially right angles to the body thereof and along the end face of said first chamber portion and clamped between the end faces of said chamber portion by said means securing said chamber portions in abutting relation with respect to each other, said second chamber portion being unlined and presenting a metallic heat conducting surface, and a body of thermally expansive material filling said first and second chamber portions within said liner.

2. The device of claim 1 in which said diaphragm is of materially greater thickness than the liner and comprises a plug substantially filling portions of said throat adjacent said cylinder.

3. The device of claim 1 in which the second chamber portion comprises a thermally conductive core about which said body of material is disposed.

4. In a thermally responsive device of the character described, the combination with a receptacle having first and second chamber portions communicating with each other with means for securing said chamber portions in abutting communicating relation with respect to each other, the first chamber portion having a cylinder having a plunger guided for extensible movement therealong and terminating within said chamber into a uniformly curved diverging throat and having a curvilinear wall portion extending from said throat, of an integral form sustaining diaphragm and skirt, the diaphragm extending across said cylinder and being movable therealong and the skirt extending inwardly from said diaphragm along said throat and the wall of said first chamber portion, and being formed to conform to the form of said throat and wall and forming a liner for said first chamber portion, said skirt having an outwardly turned flange extending at substantially right angles to the body thereof, beneath and along the end of said first chamber portion and clamped to the end of said second chamber portion by means for securing said chamber portions together, said second chamber portion comprising a cup shaped chamber providing an unlined metallic surface of concave form and of substantial extent, and a body of thermally expansive material in direct thermal contact with said wall of said second chamber portion and filling said first chamber portion within said liner.

5. In a thermally responsive device of the character described, a hollow two-part receptacle, each part of which has a chamber portion, one chamber portion terminating into a cylinder having a plunger extensibly movable therealong and having a throat diverging from said cylinder and uniformly curving into a generally cylindrical wall, the other chamber portion being of a generally cup-like form and abutting and closing the end of the cylindrical wall of said one chamber portion, a diaphragm in said cylinder engaging said plunger and having a preformed skirt formed to the curvature of said throat and wall extending from said diaphragm along said throat and cylindrical wall and forming an insulating medium for said one chamber portion, a body of thermally expansive material filling said chamber portions, and the other chamber portion having a thermally conductive post extending upwardly into the body of thermally conductive material and with the wall of said other chamber portion forming an annular thermally conductive channel for the thermally expansive material, conducting heat from the thermally expansive material upon cooling and precluding bridging of the crystals of the thermally ex-

pansible material as the material changes in state from liquid to solid.

6. In a thermally responsive device of the character described, a hollow two-part receptacle, each part of which has a chamber portion, one chamber portion terminating in a cylinder having a plunger extensibly movable therealong, and having a throat forming an inner continuation of said cylinder and uniformly curving from said cylinder into a generally cylindrical wall, the other chamber portion being of a generally cup-like form, a diaphragm extending across said cylinder and engaging said plunger and having an integral preformed skirt extending therefrom, conforming to said throat and the wall thereof, and forming an insulating medium for said one chamber portion and having a flange extending along the end of the cylindrical wall of said one chamber portion in abutment with the end of the other chamber portion and secured thereto by the means for securing said chamber portions together, a body of thermally expansible material filling said chamber portions comprising crystals expandable on melting and contractable on crystallization, the inner wall of said other chamber portion being metallic, and means precluding the bridging of the crystals of the thermally expansible material upon changes in state thereof from a liquid to a solid, comprising a hollow post extending upwardly into the other chamber portion and with the inner wall of said other chamber portion forming a metallic annular channel adapted to conduct heat from the thermally expansible material.

7. The device of claim 6 in which said post is solid.

8. A thermostat comprising a casing with fixed wall portions defining a cavity of relatively large cross-section and converging at one end to a reduced diameter cylinder extending therefrom having a diaphragm extending across said cylinder and forming a movable wall portion of said chamber and lining a portion of the wall of said cavity and forming an insulating means therefor and movable along said cylinder upon predetermined increases in temperature, the other portion of the wall of said cavity being metallic, a body of thermostatically expansible material in said casing confined by said wall portions for effecting movement of said diaphragm along said cylinder upon expansion of said body, said thermally expansible material comprising a normally crystalline substance distributed in a putty of finely divided powder and an oil which expands as it melts, and means for precluding the bridging of the crystals of said substance across said diaphragm upon cooling and recrystallization thereof comprising a metallic thermally conductive core extending within said cavity and terminating in a region remote from said diaphragm and conducting heat from said cavity and forming with said cavity an annular metallic channel about which crystals tend to form.

9. The combination with a two-part receptacle, the respective parts having flanged margins and clamping means securing said margins, one of said parts having a cylinder portion of materially reduced cross section as compared with the receptacle, a flexible partition spanning the receptacle between said parts and having its margins confined between the flanges of said parts, a flexible and resiliently elastic liner having a flange confined between the flanges of said parts and having a wall portion conforming interiorly to the wall of the receptacle part provided with the cylinder, said liner terminating in a wall disposed transversely of the cylinder, a body of at least plastic semi-fluid material confined within said liner and partition and wall portion to substantially fill the space between the wall portion and the liner in the part of said receptacle provided with said cylinder, and a thermally expansible material comprising crystals confined in and substantially filling the other part of said body and separated from the first mentioned material by said partition.

10. The device of claim 9 in which the said other part of the receptacle has a metallic wall and a core portion

connected with said wall and comprising a metal of a high thermal conductivity and extending into the crystal material.

11. The device of claim 10 in which said partition normally seats upon the core portion in the contracted state of the crystalline material.

12. In a thermally responsive device of the character described, the combination with a receptacle having first and second chamber portions communicating with each other with means for securing said chamber portions in abutting communicating relation with respect to each other, the first chamber portion having a cylinder having a plunger guided for extensible movement therealong and terminating within said chamber into a uniformly curved diverging throat and having a curvilinear wall portion extending from said throat, of an integral form sustaining diaphragm and skirt, the diaphragm extending across said cylinder and being movable therealong and the skirt extending inwardly from said diaphragm along said throat and the wall of said first chamber portion, and being formed to conform to the form of said throat and wall and forming a liner for said first chamber portion, said skirt having an outwardly turned flange extending at substantially right angles to the body thereof, beneath and along the end of said first chamber portion and clamped to the end of said second chamber portion by the means for securing said chamber portions together, said second chamber portion comprising a cup-shaped element having an unlined annular chamber therein for a body of thermally expansible material, and the thermally expansible material filling said unlined chamber portion and filling said second chamber portion within said liner.

13. In a thermally responsive device of the character described, a hollow two-part receptacle, each part of which has a chamber portion, one chamber portion terminating in a cylinder having a plunger extensibly movable therealong, and having a throat forming an inner continuation of said cylinder and uniformly curving from said cylinder into a generally cylindrical wall, the other chamber portion being of a generally cup-like form, a diaphragm extending across said cylinder and engaging said plunger and having an integral preformed skirt extending therefrom, conforming to said throat and the wall thereof, and forming an insulating medium for said one chamber portion and having a flange extending along the end of the cylindrical wall of said one chamber portion in abutment with the end of the other chamber portion and secured thereto by the means for securing said chamber portions together, a body of thermally expansible material filling said chamber portions comprising crystals expandable on melting, and contractible on crystallization, the inner wall of said other chamber portion being metallic, and means precluding the bridging of the crystals of the thermally expansible material upon changes in state thereof from a liquid to a solid comprising a metallic annular channel in the other of said chambers, the inner wall of which conducts heat from the thermally expansible material.

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