United States Patent

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[54] **TEMPERATURE ADAPTABLE FABRICS**
10 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **161/77,**
161/79, 161/159, 161/168, 161/178, 161/407, 161/410
[51] **Int. Cl.** **D01d 5/24**
[50] **Field of Search** 161/172, 178, 159, 72, 407, 410, 77, 79, 168; 752/305; 73/368.2; 264/209

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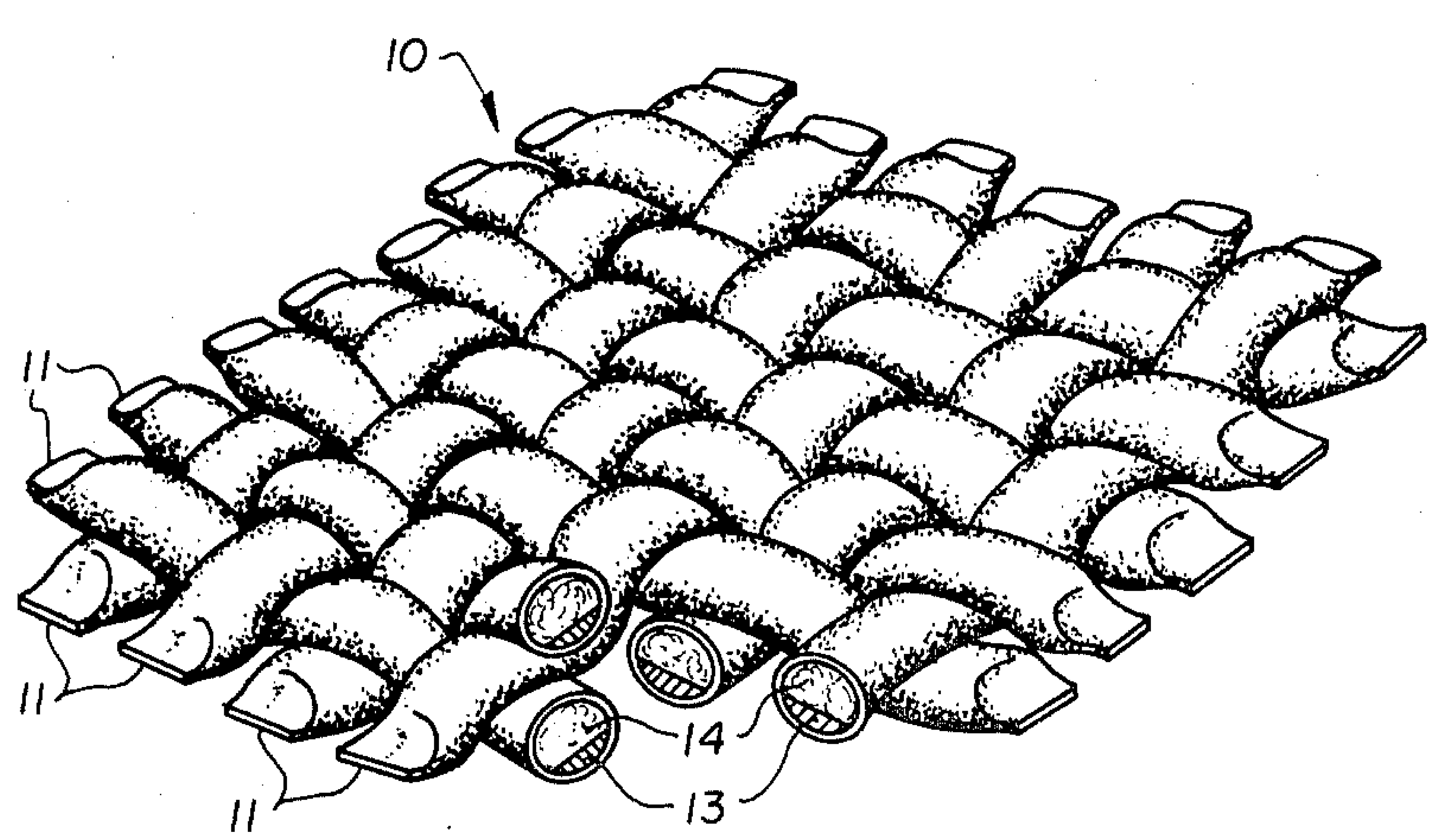
ABSTRACT: This invention relates to novel fabrics characterized by thermal insulation properties which change in response to changes in environmental temperature. The fabrics contain hollow inflatable elements having entrapped therein a gas and a solvent material which can be converted from liquid to solid phase by temperature changes within the environment of usage, said solvent material dissolving more of the gas when in the liquid phase than in the solvent phase. The elements contain more gas than can be dissolved by the solvent material within the elements when this material is in the solid phase and thus lowering the environmental temperature, so as to convert said material from the liquid to the solid phase, results in the expulsion of gas formerly dissolved in the liquid phase. The expelled gas inflates the inflatable elements within the fabric and increases the thermal-insulating properties of the fabric.



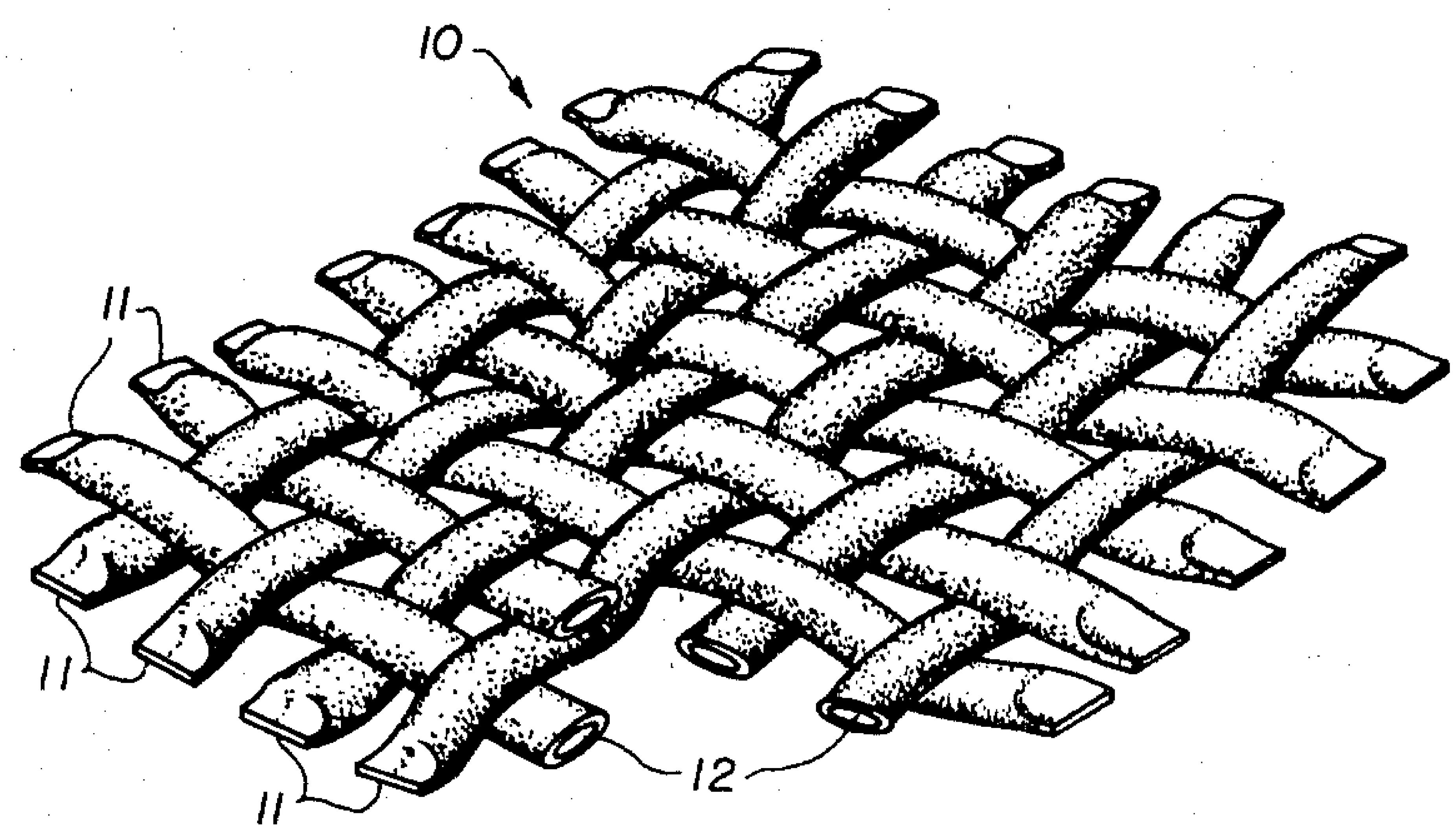


FIG. 1

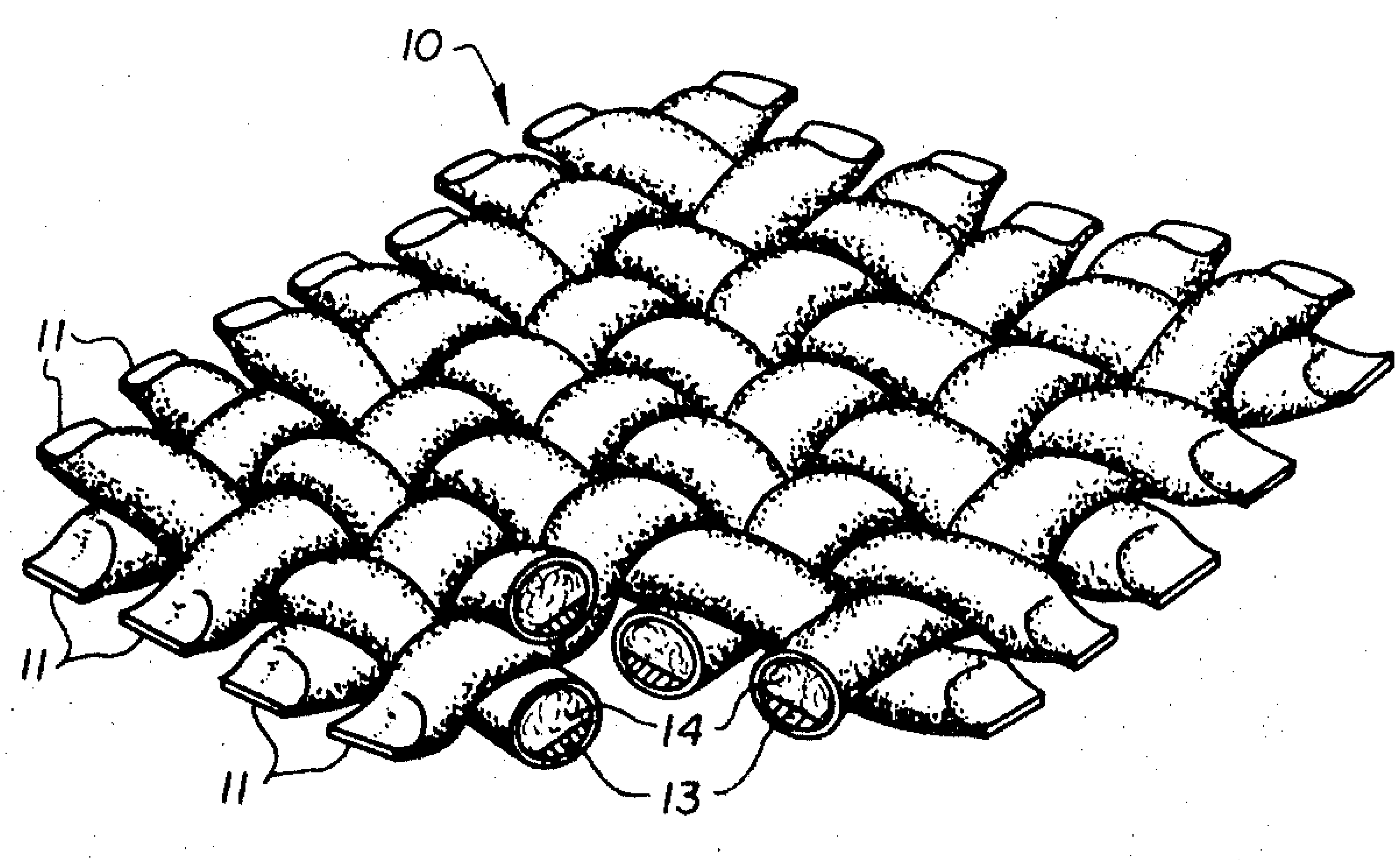


FIG. 2

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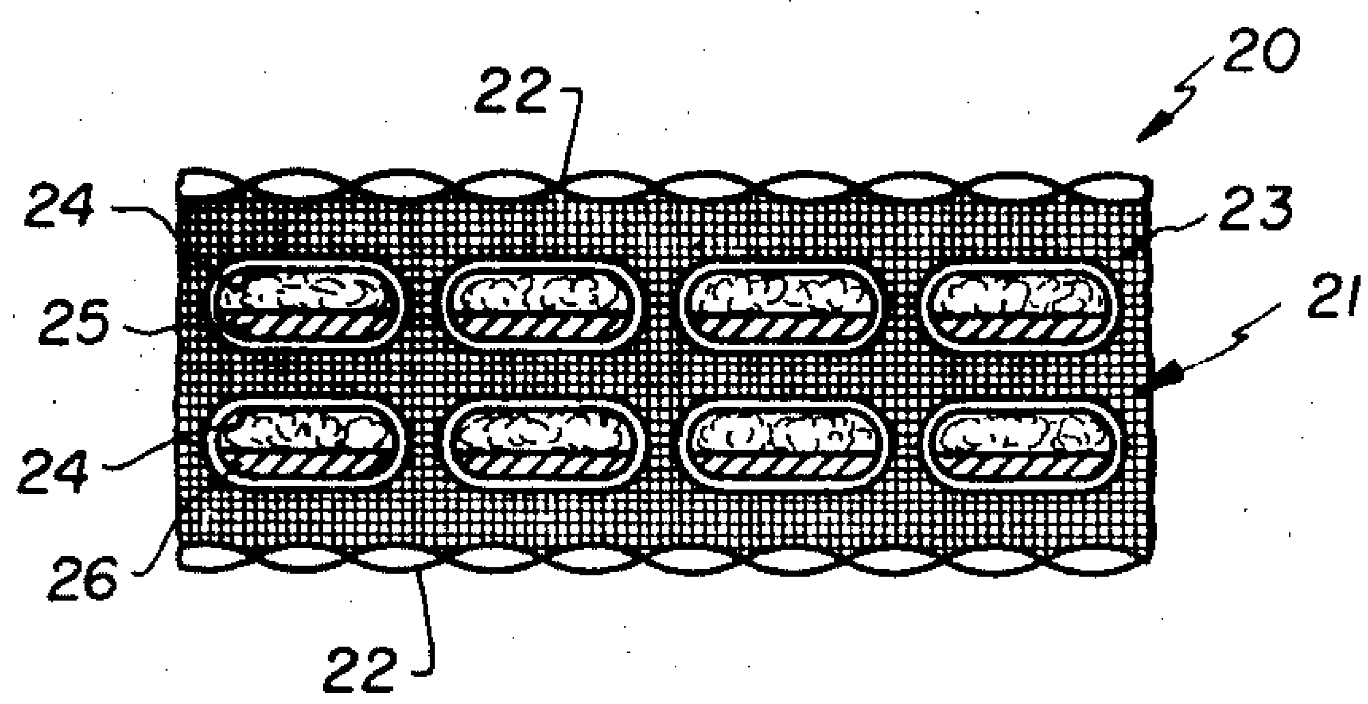
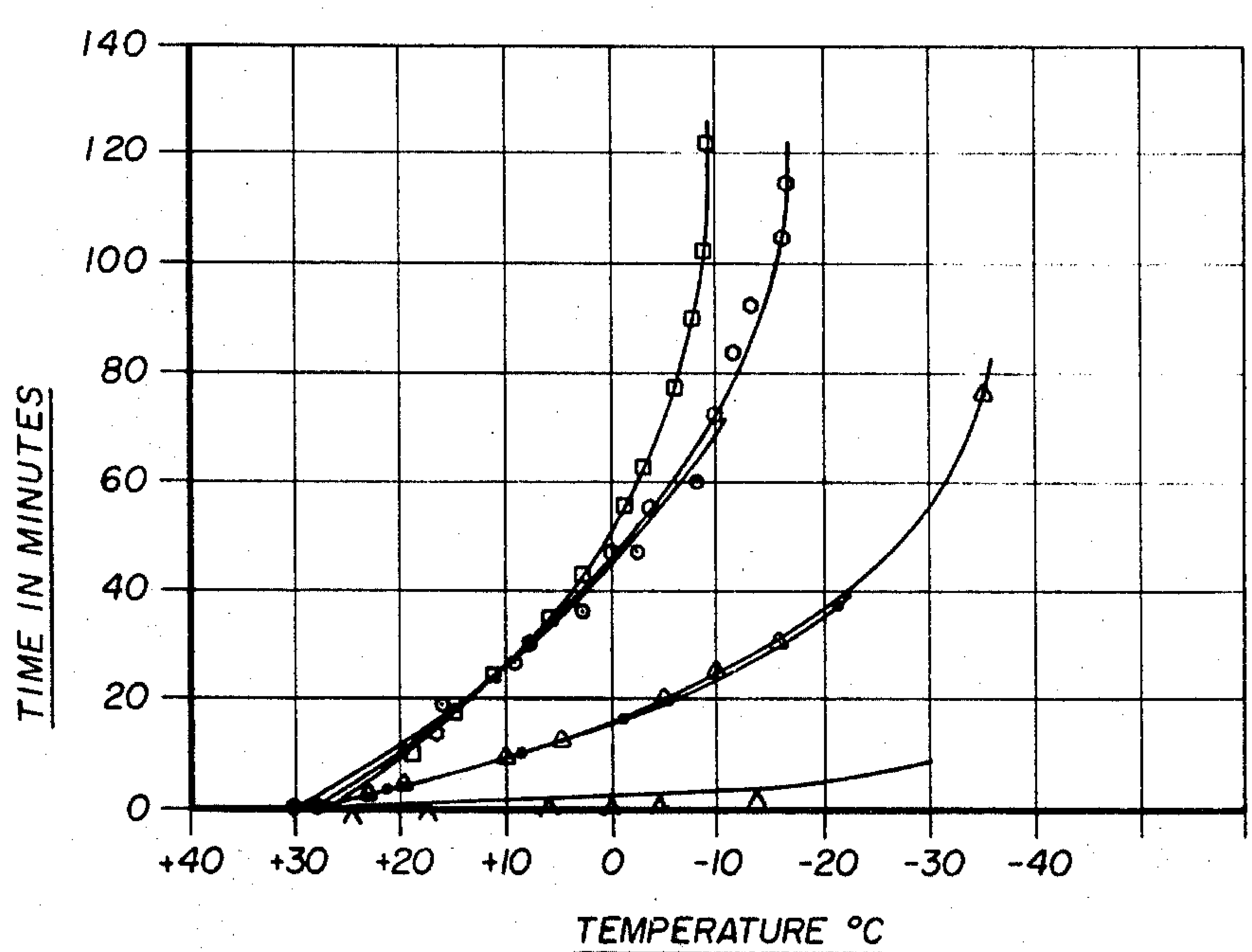


FIG. 3

FIG. 4



COMPOSITION IN FILAMENTS

- • EMPTY
- △ ACETOPHENONE
- ⊙ ACETOPHENONE AND MONOCHLORODIFLUOROMETHANE, 1st RUN
- ⊡ ACETOPHENONE AND MONOCHLORODIFLUOROMETHANE, 2nd RUN
- ⊙ ACETOPHENONE AND CO_2
- ^ COPPER BLOCK IN DIRECT CONTACT WITH ALUMINUM PLATE

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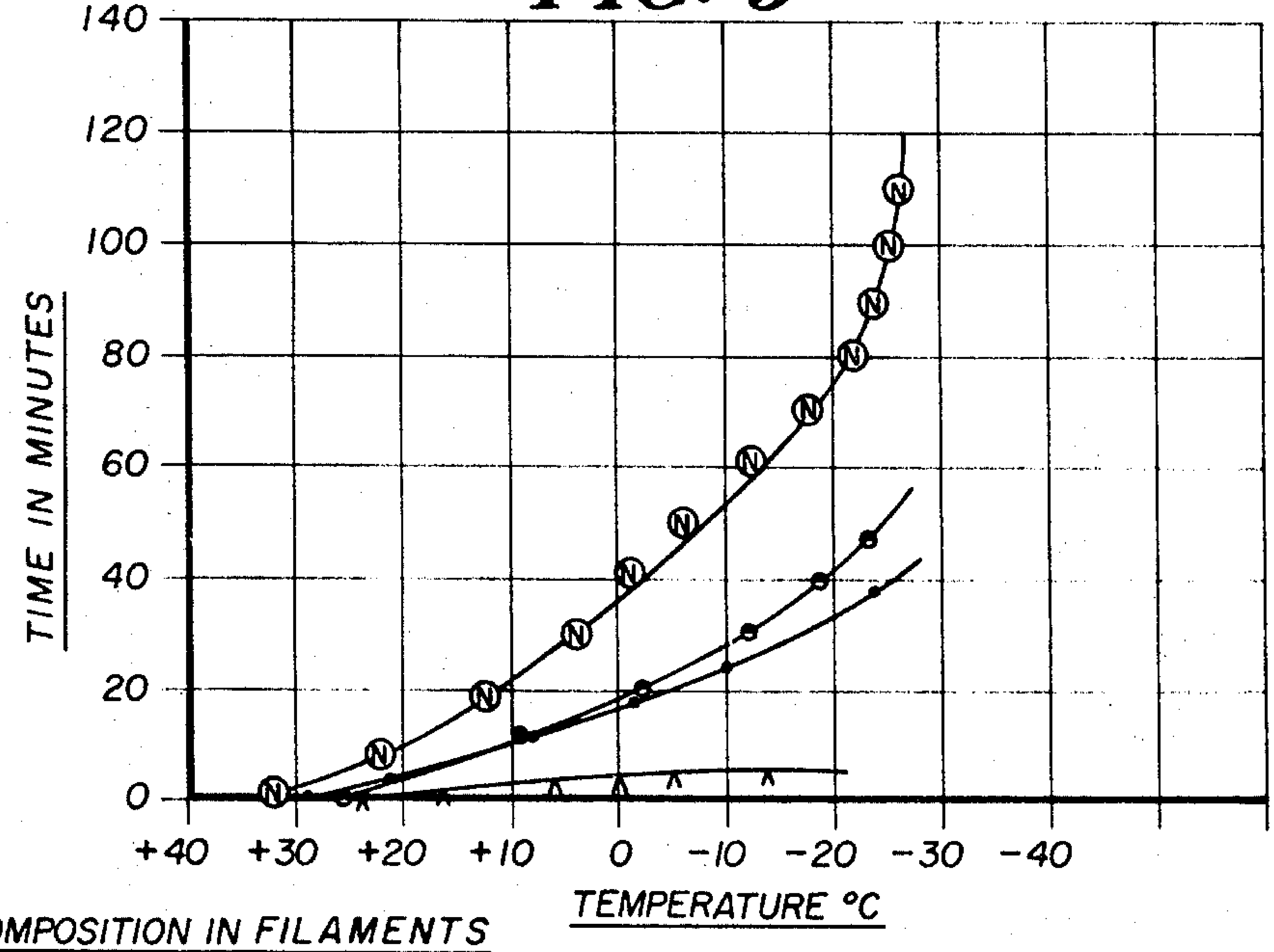
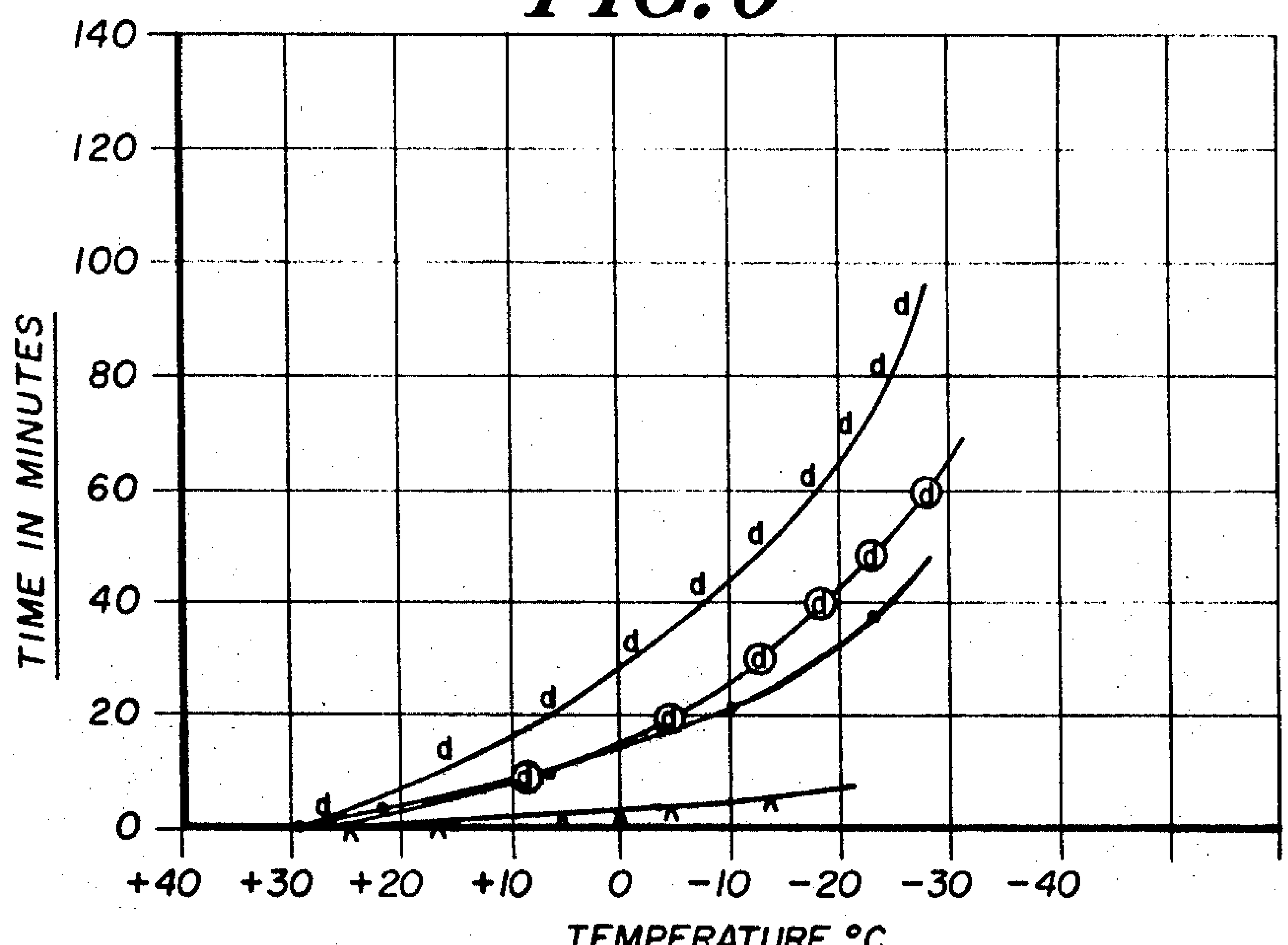
FIG. 5



COMPOSITION IN FILAMENTS
- • EMPTY
- • n-OCTADECANE
- Ⓝ n-OCTADECANE AND MONOCHLORODIFLUOROMETHANE
- ∧ COPPER BLOCK IN DIRECT CONTACT WITH ALUMINUM PLATE

FIG. 6



COMPOSITION IN FILAMENTS
- • EMPTY
- ⓓ 1,2-DIBROMOETHANE
- d 1,2-DIBROMOETHANE AND MONOCHLORODIFLUOROMETHANE
- ∧ COPPER BLOCK IN DIRECT CONTACT WITH ALUMINUM PLATE

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TEMPERATURE ADAPTABLE FABRICS

Fabrics are frequently used to provide thermal insulation such as in clothing, blankets, drapes, sleeping bags, etc. Fabrics previously employed in such products have thermal insulation properties which are substantially constant over the temperature range of usage and thus cannot compensate for the different insulation requirements desired at different temperatures. Thus, for instance, a coat which is comfortable under mild conditions provides insufficient warmth if the temperature drops, while a coat comfortable at a cold temperature is uncomfortably warm if the temperature rises.

The fabrics provided by the present invention are characterized by thermal insulation properties which substantially increase in response to a colder environment To obtain such thermal insulation properties, the fabric is provided with inflatable elements having entrapped therein a composition containing a gas and a solvent material which dissolves more gas when in the liquid state than when in the solid state. More gas is contained in the elements than the solvent material can dissolve when in the solid state and thus on converting the solvent material from a liquid to a solid, gas is expelled, inflating the elements and increasing the thermal insulation properties of the fabric. Additionally, the fabric can be constructed so that inflation of the elements reduces the transmission of air or moisture vapor through the fabric which also makes the fabric warmer. The material in which the gas is dissolved is selected so that the liquid solution employed solidifies when cooled to about the temperature at which a increase in thermal insulation is desired. By using separate elements containing different compositions solidifying at different temperatures, a fabric can be obtained in which thermal insulation properties are increased in stages as temperature is progressively decreased. When the environmental temperature is increased the above-described process reverses and gas is redissolved when the solvent melts. The invention will be more readily understood when the following detailed description is read in conjunction with the accompanying drawings. The drawings illustrate two forms of the invention, it being apparent from the present description that many other forms can be constructed by a person skilled in the art which fall within the scope of this invention.

FIG. 1 is a perspective view of an embodiment of the present invention in which the inflatable elements are hollow filaments woven into a fabric and the environmental conditions are such that the composition within the elements is in the form of a liquid solution.

FIG. 2 is a perspective view of the embodiment of FIG. 1, cooled so that the solvent has frozen, expelling gas which has inflated the hollow tubes.

FIG. 3 is an enlarged cross-sectional view of an embodiment of this invention, shown in the unexpanded state, this embodiment being a composite material having woven outer layers and a nonwoven inner layer having embedded therein inflatable envelopes containing two different liquid gas solutions which freeze at different temperatures.

FIGS. 4–6 are graphs illustrating the increased thermal insulation obtained by the present invention.

Referring now to FIG. 1, there is shown a woven fabric **10**, formed of hollow inflatable filaments **11**. The filaments contain a solution **12** of a gas in a liquid solvent, which dissolves more of the gas when in a liquid state than when frozen to the solid state. The amount of gas is greater than that which the solvent will dissolve in the solid state.

FIG. 2 shows the fabric of FIG. 1, after it has been cooled so as to freeze the solvent to a solid material **13**. Gas **14** has been expelled as a result of the freezing and has inflated the filaments **11**.

In FIG. 3 there is shown another embodiment illustrative of the present invention. The embodiment of FIG. 3 is a composite material **20** having outer layers of woven fabric **22** and a nonwoven inner layer **21**. The inner layer **21** is made up of fibers **23** having embedded therein inflatable envelopes **24**. Some of the envelopes contain a first solution of a gas in a liquid **25** solvent while the remainder of the envelopes contain a second solution of a gas and a liquid solvent **26**, the two solutions being selected so that the solvents freeze at different temperatures, thus giving a stepwise increase of thermal insulation properties as the environmental temperature becomes colder.

The inflatable hollow elements can be in the form of sealed hollow filaments, envelopes, capsules or any other configuration suitable for incorporating an inflatable body within a fabric material. The fabric can be a woven material formed wholly or partly from sealed hollow filaments such as shown in FIGS. 1 and 2. These hollow filaments can be crimped or sealed at intervals so as to retain the solution in each filament within a number of sections. Instead of monofilaments, yarn produced from a plurality of relatively small diameter hollow filaments can be used. The fabric can also be a nonwoven material into which there is incorporated inflatable elements in the form of hollow filaments, envelopes, capsules or other configurations or a fabric of any other type which can have inflatable elements embedded therein or attached thereto. The term fabric as employed herein is not limited to materials prepared from fibers, but also include other known flexible materials used or worn to provide environmental protection such as flexible plastic-foam sheets useful as inner linings. The material containing the inflatable elements can be part of a composite or laminated structure such as shown in FIG. 3. It is to be understood that the figures and the above discussion illustrate only a small number of the possible fabrics falling within the scope of the present invention and many other structures embodying this invention will be apparent from the present description.

The material from which the inflatable elements are made is not critical, it only being required that the material be capable of retaining the particular solvents and gases employed, and be capable of providing an inflatable structure. Included among the materials from which the elements can be made are a wide variety of plastic and elastomeric materials. On inflation, the elements may change in shape, such as the elements of FIGS. 1 and 2 going from flat to round and/or may expand in size in the manner of a balloon. The term inflatable elements is also meant to include elements which on being subjected to increased internal pressure, change shape without a significant change in volume. Thus, the inflatable elements can have a curved or zigzag shape which flattens out with increased internal pressure, for example, in the manner of a Bourdon tube, to reduce the porosity of the fabric.

As previously stated, a requirement of the solvent-gas system is that the solvent material dissolves more of the gas when in a liquid state than in the solid state so that upon solidifying the solvent by freezing, the gas is expelled from the solution. This type of solubility behavior is possessed by most solvents and mixtures of solvents and can be readily determined by one skilled in the art. In particular, solvents which form crystalline solids on freezing, generally dissolve substantially more gas in the liquid state than in the solid state.

The temperature at which the solvent should freeze depends upon the particular usage for which the fabric is to be employed. If the fabric is used to thermally insulate the human body, e.g., in clothing, blankets, sleeping bags, etc., the solvent-gas composition should be liquid at 70° F. and freeze to a solid at some temperature below 70° F. Preferably the solvent containing dissolved gas freezes at a temperature in the range of 65° F. to −50° F. The fabric material of this invention can also be used for other thermal insulation purposes wherein it is desirable that the solvent be converted from a liquid to a solid at an elevated temperature. Thus, for instance, a chemical reactor operating at an elevated temperature can be insulated so that if the reaction becomes too hot, there is a drop in the thermal-insulating ability of the insulation surrounding the reactor.

The solvent material employed must solidify or freeze from the solvent-gas solution at about the temperature at which an increase in thermal insulation is desired. In selecting a solvent-gas system for increasing the insulation within a given temperature range, it is to be noted that in general, as a gas is dissolved in a liquid solvent, the freezing point of the mixture is gradually lowered. The freezing point of a given system can, of course, be readily determined.

The gas selected should remain in the gaseous state throughout the temperature of intended use, i.e., should not liquify at the colder temperatures of usage. As previously stated, the amount of gas dissolved in the solvent (liquid phase) should exceed the amount of gas the solvent can dissolve when solidified. For most purposes, it is convenient to saturate the liquid solvent with gas at about 70° F. Many different gases and mixtures of gases can be employed in the present invention, the suitability of any particular gas being readily determined by those skilled in the art.

Illustrative of some gases suitable for use in the present invention are: ammonia, nitrous oxide, carbon dioxide, trifluoromethane, monochlorodifluoromethane, dichlorodifluoromethane, monochloropentafluoroethane, dimethyl ether, cyclopropane and nitrogen.

Illustrative of some of the solvents suitable for use in the present invention are: acetophenone, tert-butyl alcohol, n-octadecane, dimethyl adipate, 1,2-dibromoethane, phenyl ether, urethane, water, dimethylsulfoxide, n-propyl sulfone, tricosane, n-docosane, piperonal, formamide, 1-heradecanol, levulinic acid, eicosane, polyethylene glycol and diphenyl methane. Mixtures of solvents may also be employed, if desired.

The following examples are given to further illustrate the invention, but it is to be understood that the invention is not to be limited in any way by the details described therein.

EXAMPLE 1

Hollow tubular filaments of polypropylene were partially flattened to give filaments of the type shown in FIG. 1. The filaments were sealed at one end and then filled to a few percent of their original, unflattened internal volume with the following compositions:

1. acetophenone,
2. acetophenone saturated with monochlorodifluoromethane at 70° F. and one atmosphere pressure,
3. acetophenone saturated with carbon dioxide at 70° F. and one atmosphere pressure.

The open ends of the filaments were sealed and fabrics such as shown in FIG. 1 were woven. Additionally, a control fabric was woven from similar filaments which contained no filling composition.

Each of the samples was then treated in the following manner:

1. A layer of dry ice was placed in an open top container of insulating material.
2. Aluminum plate was placed over the dry ice.
3. The fabric to be tested was laid out on the aluminum plate.
4. A copper block having thermocouples attached thereto was located on top of the fabric.
5. The copper block was covered with a piece of foam insulation which was shaped to fit around the top and sides of the copper block, and
6. The temperature of the copper block was periodically recorded as it was cooled by the dry ice.

The fabrics containing monochlorodifluoromethane and carbon dioxide inflated in the manner illustrated in FIG. 2 when the acetophenone contained therein froze. No such inflation took place with the fabrics which were unfilled or filled with acetophenone only. The results obtained are shown in FIG. 4 and indicate that a copper block cooled much more slowly when it was insulated from the dry ice by the fabrics containing monochlorodifluoromethane and carbon dioxide gases.

EXAMPLE 2

The procedure of example 1 was repeated using n-octadecane as the solvent and monochlorodifluoromethane as the gas. The results are given in FIG. 5 which clearly demonstrates the superior thermal insulation obtained with the fabric containing the monochlorodifluoromethane dissolved in n-octadecane.

EXAMPLE 3

The procedure of example 1 was repeated using 1,2-dibromoethane as the solvent and monochlorodifluoromethane as the gas. The results are given in FIG. 6, which clearly shows that superior thermal insulation was obtained with the fabric containing the monochlorodifluoromethane dissolved in 1,2-dibromoethane.

EXAMPLE 4

Tests were carried out which established that with the following solvent-gas systems, a substantial amount of gas was expelled on freezing a saturated solution prepared at one atmosphere pressure.

Solvent	Gas
Acetophenone	Monochlorodifluoromethane
Acetophenone	Dimethyl Ether
Acetophenone	Cyclopropane
Acetophenone	Ammonia
Acetophenone	Carbon dioxide
Acetophenone	Nitrous Oxide
Acetophenone	Dichlorodifluoromethane
Acetophenone	Trifluoromethane
Acetophenone	Monochloropentaflurorethane
Tert-butyl Alcohol	Monochlorodifluoromethane
Tert-butyl Alcohol	Dimethyl Ether
Tert-butyl Alcohol	Cyclopropane
Tert-butyl Alcohol	Carbon Dioxide
Tert-butyl Alcohol	Monochloropentafluoroethane
n-Octadecane	Monochlorodifluoromethane
n-Octadecane	Dimethyl Ether
n-Octadecane	Cyclopropane
n-Octadecane	Carhobon Dioxide
Dimethyl Adipate	Monochlorodifluoromethane
Dimethyl Adipate	Dimethyl Ether
Dimethyl Adipate	Cyclopropane
Dimethyl Adipate	Carbon Dioxide
Levulinic Acid	Monochlorodifluoromethane
1,2-Dibromoethane	Monochlorodifluoromethane
1,2-Dibromethane	Dimethyl Ether
1,2-Dibromethane	Cyclopropane
1,2-Dibromoethane	Carbon Dioxide
Phenyl Ether	Monochlorodifluoromethane
Phenyl Ether	Dimethyl Ether
Urethane (Ethyl Carbamate)	Monochlorodifluoromethane
Urethane	Dimethyl Ether
Urethane	Cyclopropane
Urethane	Carbon Dioxide
Urethane	Nitrous Oxide
Urethane	Monochlorodifluoromethane
Urethane	Nitrogen
Water	Carbon Dioxide
Dimethylsulfoxide	Monochlorodifluoromethane
n-Propylsulfone	Monochlorodifluoromethane
n-Propylsulfone	Cyclopropane
Tricosane	Monochlorodifluoromethane
n-Docosane	Monochlorodifluoromethane
Formamide	
Monochlorodifluoromethane	
Formamide	Dimethyl Ether
Formamide	Cyclopropane
1 Hexadecanol	Monochlorodifluoromethane
Eicosane	Monochlorodifluoromethane
Polyethylene Glycol	Monochlorodifluoromethane
Diphenyl Methane	Monochlorodifluoromethane
Diphenyl Methane	Cyclopropane
Piperonal	Monochlorodifluoromethane
Piperonal	Cyclopropane
Piperonal	Carbon Dioxide
Piperonal	Nitrous Oxide

Results similar to those obtained in examples 1–3 can be obtained by using one of the above-listed solvent-gas systems in place of the solvent-gas systems employed in the examples.

The inflatable elements of the present invention can be used in products other than fabrics wherein it is desirable to have insulation properties which increase in response to a decrease in environmental temperature. One aspect of the present invention is the temperature responsive inflatable elements described herein per se.

It will be apparent that many modifications and variations can be effected without departing from the scope of the novel concepts of the present invention, and the illustrative details disclosed are not to be construed as imposing undue limitations on the invention.

I claim:

1. A fabric characterized by thermal insulation properties which change in response to a change in the environmental temperature, said fabric containing hollow inflatable elements having entrapped therein a composition comprising a gas and a solvent which in the liquid state dissolves a greater amount of said gas than when said solvent is in the solid state, the amount of gas in said elements being greater than the amount of gas which can be dissolved by the solvent present in the elements when in the solid state, whereby when environmental conditions cause said solvent to solidify, gas is expelled from said solution and inflates said elements thereby increasing the thermal insulation properties of said fabric.

2. A fabric as claimed in claim 1 wherein said composition is liquid at 70° F. and above.

3. A fabric material as claimed in claim 2 wherein said composition solidifies within the temperature range of about 65° F. to −50° F.

4. A fabric material as claimed in claim 1 wherein said elements are in the form of sealed hollow filaments.

5. A fabric material as claimed in claim 1 wherein said elements are in the form of sealed envelopes.

6. A fabric material as claimed in claim 1 wherein said solvent forms a crystalline material on solidifying.

7. A fabric as claimed in claim 1 wherein different compositions solidifying at different temperatures are contained within separate elements.

8. A fabric material as claimed in claim 1 wherein said elements are in the form of capsules.

9. A fabric material as claimed in claim 1 wherein said elements have a curved or zigzag shape and assume a straighter configuration when said gas is expelled.

10. A hollow inflatable filament suitable for use in fabrics, said filament having sealed therein a composition comprising a gas and a material which in the liquid state dissolves a greater amount of said gas than when said material is in the solid state, the amount of gas sealed in said filament being greater than the amount of gas which can be dissolved by the material sealed in said filament when said material is in the solid state, whereby on freezing said material, gas expelled therefrom and inflates said filament.