A method of storing liquified gas under pressure in a container from which the liquid is released as a gas into an atmosphere or region at a lower pressure than the storage pressure. This container additionally contains a solid polymer on which the liquid acts as a swelling agent so that the polymer becomes a gel which releases the liquid stored therein as a gas.

8 Claims, 7 Drawing Figures
1

PROCESS FOR STORING A LIQUID FOR ITS DISTRIBUTION IN THE GASEOUS STATE

CROSS-RELATED APPLICATION

This Application is a division of Ser. No. 288,396, filed Sept. 12, 1972 and issued as U.S. Pat. No. 3,813,041 on May 28, 1974.

The invention relates to a process for storing a liquifiable product in the liquid state, with a view to its distribution in the gaseous state.

A certain number of methods for distributing liquifiable products in the gaseous state are known.

Depending on the vapor pressure of the liquid to be distributed, very fine droplets of the liquid must be dispersed in a jet of gas, under pressure for example. The drawback of this distribution method is that the distribution device must be under this pressure.

The vapor pressure permitting, the gaseous distribution of the liquid can be sufficiently ensured by using merely the gaseous air located at the top of the storage enclosure. Depending on the desired distribution, it is necessary that the outlet be provided with either a pressure reducing device or with a device limiting the rate of flow, or with both. The main drawbacks of this storage and distribution method is that the auxiliary members considerably increase its cost price.

This is why it has been proposed to provide the storage enclosure with a double chamber: a so-called storage chamber and a distribution chamber into which is introduced a predetermined amount of liquid which vaporizes therein before being distributed. However, this distribution method has the drawbacks of necessitating a device for determining the amount of liquid admitted into the distribution chamber, of being discontinuous and of resulting in a non-constant distribution of each vaporized amount and of reducing the volume available for storage, due to the existence of the distribution chamber.

It has also been proposed to direct the liquid to its distribution point by capillary means for example, by means of a wick or a capillary tube. However, the drawback of this distribution method is that it necessitates, in addition to a pressure reducing device and/or a device limiting the rate of flow, a transformation device from the liquid to the gaseous state.

In another proposed solution, the liquid storage enclosure is filled with a porous material such as cotton or polyurethane foam. By capillary action, the porous material keeps the liquid in its pores, which liquid is therefore never, in its liquid state, in contact with the pressure reducing device, if there is one, or with the device limiting the rate of flow. This distribution method is thus more advantageous, but it has the drawback of reducing the useful capacity of the storage enclosure.

Finally, it has been proposed to dispose, in the storage enclosure of the liquid, a polymeric foam with open cells, for example a polyurethane foam. As the liquified product is introduced under pressure, this foam is soaked with liquid like a sponge and is also compressed so that it acts mechanically, by elasticity, at the moment when the product is distributed in the gaseous state, the amount of product stored however remains about the same as that which would be stored if a foam with open cells was not being used, and contrary to statements by certain authors, a storage method of this type does not make it possible to eliminate the auxiliary cut-off apparatuses so that this storage method has never been used successfully in practise, for example for supplying gas lighters from a reservoir of liquified fuel gas.

An object of the present invention is to remedy these drawbacks by providing a method of storing a liquifiable product in the liquid state with a view to its distribution in the gaseous state and make it possible to eliminate the auxiliary cut-off members for the gases.

There is provided according to the invention a process for storing a liquifiable product in the liquid state with a view to its distribution in the gaseous state into an atmosphere whose pressure is less than the storage pressure, said method comprising disposing in the storage enclosure, in conjunction with the liquid product to be distributed, a solid polymer with respect to which this liquid acts as a swelling solvent.

Certain liquid products act, with respect to certain polymers, as swelling solvents, i.e. as solvents which cause the elastomer in question to swell, by acting on the intermolecular connections (or "bridges") between chains without causing the complete dissolution of the polymer, the latter being, after the action of said swelling solvent, in the form of a gel, but again finding the integrity of its initial products after removal of said liquid product. Polymers having this property have been previously described in the prior art and it is known that it is a question of polymers having cross-links which, in the absence of these cross-links would be soluble in the solvent in question but which, due to these cross-links, swell and form gels until the osmotic pressures balance the resilient tensions of the lattice. The bridges between the chains of the polymers may be made by covalent connections, by ionic co-ordination connections by hydrogen connections or by crystallites.

The many tests carried out by the applicant have, however, proved that, for a given liquid, stored according to the present invention and intended to be distributed in the gaseous state, the polymers which can be used must have a solubility parameter which differs at the maximum by ± 2.0 and preferably by ± 0.5 from that of the stored product in question. Moreover, the temperature for transformation to the viscous state of these polymers must be at the most equal to 50°C.

Only polymers which fulfill this definition will therefore be considered as lying within the scope of the invention, the present description and the claims which will follow.

Thus, for example, polysiloxanes which have a solubility parameter of 7.3 can be used for storing liquified butane, the solubility parameter of which is 6.75.

The process according to the invention results in findings by the applicant during numerous tests which have proved that by placing, in the storage enclosure of a liquified product and in conjunction therewith, a polymer, with respect to which it acts as a swelling solvent, the gel obtained has the surprising property of releasing the stored product only in its gaseous state at the moment when it is distributed into an atmosphere whose pressure is less than that of the storage enclosure.

A first advantage of the process according to the invention lies in the fact that the presence of a gel in the storage enclosure permits the use of the latter both as a stationary reservoir as well as a movable reservoir.

A second advantage lies in the fact that the discharge of the liquid in the entirely gaseous state makes it possi-
ble to remove the devices intended to transform the fuel from its liquid to its gaseous state.

A third advantage relates to the amount of liquid which can be stored in a given reservoir. Indeed, tests have been carried out by the applicant to determine the liquified amount of gaseous hydrocarbons which could be stored, on the one hand in an empty reservoir and on the other hand in the same reservoir containing a porous material and thirdly in the same reservoir containing a polymer according to the invention. These tests have proved that the process according to the invention makes it possible to store greater quantities of liquified products, all things being equal.

The storage process according to the invention has numerous applications. A particularly important application relates to stored gas combustion devices such as lighters for smokers, luminous gas lamps or gas heating apparatuses wherein liquified hydrocarbons, particularly aliphatic hydrocarbons such as butane, propane, pentane or the like are used individually or in combination as a fuel, these hydrocarbons having the property of causing certain polymers to swell.

Another application relates to the transportation, over great distances, by vehicles provided with tanks or by ships of the type designed to carry liquified natural gas, of these liquified hydrocarbons the importance of which is becoming increasingly greater.

Another application, always in the case of liquified hydrocarbons, relates to the storage of these hydrocarbons in vehicles with a combustion engine, with a view to supplying these engines. In fact, it is known with reference to the fight against atmospheric pollution that the liquified hydrocarbons tend to replace the liquid hydrocarbons, the combustion of which results in much more harmful products (unburnt products, carbon monoxide, etc.).

Another application relating to other types of liquified compounds distributed in the gaseous state into the ambient atmosphere, relates for example, to deodorizing products or insecticides.

The numerous examples which will be described in the following description relate particularly to the case of liquified hydrocarbons, which is very important as has just been indicated. This application, however, only aims to illustrate the process according to the invention and must not be regarded as limiting.

However, it will be pointed out again that for liquified hydrocarbons stored in the liquid state with a view to their distribution in the gaseous state, the preferred polymers which can be used are divided into seven large classes of products, namely: polysiloxanes (so-called “polymers of silicon”); polyisoprenes, natural (latex) or synthetic; polyolefins with transverse connections, obtained by action of radiations or peroxides; polystyrene polymers with cross-links; block polymers, at least one constituent part of which has a maximum affinity for the solvent; polyisoprene homopolymers; silicone rubber with weak links between the chains.

The polymer used must be introduced into the storage enclosure in the solid state. It may also possibly be polymerized in the storage enclosure before it is filled with the compound in the liquid state intended to be distributed in the gaseous state. This latter modification for carrying out the invention may be found to be advantageous for certain applications (formation of liquified fuel gas cartridges which cannot be refilled for gas lighters, for example).

Various devices for carrying out the invention will also be described in the following, but they will not be limiting.

The accompanying drawings given merely by way of a non-limiting example, illustrate various embodiments of an enclosure for storing a liquified fuel gas utilizing these advantages of the storage process according to the invention. In these drawings:

FIG. 1 is a vertical section showing a first embodiment according to the invention.

FIGS. 2, 3, 5 and 6 are respectively views similar to FIG. 1 of four variations, and FIGS. 4 and 7 are detail views illustrating other variations.

In the embodiment shown in FIG. 1, a hollow body 1, which cannot be refilled, contains a plurality of pieces 2 of a solid elastomer with respect to which the liquified fuel gas to be stored acts as a swelling solvent. An aperture 3 formed at the top of the body 1 makes it possible to supply a burner with fuel gas without the interposition of a cut-off system.

In the modification, according to FIG. 2, the hollow body 4 is divided into two separate chambers 5 and 6 respectively by a grid, latticework or more usually a support 7 provided with apertures, secured in the body 1 and through which communication between the two chambers is effected. A filling valve 8 provided in the base of the body 4 makes it possible to fill the chamber 5 with a liquified fuel gas, the liquid passing through the support 7 so as to impregnate a solid polymeric material contained in the chamber 6. A burner (not shown) is supplied with fuel gas by way of the aperture 9 formed at the top of the body 4.

The embodiment according to FIG. 3 is derived directly from that of FIG. 2. The hollow body 10 is divided into two chambers 11 and 12 by a grid 13 or the like, however, the elastomer intended to be impregnated with liquified gas is constituted by a simple membrane 14 held against the grid 13 by a ring 15 force fitted into an inner groove of the body 1, the grid itself bearing against a shoulder of the inner walls of the container. The chamber 11 which may be filled with liquified gas by a valve 16 has a much greater volume that in the case of the embodiment shown in FIG. 2, whereas the chamber 12 has a minimum volume in communication with the distribution aperture 17. The membrane 14 ensures a continuous distribution of gas, releasing the latter through the face located opposite the aperture 17, whereas through the opposite face, it absorbs an amount of liquified gas which may or may not be equal to the amount of gas released.

FIG. 4 is a detail view of a modification of the device of FIG. 3, wherein the elastomeric membrane 14 surrounds the grid 13a.

In the embodiment according to FIG. 5, the hollow body 18 comprises a main chamber 19 which can be filled with liquified gas by the valve 20. The liquified gas impregnates a polymeric material which fills a tubular member 21 made of gridding and connected to the distribution aperture 22.

As shown in FIG. 7, the tubular element 21 made of gridding, may be replaced by a tube 23 of any material containing no polymer, but having perforations closed by a suitable macromolecular material 24.
out the invention with the polymers each belonging to the above-mentioned classes as capable of being used in the case where the stored liquid is a hydrocarbon in the liquid state. The following polymers have been used:

1. Polysiloxanes:
   1a. foam with closed cells and having a low density manufactured by "Silicone Engineering Ltd."
   2a. RTV foam (abbreviation of Room Temperature Vulcanizing) 558.

2. Polysoprene:
   isoprene foam with closed cells manufactured by Shell (commercial name Latex 700);

3. Polylefins with cross-links:
   3a. cross-linking by peroxide: polyethylene manufactured by Sekisui, Japan (commercial name Softlon BN 30).
   3b. cross-linking under radiation; polyethylene manufactured by Furakawa Electric, Japan (commercial name: Minicel I-200);
   3c. cross-linking under ultraviolet radiation.

4. Polyalkylstyrenes with cross-links:
   4a. poly-tert-butylstyrene, manufactured by DOW (commercial name: Imbiber bead BE-0100.31) with 0.025 percent peroxide cross-linking.

5. Black polymers:
   5a. olefinic styrene manufactured by Shell, of the type of the products "Kraton" of this Company (commercial name GXT 0650).

6. Polymethylpentene:
   product sold by I.C.I. under the commercial name TPV RT 20.

7. Butyl rubber with weak linking:
   product sold by Polysar Polymer Corp., Ltd., Canada, under the commercial name Polysar Butyl XL-20.

Tests for all these samples have been carried out by dipping them for one day into liquified n-butane except for sample No. 7 which was dipped in a mixture comprising 20 percent by weight n-butane and 80 percent by weight isobutane, or in liquified pentane. As in example I the excess liquid was removed and the appearance and capacity of the polymer was noted. The results obtained are collected in the following Table II.

**TABLE I**

<table>
<thead>
<tr>
<th>POLYMER</th>
<th>TEST IN n-BUTANE</th>
<th>Test in pentane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Appearance of</td>
<td>Capacity of</td>
</tr>
<tr>
<td></td>
<td>polymer</td>
<td>the polymer</td>
</tr>
<tr>
<td>non-cross-linked</td>
<td>dispersed</td>
<td>0.2</td>
</tr>
<tr>
<td>polystyrene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyethylene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>with 2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cross-linking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poly-tert-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>butyl-polystyrene with 0.025%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cross-linking</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This table clearly shows that only polymers with a low degree of cross-linking make it possible to store liquified n-butane or liquified pentane efficiently.

**EXAMPLE II**

This example illustrates different ways of carrying...
These tests aim only to illustrate the invention and are not limitative. On the contrary, the applicant has carried out numerous tests, just as conclusive, on a large number of compounds belonging to the various aforementioned classes of polymers.

In the ensuing examples, the operation, which consists of heating the polymer used, three times with excess butane, until complete saturation, before it is used for storage, whether the liquid to be stored is butane or not, is termed "extraction". Likewise, the treated polymer is termed the "extracted" polymer.

EXAMPLE III

This example relates to the case where the stored product is butane in the liquid state.

Three storage tests have been carried out, at 20°C and for 20 hours, with three different polymers respectively: a CAF 3 THIXO (registered trademark, abbreviation of "colle à froid") polymerized at 25°C for 24 hours, an RTV foam (abbreviation of Room Temperature Vulcanizing; rubber with silicon type) with 10 percent oil, polymerized at 150°C for 1 hour, which has not been subjected to extraction and the same RTV foam after extraction. This foam has been obtained from commercialized products under the following names:

Rhodorsil 10558
Catalyst 10052 (14 percent by weight of the preceding)
Rhodorsil Oil Y-V 20 (percent indicated above by weight of Rhodorsil 10558).

1. CAF 3THIXO

Characteristics of the polymer before absorption:
- Extract
  - Weight: 100 g
  - Apparent Volume: 97 cm³
  - Shape: cylinders having a diameter of 6 mm and a length of 20 mm.
- Swelling liquid presented (butane)
  - Weight: 300 g
  - Volume: 520 cm³

Characteristics of the polymer after absorption:
- Weight: 370 g
  - Apparent Volume: 565 cm³
  - Shape: substantially the same as that before absorption.
- Swelling liquid absorbed:
  - Weight: 270 g
  - Volume: 468 cm³

2. NOT EXTRACTED RTV FOAM.

Characteristics of the solid polymer before absorption:
- Weight: 100 g
  - Apparent volume: 286 cm³
  - Shape: Diabolo: large diameter of 12 mm small diameter of 8 mm height 20 mm with "skin" on each base.
- Swelling liquid presented (butane):
  - Weight: 400 g
  - Volume: 694 cm³

Characteristics of the polymer after absorption:
- Weight: 443 g
  - Apparent volume: 694 cm³
  - Shape: maximum swelling in the center.
- Swelling liquid absorbed:
  - Weight: 343 g
  - Volume: 594 cm³

3. EXTRACTED RTV FOAM

Characteristics of the solid polymer before absorption:
- Weight: 100 g
  - Apparent volume: 143 cm³
  - Shape: Diabolo: large diameter 12 mm small diameter 8 mm height 20 mm with skin on each base.
- Swelling liquid presented (butane)
  - Weight: 800 g
  - Volume: 1388 cm³

Characteristics of solid product after absorption:
- Weight: 825 g
  - Apparent Volume: 1356 cm³
  - Shape: maximum swelling in the center.
- Swelling liquid absorbed:
  - Weight: 725 g
  - Volume: 1256 cm³

EXAMPLE IV

This example relates to the case where the stored product is pentane in the liquid state. Three comparative tests have been carried out with the same polymers as in example 1, at 20°C and for 20 hours.

1. CAF 3THIXO

Characteristics of the solid polymer before absorption:
- Extract
  - Weight: 100 g
  - Apparent Volume: 98 cm³
  - Shape: cylinder: diameter 6 mm length 20 mm
- Swelling liquid presented (pentane):
  - Weight: 200 g
  - Volume: 319 cm³

Characteristics of the solid product after absorption:
- Weight: 227 g
  - Apparent volume: 301 cm³
  - Shape: substantially the same as that before absorption.
- Swelling liquid absorbed:
  - Weight: 127 g
  - Volume: 203 cm³

2. NOT EXTRACTED RTV FOAM

Characteristics of the solid polymer before absorption:
- Weight: 100 g
  - Apparent Volume: 286 cm³
  - Shape: diabolo: large diameter 12 mm small diameter 8 mm length 20 mm with skin on each base.
- Swelling liquid presented (pentane):
  - Weight: 400 g
  - Volume: 640 cm³

Characteristics of the solid product after absorption:
- Weight: 400 g
  - Apparent volume: 580 cm³
  - Shape: maximum swelling in the center.
- Swelling liquid absorbed:
  - Weight: 300 g
  - Volume: 480 cm³

3. EXTRACTED RTV FOAM

Characteristics of the polymer before absorption:
- Weight: 100 g
  - Apparent Volume: 143 cm³
  - Shape: diabolo: large diameter 12 mm small diameter 8 mm length 20 mm with skin on each base.
Swelling liquid presented (pentane)
Weight: 600 g
Volume: 959 cm³
Characteristics of the solid product after absorption:
Weight: 660 g
Apparent Volume: 993 cm³
Shape: maximum swelling in the center.
Swelling liquid absorbed:
Weight: 560 g
Volume: 893 cm³
Examples III and IV clearly show the importance of the treatment by extraction of the polymers used, before their application to the storage of liquids. The fact that after a first extraction, an increase in the absorption rate of the polymers is noted, could be due to the extraction, by the swelling liquid, of soluble matter "present" in the polymer and which are usually added thereto to impart certain mechanical or chemical properties thereto. Naturally, this preliminary extraction could be effected by a compound other than butane and could comprise any number of successive absorptions and deposits.
These examples also show the amount of liquid stored varies depending on the polymer used and also on the structure of the polymer. In particular, it is ascertained that the rate of filling of a polymeric foam with closed cells is always greater than that of a compact elastomer. The applicant has also ascertained that macromolecular foams with closed cells have a second advantage which is due to the fact that the liquid is absorbed and deposited more quickly than with a compact macromolecular compound.
In order to determine if the amount of liquid which can be stored in a given macromolecular product is an inverse function not only of the dimensions of the storage container which may hinder swelling but also of stresses peculiar to its structure, two series of tests were also carried out which were made from solid products of identical material, but whose outer characteristics were different. In the first case (Example V hereafter) the foam with closed cells which constituted the solid products had each of its two bases constituted by a skin, i.e. from a plane surface, evidently less flexible than an alveolar surface, while in the second case (Example VI) only one of its bases was constituted by a skin, the other being constituted by an alveolar surface.

EXAMPLE V
In this test, liquified butane was stored at 20°C for 20 hours, using the same RTV foam as in the preceding examples.
The test conditions and results obtained were as follows:
Characteristics of the solid polymer before absorption:
Extract
Weight: 100 g
Apparent Volume: 143 cm³
Shape: diabolo.
large diameter 12 mm small diameter 8 mm height 20 mm with skin on each base.
Swelling liquid presented:
Weight: 800 g
Volume: 1388 cm³
Characteristics of the solid product after absorption:
Weight: 690 g
Apparent Volume: 1122 cm³

EXAMPLE VI
In this example a test was carried out which is exactly the same as that of Example III, with the single difference that one of the bases of the solid polymer used had a skin while the other base was deprived of a skin.
Using the same amount of butane as before, in the same conditions the following results were obtained:
Characteristics of the solid product after absorption:
Weight: 860 g
Apparent Volume: 1417 cm³
Shape: maximum swelling between the center and the base without skin.
Swelling liquid absorbed:
Weight: 760 g
Volume: 1317 cm³
The comparison of these results with those of example V reveals the fact that the amount of liquid which can be stored by the process according to the invention is directly related to the structure of the solid polymer used for carrying out this process.
Other tests carried out by the applicant for the same purpose have also proved that, for the same solid polymer used, the amount of liquid stored depends on the sum of the volumes of the alveolus per unit of apparent volume.
Various tests, intended to illustrate the various ways of carrying out the invention, will now be described in the following examples, which are not limitative. These examples do not relate merely to the storage, in the liquid state, of compounds intended to be distributed in the gaseous state into the same temperature conditions, but also to the conditioning of products (normally liquid) at the temperature in question and consequently intended to be distributed in the liquid state. Indeed, these tests give valuable information about the function of the solid polymer used in the framework of the invention. Moreover, they prove that, at the limit, the process described in the main patent may also be applied to the storage of liquid products intended to be distributed in the liquid state by increasing the pressure inside the enclosure.

EXAMPLE VII
Solid polymer used: Viton (registered trademark; a fluoric elastomer having as a base the copolymer of fluoride of vinylidene and of hexafluoropropylene).
Product stored: acetone
Storage temperature: 20°C
Duration of storage: 20 hours.
The conditions and results of this test were as follows:
Characteristics of the solid product before absorption:
Not extracted:
Weight: 200 g
Apparent volume: 109 cm³
Shape: small plate:
length 20 mm
width 20 mm
thickness 1 mm
Swelling liquid presented:
Weight: 200 g
Volume: 253 cm³
Characteristics of solid product after absorption:
Weight: 324 g
Apparent volume: 226 cm³
Shape: swelling in thickness
Swelling liquid absorbed:
Weight: 124 g
Volume: 157 cm³

EXAMPLE VIII
Solid polymer used: natural rubber
Swelling solvent stored: hexane
Temperature of the test: 20°C
Duration of test: 20 hours
The conditions and results of the test were as follows:
Characteristics of the solid product before absorption:
Not extracted
Weight: 100 g
Apparent volume: 107 cm³
Shape:
circular rings:
outer diameter: 10 mm
inner diameter: 3 mm
thickness: 3 mm
Swelling liquid presented:
Weight: 200 g
Volume: 303 cm³
Characteristics of the solid product after absorption:
Weight: 270 g
Apparent volume: 364 cm³
Shape: substantially the same as before absorption.
Swelling liquid absorbed:
Weight: 170 g
Volume: 257 cm³

EXAMPLE IX
Polymer used: CAF 3 THIXO
(registered trademark; product similar to that described in the preceding examples)

Swelling solvent (product stored): hexane
Temperature of the test: 20°C
Duration of test: 20 hours
The conditions of the test and the results obtained are as follows:
Characteristics of the solid product before absorption:
Extracted
Weight: 100 g
Apparent volume: 97 cm³
Shape: cylinder:
diameter 6 mm length 20 mm
Swelling liquid presented:
Weight: 300 g
Volume: 455 cm³
Characteristics of the solid product after absorption:
Weight: 368 g
Apparent volume: 504 cm³
Shape: substantially the same as that before absorption.
Swelling liquid absorbed:
Weight: 268 g
Volume: 407 cm³

EXAMPLE X
Polymer used: natural rubber
Swelling solvent (Liquid stored): pentane

Temperature of the test: 20°C
Duration of the test: 20 hours
The conditions of this test and the results obtained are as follows:
Characteristics of the solid product before absorption:
Not extracted
Weight: 100 g
Apparent volume: 108 cm³
Shape:
circular rings:
outer diameter: 10 mm
inner diameter: 3 mm
thickness: 3 mm
Swelling liquid presented:
Weight: 100 g
Volume: 160 cm³
Characteristics of the solid product after absorption:
Weight: 163 g
Apparent volume: 208 cm³
Shape: substantially the same as that before absorption.
Swelling liquid absorbed:
Weight: 63 g
Volume: 100 cm³

EXAMPLE XI
Polymer used: CAF 4 THIXO
Swelling solvent: butane
Temperature of the test: 20°C
Duration of the test: 20 hours
The conditions of the test and the results obtained are as follows:
Characteristics of the solid product before absorption:
Not extracted
Weight: 100 g
Apparent volume: 91 cm³
Shape: cylinder:
diameter 6 mm length 20 mm
Swelling liquid presented:
Weight: 200 g
Volume: 347 cm³
Characteristics of the solid product after absorption:
Weight: 250 g
Apparent volume: 351 cm³
Shape: substantially the same as that before absorption.
Swelling liquid absorbed:
Weight: 150 g
Volume: 260 cm³

EXAMPLE XII
Solid polymer: natural rubber
Swelling solvent: carbon sulphate
Temperature of the test: 20°C
Duration of the test: 20 hours
The conditions of the test and the results obtained are as follows:
Characteristics of the solid product before absorption:
Not extracted
Weight: 100 g
Apparent volume: 107 cm³
Shape:
circular rings:
outer diameter: 10 mm
inner diameter: 3 mm
thickness: 3 mm
Swelling liquid presented:
Weight: 400 g
Volume: 317 cm³
Characteristics of the solid product after absorption:
Weight: 430 g
Apparent volume: 309 cm³
Shape: substantially the same as that before absorption.
Swelling liquid absorbed:
Weight: 330 g
Volume: 202 cm³

The above examples clearly show the various polymers which can be used in various physical forms, and the numerous applications of the process according to the invention both to the storage of liquefied products and products normally liquid at ambient temperatures.

As has already been emphasized, one of the most important and most advantageous applications of the process according to the invention relates to liquefied fuel gases, in particular liquefied, gaseous aliphatic hydrocarbons.

In this application, the storage process according to the invention has surprising advantages which were not evident to the man skilled in the art. These advantages will now be revealed.

Firstly, it is evident that the process according to the invention retains the advantages of processes for storing liquids with spongy supports, namely stabilization of the stored liquid and possibility of using the storage container in any position whatsoever.

With respect to known processes, the process according to the invention also has the advantage of improving the checking of the distribution, which in the case of easily combustible liquids, reduces the risks of explosion.

In order to illustrate the improvement made by the invention, a certain number of tests have been initiated of the combustion of butane either alone, or stored in polyurethane with open cells, or stored in cotton, or stored in RTV elastomer foams with closed cells or finally stored in elastomers of the CAF series.

All these tests were effected in the open air. During each test, the combustion of the same amount of butane was initiated. The supports used all had a thickness of 1 cm and had, at the beginning of the test, the same evaporation surface as the free butane.

In these conditions, the results expressed as coefficient of combustion duration were as follows:
- butane alone: 1.0;
- butane stored in polyurethane foam with open cells: 1.4;
- butane stored in cotton: 1.9;
- butane stored in RTV elastomer foam with closed cells: 2.5;
- butane stored in compact elastomer of the CAF series: 3.0.

A second advantage made by the invention lies in the fact that the pressure of the gaseous air above the liquid stored in the storage container is less than that of the gaseous air in a container with liquefied gas alone or in a container with gas and cotton or gas and alveolar foam with open cells.

The tests which have been carried out to illustrate this point have been greatly influenced by the variables which could not be exactly identified (probably variations in composition both of liquids and elastomers).

Nevertheless, even if the favorable results which cannot be reproduced are excluded to retain only the average values of the results obtained, it is established that the process according to the invention is found to be generally superior to the conventional processes. This is proved by the following numbers which relate to the value, in bars, at a temperature of 25°C, of the relative pressure of the gaseous air in a storage container containing a mixture of liquefied hydrocarbons comprising (in percent by weight) 79.0 percent n-butane, 19.0 percent isobutane, 1.0 percent propane, 0.5 percent ethane and 0.5 percent pentane and butane:
- with this mixture alone: 1.65
- with this mixture and a polyurethane foam with open cells: 1.65
- with this mixture and a cotton: 1.65
- with this mixture and an RTV elastomer foam with closed cells: 1.51
- with this mixture and a compact CAF elastomer: 1.45

It is to be noted that the tests carried out by the applicant have proved that the difference between the gaseous air pressures in the process according to the invention and in conventional processes is more accentuated for containers with a leakage having a constant cross-section.

Finally, in the application of the process according to the invention to the storage of liquefied fuel gases intended to supply a combustion means, an extremely important advantage lies in the fact that the combustion device can be supplied directly without the interposition of a device for transformation from the liquid to the vapor state.

Another advantage peculiar to this application is due to the fact that the device limiting the rate of flow may be removed, which is usually mounted on the supply line of the combustion device so as to keep only a regulating device at the users disposal.

What is claimed is:
1. A process for storing, in the liquid state, a liquefiable product with a view to its distribution in the gaseous state, into an atmosphere whose pressure is less than the storage pressure, said process comprising disposing in the storage enclosure, in conjunction with the liquid product to be distributed, a solid polymer with respect to which the liquid acts as a swelling solvent, said polymer being absorbative of the liquefied gas and having a limited solubility parameter with respect to said liquefied gas so as to undergo swelling and form a gel which releases the liquid only in gaseous state, said solubility parameter of the polymer differing at most from the liquefied gas by ±2.0.
2. A process according to claim 1, in which said polymer is a foam with closed cells.
3. A process according to claim 1, in which the solid polymer used was previously subjected to a treatment consisting of at least one absorption-deposit cycle with an excess liquid acting like a swelling solvent with respect to said polymer.
4. A process according to claim 3, in which the liquid used during the previous absorption-deposit treatment is the same as the liquid to be stored.
5. A process according to any one of claim 1, wherein the polymer is polymerized “in situ” in the storage enclosure before it is filled with the liquid to be stored.
6. A process according to claim 1, in which the liquid to be stored comprises a major part of at least one liquefied saturated hydrocarbon and the solid polymer is selected from the group consisting of polyisoxanes.
7. A process according to claim 1 wherein said polymer is weakly cross-linked.

8. A process according to claim 1 wherein the solubility parameter of the polymer differs at most from the liquefied gas by ±0.5.

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