A diaphragm (10) suitable for extreme temperature usage, such as encountered in critical aerospace applications, is fabricated by a unique method, and of a unique combination of materials, which include multi-layered lay-ups of diaphragm materials (20a, 22, 20b) sandwiched between layers of bleeder fabric (29, 36), which, after being formed in the desired shape on a mold (26), are vacuum sealed (38) and then cured under pressure, in a heated autoclave, to produce a bond capable of withstanding extreme temperatures.

5 Claims, 4 Drawing Figures
FIG. 4

- CLEAN MOLD
- SPRAY ADHESIVE ON MOLD
- APPLY BLEEDER FABRIC
- APPLY RELEASE AGENT
- APPLY FIRST LAYER OF SILICONE RUBBER
- APPLY FABRIC REINFORCEMENT
- COAT FABRIC REINFORCEMENT WITH ADHESIVE PRIMER
- APPLY SECOND LAYER OF SILICONE RUBBER
- APPLY LAYER OF PARTING FABRIC
- APPLY ANOTHER BLEEDER FABRIC LAYER
- SEAL VACUUM BAG TO TOOL OVER ASSEMBLY
- CURE USING HEAT AND EXTERNAL PRESSURE, WITH FULL VACUUM ON ASSEMBLY UNDER BAG
- SEPARATE AND REMOVE FINISHED DIAPHRAGM
- TRIM TO REQUIRED DIMENSIONS
METHOD OF MAKING A FLEXIBLE DIAPHRAGM

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

The present invention relates to flexible membranes, and more particularly to a flexible diaphragm seal assembly suitable for use in extreme temperature ranges. Flexible diaphragms used as seals, as pressure transducers, as barriers for separating differing media, and to a greater extent, are well known. Numerous examples may be found in the technical literature, in industrial applications, and of course in nature itself. The man-made diaphragm configurations and methods for their fabrication are as varied as the application to which they are put.

However, although there are many diaphragms designed for rigorous environments, none could be found which was suitable for certain especially demanding aerospace applications. For example, in the Shuttle Orbiter there is a need for a diaphragm seal capable of operating at temperature extremes ranging from -200°F to +600°F, and capable of withstanding physical excursions imposed at these temperatures by induced motions during the Shuttle engine ignition, ascent, and External Tank and Orbiter separation. In one instance, these motions require a diaphragm capable of deflecting 0.5 inch in all directions while subjected to -150°F ±10°F, and while containing an inert gaseous purge. The leakage is not to exceed 10.4 SCFM @ 3.26 PSI, and 18.8 SCFM @ -2.76 PSI. After external tank/Orbiter separation, the diaphragm then has to provide a seal between the aft fuselage area and outer space. The gaseous purge requirement (as with an inert gas to prevent explosive risks) means that the diaphragm seal must be capable of maintaining a positive pressure during such maneuvers. After separation in outer space, these pressure conditions then reverse. It is intended for above normal operational temperatures ranging from -2.76 PSI to +2000 psi at 150°F.

Retesting (of the same configuration and material, but with material from a different supplier) resulted in the same failure. As presently understood, this failure is believed to have resulted from the necessity to thin the liquid rubber so that it could impregnate into the weave or knit of the fabric. Such thinning lowers the molecular weight consistency, thereby reducing the rubber film strength.

A substantial need therefore remains for a flexible diaphragm suitable for extreme temperature usage, and particularly one which can meet the rigorous aerospace applications described above. Ideally, such a diaphragm construction, and its method of fabrication, will be not only durable (and thus suitable for multiple aerospace mission use), but will also be uncomplicated, versatile, and relatively inexpensive to manufacture. In addition, it should ideally be suitable for use in a great variety of other applications, such as refrigeration seals, autoclaves, storage lockers, and other sealing applications subjected to extreme temperature differentials.

SUMMARY OF THE INVENTION

Briefly, the present invention meets the above needs and purposes with a flexible diaphragm construction, and a method for the fabrication thereof, which furnish diaphragms particularly well suited for extreme temperature usage. The diaphragms are durable, uncomplicated, versatile, relatively inexpensive to manufacture, and as a result are suitable for use in a great variety of applications in addition to such specialized aerospace applications as those discussed above.
According to the teachings of the present invention, a preferred embodiment of the invention furnishes such diaphragms as an assembly fabricated on a 2% oversize aluminum layup mold which has been suitably formed and a shaped according to the intended shape of the diaphragm. The mold is oversized to allow for calendered silicon rubber shrinkage after cure.

In use, the working surface of the layup mold is first cleaned. Then a continuous adhesive coat is sprayed onto the mold working surface, and the adhesive is allowed to develop good tack. Next a first bleeder fabric layer is smoothly applied to the adhesive on the mold working surface, extending beyond the finished diaphragm size. The bleeder fabric is then coated and saturated with a release agent. Then a wrinkle free continuous first layer of calendered uncured high molecular weight consistency silicone rubber sheet material is hand applied to the bleeder fabric. Parting fabric is used to aid in applying the silicone rubber sheet material in order to minimize contact lifting of the uncured rubber while this first layer is applied.

Next, a wrinkle free, splice free, and fold free layer of continuous glass fabric reinforcement is applied onto the first layer of silicone rubber sheet material, extending beyond the silicon rubber sheet edge. The fabric reinforcement is then coated, saturated, or impregnated with an adhesive primer. Then a wrinkle free continuous second layer of calendered uncured high molecular weight consistency silicone rubber sheet material is hand applied to the layer of fabric reinforcement. Using a parting fabric aid to prevent contact lifting, a layer of parting fabric is then applied to the second layer of silicone rubber sheet material, and an external layer of bleeder fabric is applied to the parting fabric. As with the first bleeder fabric layer and the continuous glass fabric reinforcement layer, the external layer of bleeder fabric also extends beyond the edge of the parting fabric and the silicone rubber sheet layers, so that all three such extended layers provide for vacuum removal (as further discussed below) of any entrapped air between the impregnated glass fabric and the two layers of calendered silicone rubber. This provides for a void free composite.

The process is continued by sealing a vacuum bag to the layup mold over this assembly of layers. Then a vacuum is applied between the vacuum bag and the layup mold, and the assembly is cured under heat and augmented autoclave pressure applied externally to the vacuum bag, while maintaining a vacuum between the vacuum bag and the layup mold; in which the finished diaphragm assembly is then separated and removed from the first bleeder means and the parting means; and to accomplish the above objects and purposes in an uncomplicated, durable, versatile, and reliable method and apparatus, inexpensive to manufacture, and suitable for use in a great variety of other applications having extreme temperature differentials.

These and other objects and advantages of the invention will be apparent from the following description, the accompanying drawings, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a somewhat figurative and simplified cross-sectional illustration showing the diaphragm bridging a ring-shaped space between two bulkhead members; FIG. 2 is an enlarged detail of the FIG. 1 illustration showing the diaphragm in cross-section; FIG. 3 is a schematic drawing, broken away layer by layer, illustrating the method of fabrication and the structure of the diaphragm; and FIG. 4 is a flow diagram showing the sequence of steps in the manufacture of the diaphragm.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to the drawings, the new and improved flexible diaphragm suitable for extreme temperature usage, and the method for the manufacture thereof according to the present invention, will now be described. FIG. 1 shows, in simplified figurative form, a barrier such as a bulkhead, having a ring-shaped gap running therearound. The central portion of the bulkhead is free to move, to some extent, with respect to the outer portion thereof. Thus, for example, the central portion in the bulkhead central portion might have sealed therein an assembly, or an umbilical disconnect, etc. The conceivable applications are virtually limitless. Here, however, it is assumed that extreme differences in temperature will be encountered, and particularly conditions which can be extremely cold.

The diaphragm, as shown in greater detail in cross-section in FIG. 2, can meet the extreme conditions described at length earlier herein. It consists of two separate sheets of high molecular weight consistency silicone rubber placed on each side of a continuously layed up layer of glass fabric, coated, saturated, or impregnated with a thinned adhesive. This sandwich is bonded using a co-cure process in a vacuum/pressure bag in an autoclave. The resultant structure is, in effect, a double seal, with sealing capability.
5
down to -180° F. Tests for aerospace applications have
shown it capable of multi-mission use in situations
where no prior art structure could be found which
could meet the required performance capabilities.

With reference particularly to FIGS. 3 and
4, the step-wise method for fabricating the diaphragm
is as follows. First a male layup mold 26 is prepared in
the shape desired for the diaphragm. In the preferred em-
6
bodiment, mold 26 is made of aluminum and machined
2% oversize to allow for the silicone rubber shrinkage
factor.

The layup or working surface 27 of mold 26 is then
cleaned, for example with 1,1,1 trichloroethane, and
scraped if necessary (with non-metallic scrapers). Then
a continuous coat of adhesive is sprayed on the working
surface 27, and allowed to develop good tack (e.g.,
about two to five minutes). A spray adhesive such as
that sold under the trademark "SCOTCH" 6082, or the
like, may be used.

To allow air to exit from either side of the diaphragm
10 as it is being formed, a first bleeder layer 29, of 181
weave, type 6, glass fabric, available from Burlington
Glass Fabric Co., Alta Vista, Va., is applied smoothly
(preferably by hand forming) to the adhesive on the
mold layup surface 27, with the warp in the long direc-
tion of the mold, and extending beyond the diaphragm
finished edge. The full fabric surface is then rubbed
down with "TEFLON" paddles or rollers to prevent
any bridging of the fabric. The adhesive is then allowed
to air dry for 30 minutes, minimum. The bleeder fabric
is then coated and saturated with a release agent such as
a fluorocarbon parting agent (for example "MS 143",
available from Miller-Stephenson, Danbury, Conn.).

Next, a continuous first layer or sheet of calendered
uncured silicone rubber is applied wrinkle free to the
bleeder fabric 29, to form sheet 20a. Good results have
been obtained with a 0.030 in. thick calendered, uncured
methy1 phenyl siloxane polymer sheet, such as "SMC
1050" sold by "D" Aircraft Products Company, 1191
Hawk Circle, Anaheim, Calif. Gloved hands should be
used, and during the hand forming of the rubber sheet
20a to the contour of the mold 26, it is helpful to use a
piece of "TEFLON" coated parting fabric (such as
"TX 1040", available from Richmont Corporation,
Redlonde, Calif.) to minimize tacking of the rubber

sheet to the gloved hands.

Next, the central glass fabric layer 22 is formed by
applying a wrinkle free, splice free, and fold free layer
of continuous glass fabric reinforcement onto the first
layer 20a of silicone rubber sheet material, maintaining
warp direction identity, and extending beyond the edge
of the silicon rubber material. The glass fabric 22 is
formed to the mold contour and smoothed into intimate
contact with the silicone rubber layer 20a using a
"TEFLON" paddle or a roller. In the preferred em-
"boodiment, glass fabric, 120 weave, Type 8, Finish B,
available from Burlington Glass Fabric Co., Alta Vista,
Va.) is used for layer 22.

Following this, an adhesive primer is brushed onto
and impregnated into the full surface of the reinforcing
fabric layer 22 and allowed to air dry for at least two
hours. In the preferred embodiment, a diluted mix of
commercially available silicone rubber primer, such as
that sold under the trademark "DAPCOTAC" 3300Th,
Part A, mixed with "DAPCOTAC" 3300Th, Part B, in
the ratio of ten parts by weight of Part A to one part of
Part B, and this is mixed with eleven parts by weight of
toluene.

6
Outer rubber sheet 20b is then hand applied to the
adhesive impregnated fabric reinforcement layer 22.
The second layer 20b, like layer 20a, is a continuous
sheet of calendered, uncured silicone rubber, applied
wrinkle free by hand. The same 0.030 in. thick "SMC
1050" methyl phenyl siloxane polymer sheet is prefera-
ably used in the preferred embodiment.

Next, a layer 33 of parting fabric (such as "TX 1040"
"TEFLON" coated fabric) is applied to the second
layer 20b of the silicone rubber sheet material. This, in
turn, is covered with one additional layer 36 of bleeder
fabric, such as the 181 glass fabric used for layer 29,
and also extending beyond the edge of the silicon rubber
material.

Finally, a vacuum bag 38 is sealed to the layup mold
26 over layers 29, 20a, 22, 20b, 33, and 36. Bag 38 may
simply be a sheet of suitable nylon bagging film (such as
"WRIGHTON" 7400, sold by International Plastics
Products, Inc., Los Angeles, Calif.). The sealant may be
a bead of commercially available, compatible sealant,
such as "GS43" available from the W. P. Fuller Com-
pany, Los Angeles, Calif.

A vacuum is then slowly applied between the vac-
uum bag 38 and mold 26, and the assembly of layers is
cured under heat and pressure applied externally to the
vacuum bag 38 (the vacuum between the vacuum bag
38 and the layup mold 26 being maintained). In the
preferred embodiment, 26 inches of mercury vacuum is
maintained; the externally applied pressure is 75±10
PSI; the cure temperature is 345±10° F.; and the cure
time is from 60 to 120 minutes.

The assembly is then cooled to less than 150° F. be-
fore the vacuum and pressure are released, and the
finished diaphragm 10 is separated and removed from
the first bleeder fabric layer 29 and the parting fabric
layer 33. The diaphragm flanges are then trimmed to
the desired finished dimensions.

As may be seen therefore, the present invention pro-
vides numerous advantages. Principally, it furnishes a
flexible, durable diaphragm structure, and method of
fabrication, suitable for the rigorous and extreme tem-
perature conditions found in aerospace applications
such as the Shuttle Orbiter. The diaphragm and its
method of fabrication are uncommplicated, versatile,
and relatively inexpensive to implement. The invention
thus lends itself ideally to many other demanding appli-
cations and configurations, such as refrigeration seals,
autoclaves, storage lockers, and other sealing applica-
tions having extreme temperature differentials and long
life requirements.

While the methods and forms of apparatus herein
described constitute preferred embodiments of this in-
vention, it is to be understood that the invention is not
limited to these precise methods and forms of apparatus,
and that changes may be made therein without depart-
ing from the scope of the invention.

What is claimed is:

1. A method for fabricating a flexible diaphragm
suitable for extreme temperature usage, comprising:
(a) preparing the working surface of a layup mold
shaped for forming the diaphragm thereon,
(b) applying adhesive to the mold working surface
and allowing the adhesive to develop good tack,
(c) applying a first bleeder means to the adhesive
on the mold working surface,
(d) applying a first layer of silicone rubber sheet mate-
rial over the bleeder means,
4,676,853

(e) applying a layer of fabric reinforcement onto the first layer of silicone rubber sheet material,
(f) coating the fabric reinforcement with an adhesive,
(g) applying a second layer of silicone rubber sheet material over the layer of fabric reinforcement,
(h) applying a parting means to the second layer of silicone rubber sheet material,
(i) applying a second bleeder means to the parting fabric,
(j) sealing a vacuum bag to the layup mold over the 10 assembly of layers recited in the preceding steps (c) through (i),
(k) applying a vacuum between the vacuum bag and the layup mold,
(l) curing the assembly under heat and pressure above 15 atmospheric applied externally to the vacuum bag, while maintaining a vacuum between the vacuum bag and the layup mold, and
(m) separating and removing the finished diaphragm assembly from the first bleeder means and the parting means.

2. The method of claim 1 wherein step b) further comprises coating the bleeder means with a release agent.

3. The method of claim 1 wherein steps (c) and (f) further comprise using smoothing means and “TEFLON” coated parting fabric to minimize tacking of the silicon rubber to the smoothing means while applying the silicon rubber sheet material.

4. A method for fabricating a flexible diaphragm suitable for extreme temperature usage, comprising:
(a) cleaning the working surface of a layup mold shaped for forming the diaphragm thereon,
(b) spraying a continuous adhesive coat on the mold working surface and allowing the adhesive to develop good tack,
(c) smoothly applying a first bleeder fabric layer to the adhesive on the mold working surface,
(d) coating and saturating the bleeder fabric with a release agent,
(e) hand applying a wrinkle free continuous first layer of uncured silicone rubber sheet material to the bleeder fabric,
(f) using parting fabric to minimize tacking while applying the layer of silicone rubber sheet material,
(g) applying a wrinkle free, splice free, and fold free layer of continuous glass fabric reinforcement onto the first layer of silicone rubber sheet material,
(h) coating the fabric reinforcement with an adhesive primer,
(i) hand applying a wrinkle free continuous second layer of uncured silicone rubber sheet material to the layer of fabric reinforcement,
(j) applying a layer of parting fabric to the second layer of silicone rubber sheet material,
(k) applying a layer of bleeder fabric to the parting fabric,
(l) sealing a vacuum bag to the layup mold over the assembly of layers recited in the preceding steps (c) through (k),
(m) applying a vacuum between the vacuum bag and the layup mold,
(n) curing the assembly under heat and pressure applied externally to the vacuum bag, while maintaining a vacuum between the vacuum bag and the layup mold,
(o) cooling the assembly,
(p) releasing the vacuum and pressure and,
(q) separating and removing the finished diaphragm assembly from the first layer of bleeder fabric and the layer of parting fabric.

5. The method of claim 1 wherein step (k) further comprises curing the assembly by maintaining a vacuum of approximately 26 inches of mercury between the vacuum bag and the layup mold, maintaining a pressure applied externally to the vacuum bag of 75 ±10 pounds per square inch above atmospheric, and maintaining a temperature of 345°±10° F. for 60 to 100 minutes, all, at least in part, simultaneously.