

Sept. 26, 1961

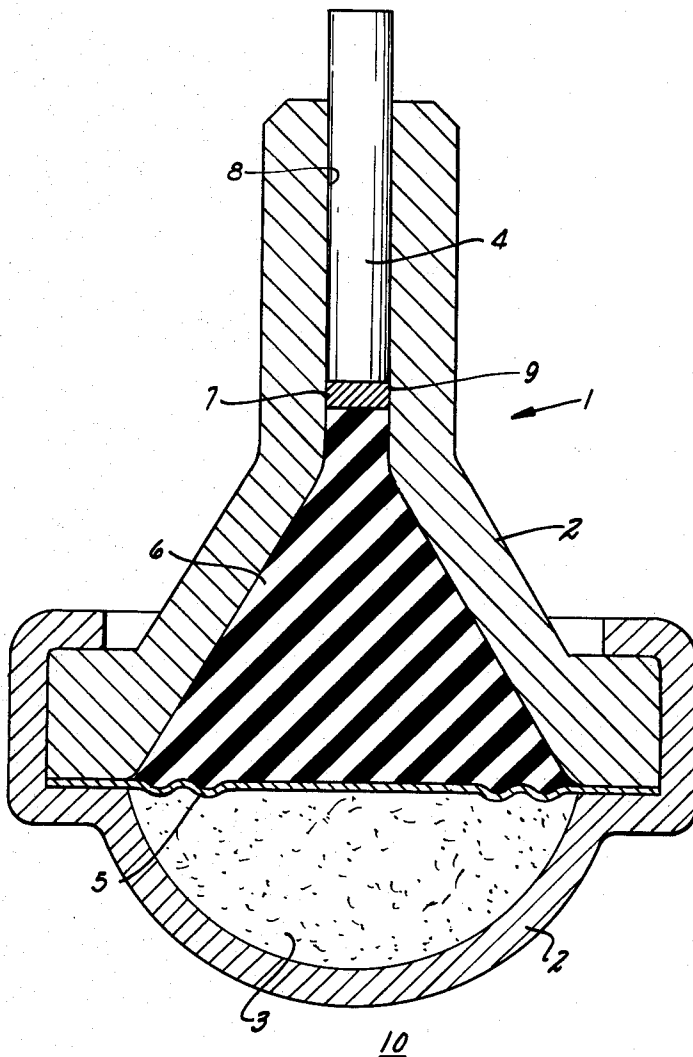
S. VERNET ET AL
MULTI-RANGE EXPANSION MATERIAL

3,001,401

Filed July 11, 1956

3 Sheets-Sheet 1

FIG. 1



INVENTORS
SERGIUS VERNET
JAMES FAY CORWIN
GEORGE ASAKAWA
BY
SMITH, OLSEN, LEWIS & McRAE
ATTORNEYS

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S. VERNET ET AL

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FIG. 2

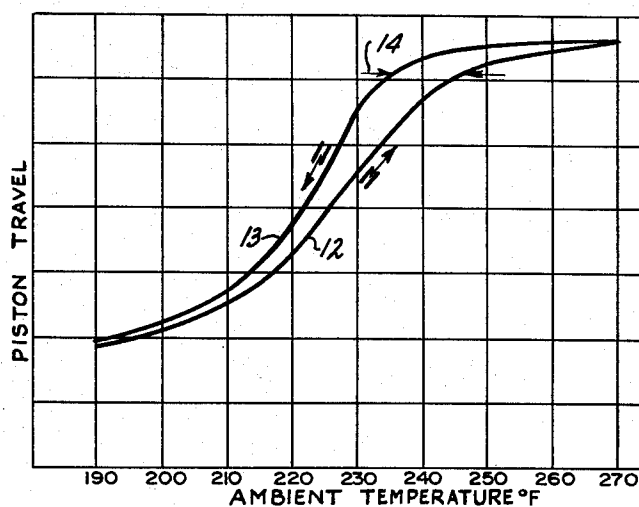
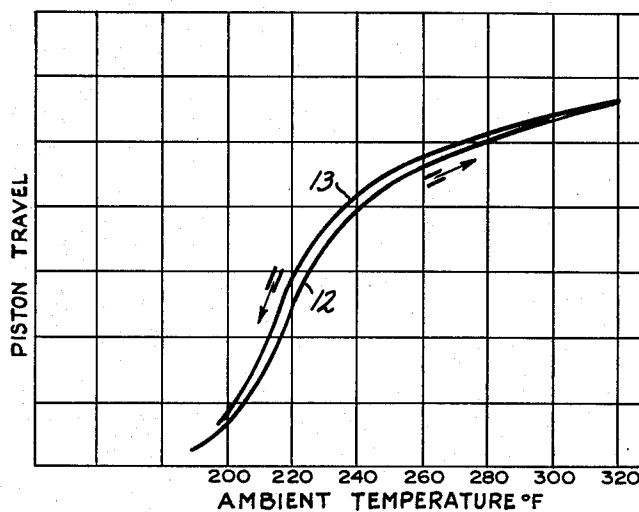


FIG. 3



INVENTORS
SERGIUS VERNET
JAMES FAY CORWIN
GEORGE ASAKAWA
BY SMITH, OLSEN, LEWIS & McRAE
ATTORNEYS

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S. VERNET ET AL

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FIG. 4

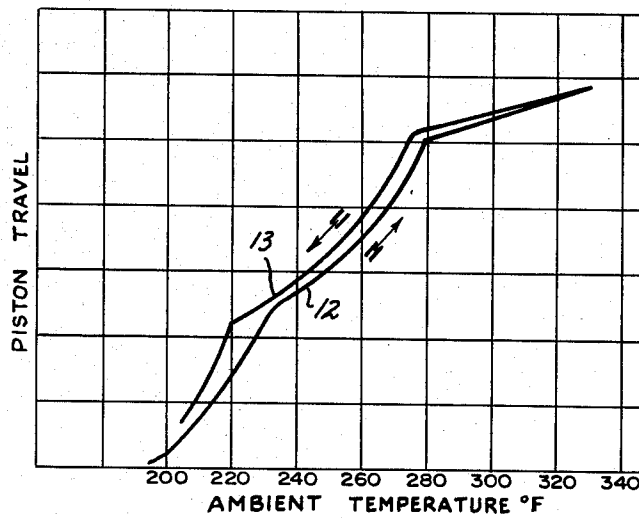
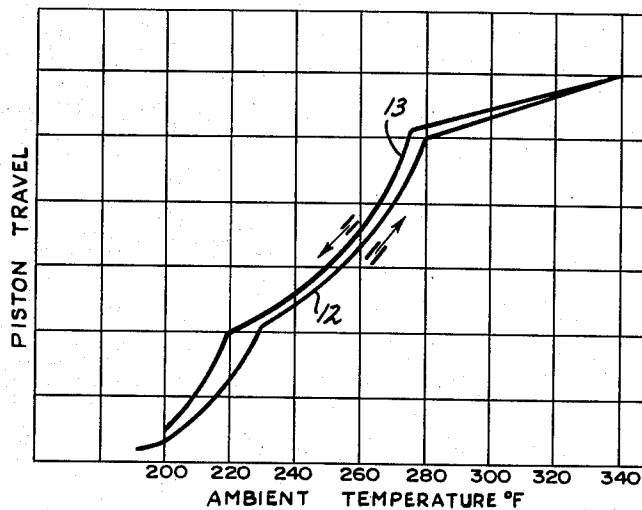


FIG. 5



INVENTORS
SERGIUS VERNET
JAMES FAY CORWIN
GEORGE ASAKAWA
BY
SMITH, OLSEN, LEWIS & McRAE
ATTORNEYS

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3,001,401

MULTI-RANGE EXPANSION MATERIAL

Sergius Vernet, James Fay Corwin, and George Asakawa,
Yellow Springs, Ohio, assignors, by direct and mesne
assignments, to Antioch College, Yellow Springs, Ohio,
a corporation of Ohio

Filed July 11, 1956, Ser. No. 597,293

8 Claims. (Cl. 73-358)

This invention relates to thermally expansible materials, and to power elements of the type disclosed in copending patent applications, Serial No. 551,829 filed on December 8, 1955, and Serial No. 510,078 filed on May 24, 1955, now abandoned. Such power elements are commonly employed to operate switches and valves.

Objects of the invention are to provide power elements employing "solid to liquid" type expansion materials; wherein the expansion materials have good resistance to chemical decomposition at elevated temperatures, and the expansion materials include mixtures of materials which in some instances undergo a plurality of separate relatively large expansions in a temperature range from about 200° F. to about 300° F.

Other objects of this invention will appear in the following description and appended claims, reference being had to the accompanying drawings forming a part of this specification wherein like reference characters designate corresponding parts in the several views.

In the drawings:

FIG. 1 is a sectional view through a power element incorporating the invention.

FIG. 2 is a performance chart of a power element utilizing a paraffin wax; wherein the position of the power element piston is plotted against ambient temperature.

FIG. 3 is a performance chart of a power element utilizing 50% paraffin wax and 50% tetrachlorobenzene.

FIG. 4 is a performance chart of a power element utilizing 37% paraffin wax and 63% tetrachlorobenzene.

FIG. 5 is a performance chart of a power element utilizing 25% paraffin wax and 75% tetrachlorobenzene.

Before explaining the present invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also, it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

In the drawings there is shown a power element 1 including a casing 2, a body or pellet of thermally expansible material 3, a movable wall or piston 4, a corrugated stainless steel diaphragm 5, and a body of pliable force-transmitting material 6. Material 6 is preferably the pliable material disclosed in copending application, Serial No. 583,881, filed May 9, 1956. A disc 7 of polytetrafluoroethylene is positioned between material 6 and piston 4 in order to prevent material 6 from extruding into the clearance space 9 between piston 4 and bore 8. A spring (not shown) is provided for returning piston 4 to its illustrated position during contractive movement of material 3.

Operation of the power element is such that during temperature increase in ambient atmosphere 10 material 3 expands against diaphragm 5 so as to force material 6 upwardly in bore 8 and thereby propel piston 4 outwardly against the aforementioned spring. During temperature decrease in atmosphere 10 material 3 contracts so as to allow the spring to return piston 4 downwardly to its illustrated position.

Material 3 is preferably a straight chain paraffin wax having a molecular weight above 400 or a mixture of said

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wax with 1,2,4,5 tetrachlorobenzene. Preferably discrete particles of a good heat conductor such as copper are dispersed through material 3 to quickly and evenly transmit heat through the pellet.

FIG. 2 illustrates the performance of the power element when material 3 is composed entirely of a straight chain paraffin wax having a molecular weight above 400. This straight chain paraffin wax gives a comparatively large total expansion, which for many applications is very desirable. The large total expansion is believed to be due primarily to the "straight chain" character of the wax. Branched chain paraffin waxes tend to give lower total expansions because the "branches" on the chains are believed to interfere with one another so as to produce a rather loosely packed molecular arrangement when the wax is in the solid state; as a result of this loose molecular packing a relatively small number of molecules are available for expansion, and the total volumetric expansion is therefore relatively low. The straight chain molecules on the other hand do not obstruct one another, and they therefore tend to pack closely together in the solid state so as to give a comparatively high volumetric expansion during temperature increase.

There is an advantage in using straight chain waxes with molecular weights above 400. It has been found that when mixtures of lower molecular weight waxes (i.e. around values of 200) are employed the melting point tends to be undesirably depressed (as compared with the melting points of the component waxes in their pure state) when there is a substantial variation in the chain length of the component waxes; also the expansion characteristics of such low molecular weight mixtures are poor. The undesired characteristics appear to be a function of the variation in chain length as compared with the lengths of the chains. When mixtures of high molecular weight waxes are employed the effect of variation in chain length is relatively slight because of the relatively long length chains. The straight chain paraffin waxes with molecular weights above 400 have the further advantage that they are much more resistant to chemical decomposition at elevated temperatures than the branched chain paraffin waxes.

FIG. 3 illustrates the performance of the power element when material 3 is composed of a mixture of 50% by weight straight chain wax having a molecular weight above 400 and 50% by weight of 1,2,4,5-tetrachlorobenzene. The molecular shape of tetrachlorobenzene would seem to prevent it from mixing satisfactorily with the paraffin wax. Yet, as indicated by FIG. 3, an equal weight mixture of the two materials produces a relatively large total expansion over a relatively small temperature range. Additionally the hysteresis is relatively low at the higher temperatures. The term "hysteresis" will be understood as a measure of the expansion material's ability to contract immediately when the ambient temperature is initially increased and then decreased. During temperature increase material 3 expands substantially in accordance with the position of piston 4 as indicated by line 12 in FIG. 3. During temperature decrease material 3 follows substantially along line 13. In FIG. 3 only about a two degree decrease in temperature is required to transfer material 3 from line 12 to line 13, whereas in FIG. 2 an eleven degree decrease in temperature (see arrows 14) is required to transfer material 3 from line 12 to line 13. In other words the FIG. 3 material has about a two degree hysteresis and the FIG. 2 material has about an eleven degree hysteresis (at the upper end of the curve). This difference in the hysteresis is believed to be due primarily to the fact that the FIG. 2 material is a pure material, whereas the FIG. 3 material is a mixture of different materials. Apparently the pure material undergoes

a certain amount of supercooling during temperature decrease, whereas the mixture of materials provides seed crystals to prevent such supercooling. Thus the tetrachlorobenzene crystals are thought to act as seeding crystals for the wax.

It was mentioned earlier that logically the tetrachlorobenzene should not mix satisfactorily with the wax. Yet, as can be seen from FIG. 3, an equal weight mixture of the two materials produces a very smooth, steep expansion curve with a relatively large total expansion. It is believed that the wax molecules form crystals and the tetrachlorobenzene molecules form other crystals so as to provide an "eutectic" type crystalline material; i.e. a material wherein crystals of wax exist separately from crystals of tetrachlorobenzene, with each type of crystal insoluble in the other and with no molecular mixing of the wax molecules and tetrachlorobenzene molecules. Apparently the expansion material undergoes two separate melting stages. First the wax melts and then the tetrachlorobenzene melts, with the expansion curve of the tetrachlorobenzene merely added or appended to that of the wax. When equal weight amounts of the wax and tetrachlorobenzene are employed the tetrachlorobenzene crystals are apparently in just the correct amounts to carry the total expansion along the smooth, steep line 12 (FIG. 3).

FIG. 4 illustrates the performance of the power element when material 3 is composed of a mixture of 37% by weight straight chain paraffin wax having a molecular weight above 400 and 63% by weight of 1,2,4,5 tetrachlorobenzene. The existence of two separate melting stages gives the power element two relatively steep but separate motions; i.e. a first relatively steep motion between 210° and 230°, and a second relatively steep motion between about 250° and 280°.

FIG. 5 illustrates the performance of the power element when material 3 is composed of a mixture of 25% by weight straight chain paraffin wax having a molecular weight above 400 and 75% of 1,2,4,5 tetrachlorobenzene. This mixture gives substantially the same type performance curve as the FIG. 3 material.

During the foregoing specification the expansion materials have been described with reference to their use in power elements of the type which are responsive to ambient temperature change. It is contemplated however that the expansion materials could be employed with power elements of the type which are responsive to variations in electric current, as for example the power elements disclosed in aforementioned application, Serial No. 551,829. It will be understood therefore that the term "power element" as used herein refers to both temperature responsive mechanisms and electric current responsive mechanisms.

We claim:

1. A power element comprising a container and connected sleeve; thermally expansible material within said container; a metal diaphragm sealing the expansible material in the container; a piston in said sleeve; and a force-transmitting material between the diaphragm and piston; said force-transmitting material being operable at temperatures in the neighborhood of 250° F.; and said thermally expansible material being a mixture of 1,2,4,5 tetrachlorobenzene and a straight chain paraffin wax having a molecular weight above 400, the tetrachlorobenzene and paraffin wax each accounting for a substantial percentage of the weight of the thermally expansible material.
2. The combination of claim 1 wherein the tetrachlorobenzene and wax each account for about one-half the weight of the thermally expansible material.
3. The combination of claim 1 wherein the tetrachlorobenzene accounts for about 63% of the weight of the thermally expansible material.
4. The combination of claim 1 wherein the tetrachlorobenzene accounts for about 75% of the weight of the thermally expansible material.
5. A thermostatic power element component formed as a solid three dimensional expansion pellet; said pellet comprising expansion material and a network of heat conducting material extending substantially evenly therein; said expansion material being formed as a mixture of 1,2,4,5 tetrachlorobenzene and a straight chain paraffin wax having a molecular weight above 400, the tetrachlorobenzene and wax each accounting for a substantial percentage of the weight of the expansion material.
6. A combination of claim 5 wherein the tetrachlorobenzene and wax each account for about one-half the weight of thermally expansible material.
7. A combination of claim 5 wherein the tetrachlorobenzene accounts for about 63% of the weight of the thermally expansible material.
8. The combination of claim 5 wherein the tetrachlorobenzene accounts for about 75% of the weight of the thermally expansible material.

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