NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF:

July 21, 1970

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned
U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

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Corporate Source	:	Nat'l Aeronautics & Space Admin.
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Gayle Parker

Enclosure:
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APPARATUS FOR TRANSFERRING CRYOGENIC LIQUIDS

Filed March 30, 1962 2 Sheets-Sheet 1

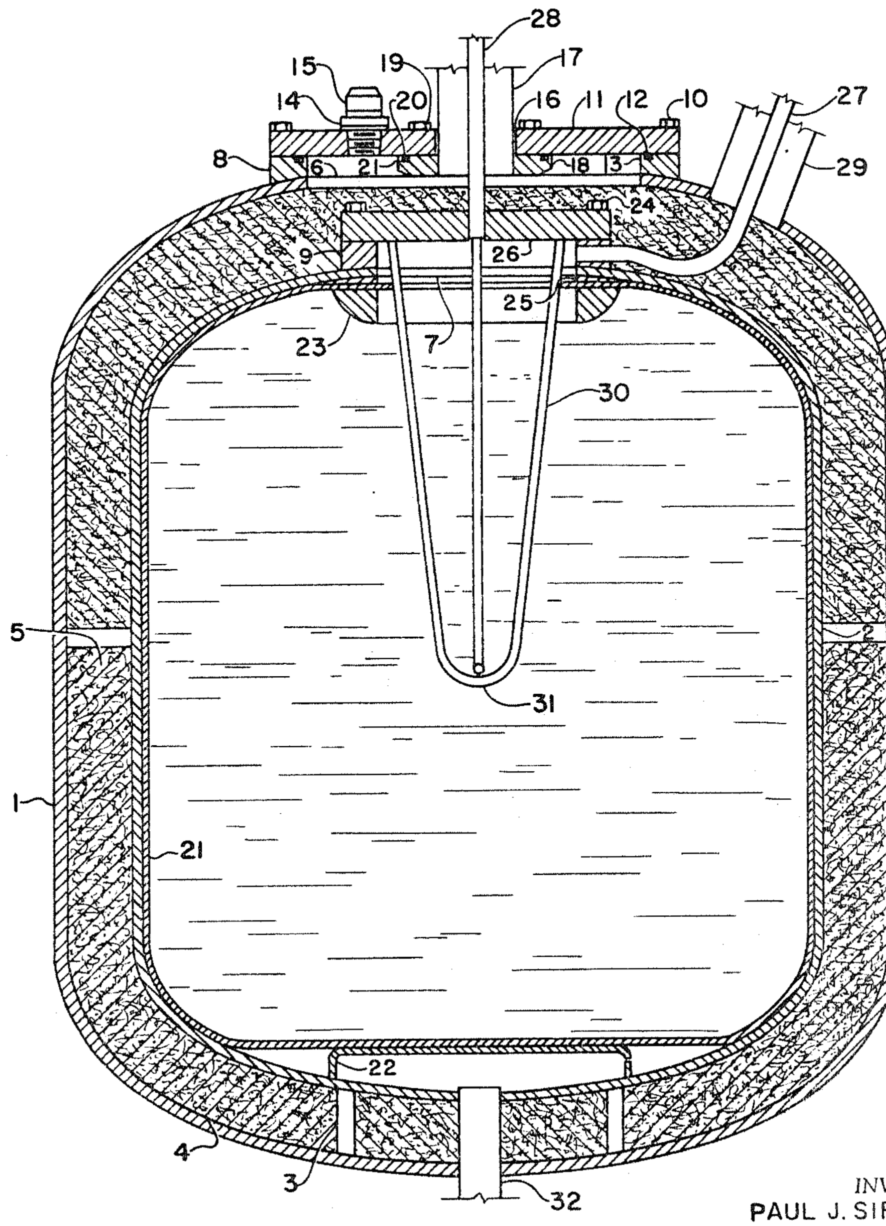

FIG I

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APPARATUS FOR TRANSFERRING CRYOGENIC LIQUIDS

Filed March 30, 1962 2 Sheets-Sheet 2

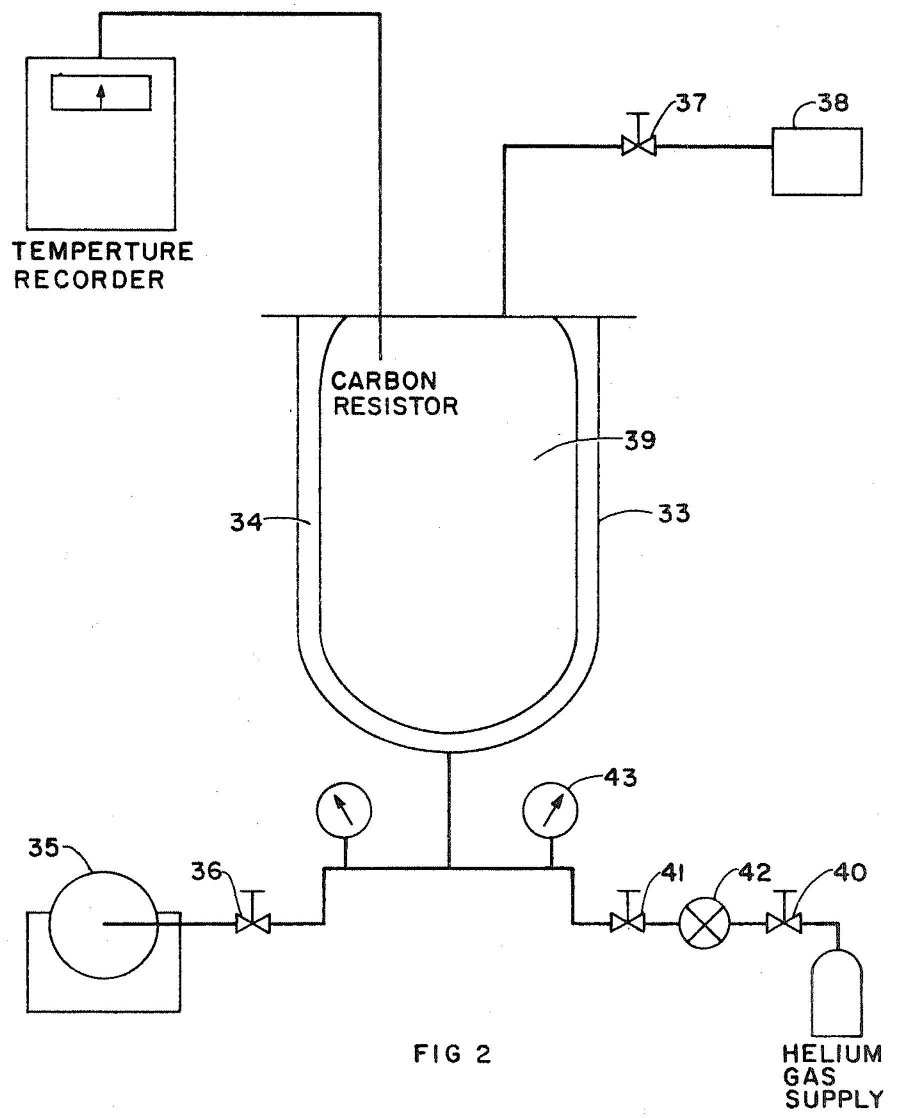

FIG 2

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United States Patent Office

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3,122,000

APPARATUS FOR TRANSFERRING CRYOGENIC LIQUIDS

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2 Claims. (Cl. 62—55)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates generally to a fluid transferring system and, more particularly, to an apparatus for effecting transfer of a cryogenic fluid from a storage container.

Further, the invention relates to an apparatus for carrying out the method of transferring cryogenic liquids under zero-gravity conditions.

Still further, the invention relates to an apparatus employing a bladder comprising a polyethylene terephthalate polyester or a polyhaloethylene resin.

Cryogenic liquids such as liquefied nitrogen, helium, hydrogen, oxygen, ozone, and fluorine are needed for many uses in space vehicles. For several operations it is necessary to transfer them to different locations. However, because of zero-gravity conditions the transfer cannot be effected by pumping, pouring, "leaking" or siphoning to the desired locations.

Transferring these liquids by any other means such as pumps and the like is extremely difficult because of the many problems encountered when the temperature of operation approaches absolute zero. Most pumps become inoperative at these low temperatures because the lubricants freeze and their component parts shrink up out of proportion to the tolerances. Additionally, cavitation problems occur and random displacement of liquid by gas occurs at zero-gravity conditions. Moreover, because of the low specific heats and the low temperatures of vaporization of these "liquid gases" they must be stored in a reservoir having only the very minimum in heat-transfer properties. An apparatus for the above-mentioned purpose must also be as light as possible to provide minimum additional weight to a rocket-propelled vehicle which must attain orbital velocities.

Accordingly, one object of the instant invention is to provide a suitable apparatus for carrying out the transfer of the cryogenic liquids, this apparatus being as light as possible for use in rocket-propelled orbital vehicles.

A further object of this invention is to provide an apparatus which also operates as a reservoir for cryogenic liquids by being constructed so that a very minimum of heat transfer occurs during the storage of the liquid.

It is also an object in constructing this apparatus to provide a zone surrounding the cryogenic liquid container which has the dual function of insulating a cryogenic liquid and effecting transfer of a cryogenic liquid.

Briefly, in accordance with one embodiment of this invention, these and other objects are attained by applying pressure to a container of a cryogenic liquid which remains flexible at temperatures approaching absolute zero. By this procedure there are no problems with cavitation or random displacement of the liquid by gas. Surprisingly it has been found that certain resin, particularly terephthalate polyesters and polyhaloethylenes, maintain their flexibility at temperatures approaching absolute zero. Containers made from these polyesters and polyhaloethylenes provide a reservoir for these cryogenic liquids which can be collapsed under pressure to expel the desired amount of cryogenic liquid for transfer to the point of use.

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The instant invention is advantageously carried out by providing a flexible container with a conduit for filling and expelling the cryogenic fluid. The container is disposed within a rigid larger container of similar configuration and preferably spaced at all points from said larger container providing a spacial zone of similar configuration. Affixed to the larger container is a conduit for instituting a vacuum in the zone between the outside container and the flexible container to reduce heat transfer during storage. A preferred embodiment additionally comprises a rigid inner housing having its wall substantially contiguous with the flexible container in its normally expanded state. In order to be able to apply a gaseous pressure to the surface of the flexible container, a small area of the inner housing contains an aperture for gaseous communication between the outer container and the outside surface of the flexible container.

These and various other objects and advantages are obtained with this invention and will become apparent from the following description when taken in connection with the accompanying drawings wherein there is shown the preferred form, it being evident that other arrangements may be resorted to in carrying out the objects and purposes of this invention.

FIG. 1 in the accompanying drawing is a vertical sectional view illustrating a preferred form of the apparatus of the instant invention showing a flexible bladder contiguous to the rigid inner container which, in turn, is surrounded by a spacial zone enclosed by a rigid outer container.

FIG. 2 is a schematic diagram of a system employing the said apparatus.

In carrying the invention into effect in a convenient and preferred manner when applied to the apparatus in FIG. 1, there is provided a cylindrical metal outer container, e.g. stainless steel, aluminum, titanium, etc. Enclosed within container **1** is an inner container **2** of similar configuration and being supported by spacers **3** of a poor heat conducting material such as glass fiber or polymethylmethacrylate to provide an insulating chamber **4**. Filling said chamber **4** and surrounding substantially the entire outer surface of container **2** is insulating material **5** comprising, for example, aluminum foil and glass fiber. Located in the upper portion of the apparatus are centrally axially aligned apertures **6** and **7** having outwardly extending mounting flanges **8** and **9**, respectively.

Secured to mounting flange **8** with cap screws **10** is a flat head **11** forming a pressure seal with O ring **12** situated in annular groove **13**. Located in head **11** is fitting **14** providing communication with chamber 4 having a male connector **15** for attaching to an evacuating source (not shown). Axially aligned with aperture **6** is opening **16** centrally located in head **11**. Passing through and extending from aperture **16** is conduit **17** having flange **18**. Flange **18** is secured to head **11** with cap screws **19** forming a pressure seal with O ring **20** in annular groove **21**.

Located in container **2** is flexible bladder **21** having outside transverse dimensions substantially similar to the inside dimension of the container 2 but slightly longitudinally shorter than the container. In FIG. 1 the bladder **21** is shown as expanded, being contiguous to substantially the entire inner surface of container **2** except for the bottom which is contiguous to radial gas distributing member **22** having lateral openings (not shown). As previously mentioned, the bladder **21** is composed of certain synthetic organic sheet having flexibility at temperatures of cryogenic liquids, particularly those materials which are normally gases at −100° F. or above. The bladder is completely closed except for a neck for exiting the cryogenic liquid, which neck is secured at aperture **7** by elliptical sealing ring **23** and by cap screws **24** drawing the neck into a pressure tight seal with ring member **25** and at the same time pressure sealing and securing cover **26** to mounting flange **9**.

Ring member **25** is cross-sectioned at an angle to complement the cross-section of mounting flange **9**, thus providing a rectangular cross-sectioned ring which includes a segment of container **2** peripheral to aperture **7**. The zone enclosed by the inner wall of said rectangular cross-sectioned ring includes communication with inlet **27** through mounting flange **9** and with outlet **28** through the center of cover **26**. Outlet **28** extends through chamber **4** and into conduit **17** in coaxial relationship, thus providing a conducting means to the desired point (not shown) providing a radially-extending zone which is in communication with chamber **4** and may be evacuated with chamber **4**. Inlet **27**, connectable to a source of cryogenic liquid, also extends through chamber **4** and coaxially into a similar conduit **29**. Conduit **29** is also in communication with chamber **4** and also provides a radially-extending zone around inlet **27** which may be evacuated with chamber **4** for reducing heat transfer into the cryogenic liquid.

Pendant from cover **26** and fixedly attached thereto is guard **30** to prevent the collapsing bladder from choking the outlet **28**. Guard **30**, as shown in FIG. 1, is merely heavy gauge wire bent to form two sets of converging lines where each set defines a plane substantially perpendicular to the other. Instead of converging to a point, the terminus is rounded at point **31** to eliminate possible puncture of the bladder. Other equivalent devices such as screens, sieves, and the like may also be used.

Axially aligned with outlet means **28** at the opposite end of container **2** is gas inlet **32** providing communication between gas distributing member **22** and the pressure source (not shown). In traversing chamber **4**, gas inlet **32** forms a gas tight seal with both the inner container **2** and the outer container **1**.

In operation, chamber **4** is evacuated along with the radially-extending zones enclosed by conduits **17** and **29** around outlet **28** and inlet **27**, respectively, and in communication with chamber **4**. After a high vacuum has been obtained (less than 10 microns), the cryogenic liquid is admitted through inlet **27**, while outlet **28** is open to vent the resulting pressure build-up. After the cryogenic liquid has been added, both the inlet **27** and outlet **28** are closed for storage. While the vacuum is present in chamber **4**, the cryogenic liquid may be stored indefinitely (at least six months).

Transferring of the cryogenic liquid is effected by merely opening outlet **28** and admitting a pressurizing gas through gas inlet **32** into gas distributing member **22** and into the lower areas of the container **2** whereby the bladder **21** proceeds to collapse as the pressure builds up.

As the bladder is collapsing, an even flow of cryogenic liquid is obtained with no cavitation and erratic pressure fluctuations.

After the cryogenic liquid is completely or partially expelled, the bladder may be refilled again and again in the same manner as before.

The following example is given by way of illustration and not by way of limitation.

Example

This example is given to illustrate the significance of the material utilized for the flexible bladder.

An apparatus was built utilizing a polymethylmethacrylate (Lucite) bell jar and a Dacron cloth bag (bladder) laminated with a Mylar film less than 1.0 mil in thickness having dimensions such that it could be suspended in the jar without touching the jar at any point, thus providing a chamber surrounding the annular portions and the bottom portion of the "bag". The "bag" was then suspended from a flat aluminum head which was secured with bolts to a flange extending radially from the periphery of the top of the bell jar. The head was provided with a first member for evacuating the chamber and applying pressure to the chamber and a second member for filling and expelling the liquid. In order to effect a pressure tight seal, an annular ring and an annular gasket both having the same dimensions as the flange were fitted to the flange in pressure-tight relationship. In order to record the temperature, a carbon resistor was fitted to the top of the bag and electrically connected to a temperature recorder.

Reference is made to FIG. 2 setting forth a schematic diagram illustrating the system employed to carry out the method set forth in the instant example. Container **33** represents the above-described apparatus. Chamber **34** was evacuated to a partial vacuum with vacuum pump **35**, valve **36** being open and valves **37**, **40** and **41** being closed. Valve **37** was then opened to admit liquid nitrogen into the Mylar laminated Dacron "bag" **39**. After the "bag" was filled (13 quarts), valve **37** was closed.

During storage of the liquid nitrogen the partial vacuum was maintained. The temperature of the "bag" was 140° R. Prior to expelling the liquid nitrogen, valve **36** was closed. Valves **40** and **41** were then opened.

Gaseous helium at a temperature below the temperature of liquid nitrogen was admitted under pressure controlled by pressure regulator **42** and pressure gauge **43** into the chamber to effect a continuous uniform flow of liquid nitrogen to another receptacle. After the "bag" **39** completely collapsed, the outlet connection was severed and the pressure withdrawn. The "bag" was examined with the finding of no manifest damage.

The above procedure was repeated at least 6 times with no damage to the "bag."

A "bag" of woven polytetrafluoroethylene (Teflon) laminated with a film of Teflon was substituted for the Mylar-coated Dacron "bag" with complete success.

It is quite surprising that Mylar films and Teflon films may be used for the purposes of the instant invention since the vast majority of normally-flexible materials, particularly the thermoplastic and elastomeric materials, become so rigid at temperatures below about −100° F. that they crack with the slightest change of shape. Rubber, for example, becomes inoperative at temperatures substantially above −100° F. Other materials which cannot be used include resinous films of polyethylene, polyvinylchloride, polyacrylonitrile, polyolefins, polystyrene, polyurethanes, polyvinylbutyral, and the like.

It is preferred that the film on the surface of the cloth be less than 1.0 mil in thickness in order to obtain a maximum in flexibility and at least 0.5 mil for maximum in durability.

In addition to Mylar, other polyesters prepared from terephthalic acid or simple esters thereof and a polyol, particularly ethylene glycol may be employed. Of course, the resulting polymer should have a high enough molecular weight to be sufficiently tough and low enough molecular weight to be flexible. While Mylar forms films which are not overly flexible at room temperature, the films surprisingly maintain their flexibility down to temperatures approaching absolute zero.

In addition to Teflon, other polyhaloethylenes may be used. For example, polymonochlorotrifluoroethylene (Kel–F) may be used.

Another important aspect of the instant invention is in the insulation of the chamber surrounding the inner container. Aluminum foil and glass fibers are extremely effective insulation against irradiation. In lieu of this, a sheet of aluminum foil may be used but is not quite as effective. Other reflecting materials, however, may be used such as a silver-backed mirror or other polished metals. The glass fibers may be substituted with other fibers including both natural and synthetic, preferably those not treated with antistatic agents. One very effective commercially available combination of glass fibers and aluminum foil is Superinsulation.

The apparatus of the instant invention may be varied considerably in structure. Important considerations are in providing a good insulating jacket surrounding the cryogenic liquid and a bladder which is flexible at the temperatures of these liquids. Moreover, the inlet and outlet should be surrounded with insulation.

The insulating chamber should be at least ¼-inch thick, but this is not critical. There is really no maximum thickness which is critical; it is preferred that the chamber be 1 to 5 inches thick, depending on the size of the apparatus. If the chamber is too thin, there is difficulty in distributing the insulation uniformly throughout the chamber and if the chamber is excessively thick, the evacuation time becomes inordinately long.

The shape of the apparatus is governed only by engineering expedients, the ability to collapse the bladder, and by sufficient supporting strength to resist strains and tension from the accelerating forces employed in attaining orbiting velocities. A particularly preferred design for an orbiting refueling station comprises a cylindrical container with several pillow-shaped bladders located around the inner surface. A gas is admitted into the center which squeezes the bladders against the inside surface whereby the cryogenic liquid is ejected.

Other designs utilizing multiple bladders are also envisioned and are considered part of the instant invention.

The present invention is not limited to the embodiments described and illustrated but includes all those embodiments falling within the scope of the appended claims.

What is claimed is:

1. An apparatus comprising a rigid inner container enclosed by a rigid outer container; said rigid inner container being positively spaced from said outer container by a plurality of low heat conducting blocks to thereby provide a chamber between said inner and outer container that completely surrounds said inner container; conduit means sealingly connected to said outer container and communicating with said chamber to permit inducing of a vacuum in said chamber; an inlet and an outlet disposed within said conduit means and extending inwardly therefrom to traverse said chamber; a bladder encased in said inner container and communicating with said inlet and outlet and having a similar configuration and dimension as the inner container to thereby be disposed adjacent to and extend contiguous with the inner surface of the container during the storage of cryogenic fluid; said bladder including an open neck portion at its upper end secured to the inner container by an elliptical sealing ring contiguous to the inside of said bladder, a ring member disposed between said bladder and inner container, a mounting flange attached to the outside of said inner container, and a head boltingly attached to said sealing ring, said ring member and said mounting flange; a smoothly rounded guard disposed within said neck portion and depending from said inner head; and a gas pressure supplying inlet means traversing said chamber and in communication with the inner container and the outside surface of the bladder.

2. A storage vessel for cryogenic fluid comprising a rigid inner container enclosed by a rigid outer container; said rigid inner container being spaced from said outer container to provide a gas tight chamber surrounding said inner container; conduit means providing communication with said chamber and permitting induction of a vacuum in said chamber; an inlet and an outlet traversing said chamber; a bladder disposed in said inner container and having a similar configuration and dimension to enable the bladder to be substantially contiguous with the inside of said inner container during the storage of cryogenic fluid; said bladder having an open neck portion secured to the inner container by an elliptical sealing ring contiguous to the inside of said bladder, a ring member disposed between said bladder and inner container, a mounting flange attached to the outside of said inner container, and a head boltingly attached to the said elliptical sealing ring, said ring member and said mounting flange; said neck portion communicating with said inlet and outlet; a guard terminating in a smoothly rounded portion disposed in said neck portion; and a gas inlet means traversing the outer container and in gaseous communication with said inner container and the outside surface of said bladder.

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