Jan. 23, 1968 P. ISAAC 3,364,632

INFLATABLE STRUCTURAL MEMBERS

Original Filed Sept. 2, 1965 2 Sheets-Sheet 1

FIG. 2

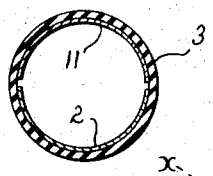


FIG. 1

FIG. 3

FIG. 4

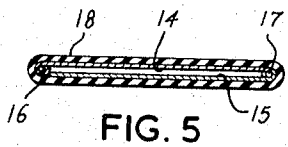


FIG. 5

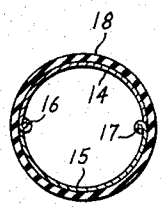


FIG. 6

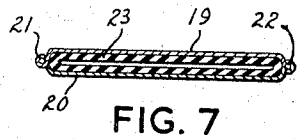


FIG. 7

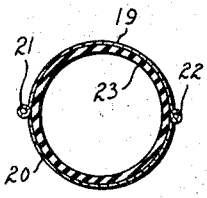


FIG. 8

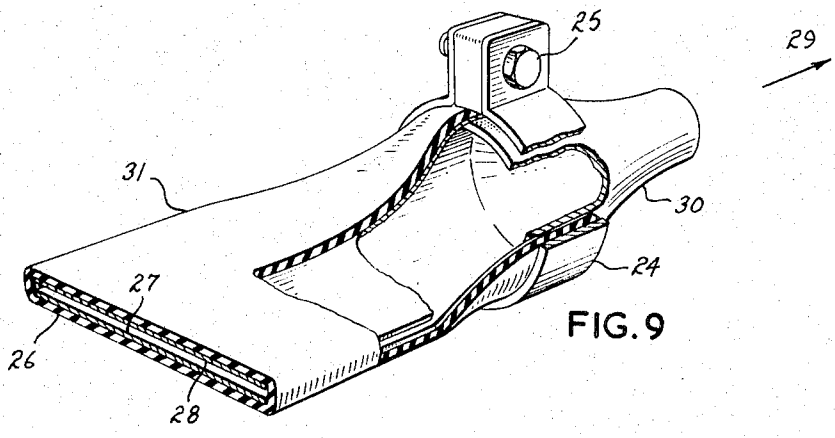


FIG. 9

Peter Isaac

Jan. 23, 1968 P. ISAAC 3,364,632

INFLATABLE STRUCTURAL MEMBERS

Original Filed Sept. 2, 1965 2 Sheets-Sheet 2

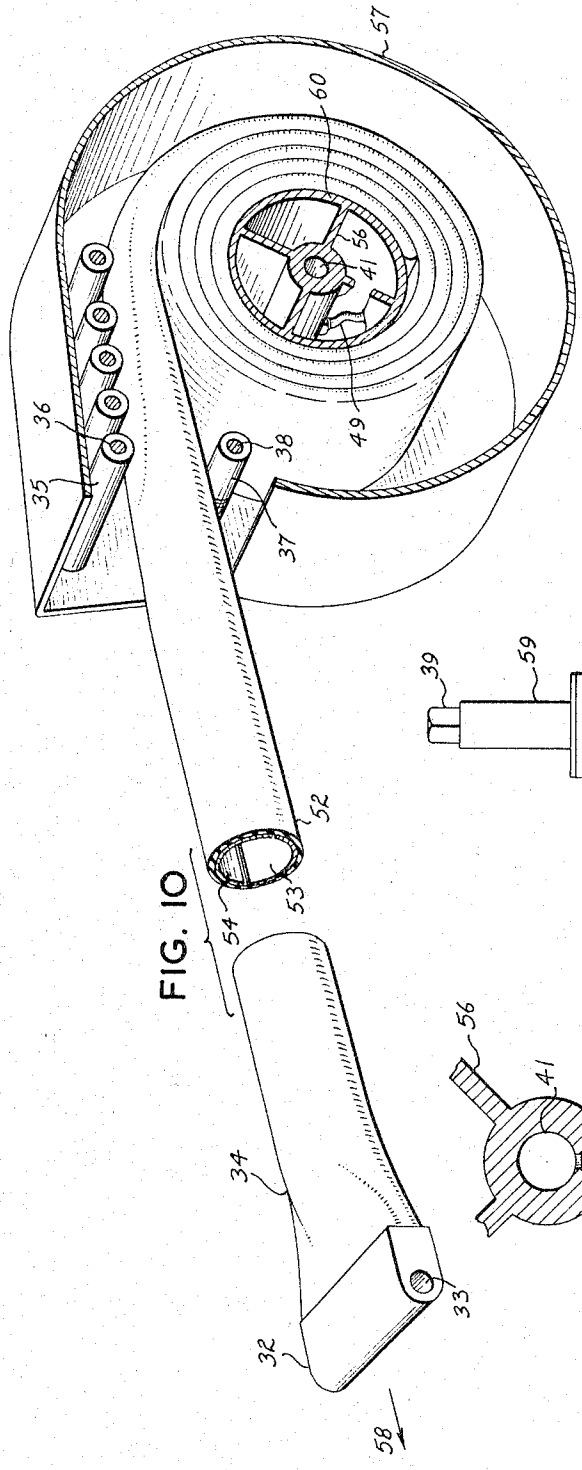


FIG. 10

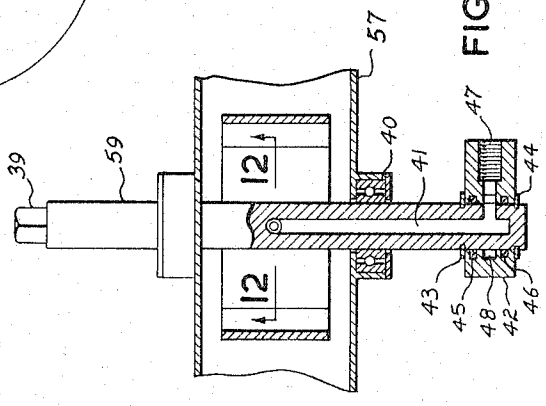


FIG. 11

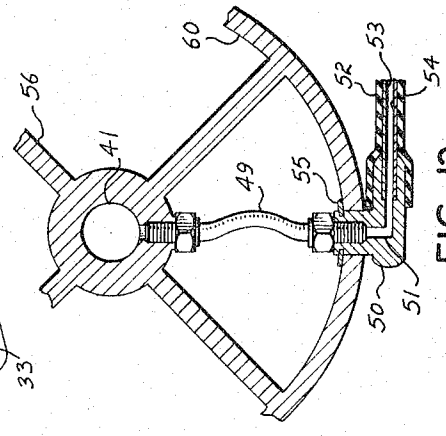


FIG. 12

United States Patent Office 3,364,632
Patented Jan. 23, 1968

3,364,632

INFLATABLE STRUCTURAL MEMBERS

Peter Isaac, 65 N. Service Road, Apt. 609,
Cooksville, Ontario, Canada

Continuation of application Ser. No. 485,147, Sept. 2, 1965. This application July 18, 1966, Ser. No. 567,347
6 Claims. (Cl. 52—2)

ABSTRACT OF THE DISCLOSURE

The specification describes inflatable members made of stiff resilient material which normally are flexible and reelable but become erectly rigid when inflated. Also described is a device comprising the combination of such an inflatable member with a reel from which said inflatable member may be extended and retracted in an erectly rigid state. Applications of such members and devices such as reelable beams, booms, gates, fishing poles and antennas are cited.

This application is a continuation of application Serial No. 485,147, filed September 2, 1965, now abandoned, which in turn is a substitute of application Serial No. 231,167, filed October 17, 1962, also abandoned.

My invention pertains to inflatable structural members which may be made flexible for convenience, storage or transportation and rigid when required for carrying compressive or flexural loads.

Various flexible and various rigid members are in use every day. However, no invention is known of whereby the same member may be made deliberately flexible or rigid at will.

The object of this invention is to provide a flexible member which may be reeled for transportation and unreeled and used as a rigid construction member or as a component of a device or machine.

A further object of my invention is to provide a member which is stored on a reel in the flexible state, and which may be fed from the reel in a rigid state in a cantilever manner without any guidance other than from the reel, and which is capable of carrying tensile, compressive or flexural loads while or after it is unreeled.

A still further object of my invention is to provide a hose for conveying fluids which is flexible and may be reeled for storage but which becomes rigid when it is subject to a fluid under pressure.

This specification purports to cover only the basic principles involved and the method of constructing inflatable structural members, it being understood that the possible applications of such members are too numerous to be described in detail in this specification. Such applications may be readily executed by those skilled in the mechanical arts. However, a few applications will be listed here to indicate the usefulness of the invention: construction members, such as beams or booms, for temporary shelters or bridges; gates or doors which reel out of the way rather than swing; fishing poles or tent which may be reeled when not in use; antennas for spacecraft which may be reeled when not in use; aerial ladders which may be reeled when not in use; refuelling hoses which may be fed from one aircraft to another in a rigid state while the aircraft are in flight; linear actuators.

Many other applications will become apparent as this invention is understood.

With the foregoing objects and purposes in view and such others as may become apparent as this specification proceeds the present invention consists of the following construction and arrangement of parts, all as hereinafter more particularly described reference being had to the accompanying figures in which:

FIGURE 1 is a perspective sectional view which illustrates a portion of an inflatable structural member in the flexible state and details of construction of the main body and end fitting and how an external fluid supply may be utilized for inflating and deflating the member.

FIGURE 2 illustrates the cross sectional shape of the main body of the member in FIGURE 1 when it is made rigid by inflation.

FIGURE 3 illustrates the first modification of the main body of the member according to FIGURE 1 and shows the cross sectional shape of the main body when the member is flexible.

FIGURE 4 illustrates the cross sectional shape of the modification according to FIGURE 3 when it is made rigid by inflation.

FIGURE 5 illustrates the second modification of the main body of the member in FIGURE 1 and the cross sectional shape of the main body when it is in the flexible state.

FIGURE 6 illustrates the cross sectional shape of the modification according to FIGURE 5 when it is made rigid by inflation.

FIGURE 7 illustrates the third modification of the main body of the member and shows the cross sectional shape when the member is in the flexible state.

FIGURE 8 illustrates the cross sectional shape of the modification according to FIGURE 7 when it is made rigid by inflation.

FIGURE 9 shows a hose for conveying fluids, which is constructed in accordance with the concepts shown in FIGURE 1, attached to a nozzle with the hose in the flexible state.

FIGURE 10 is a perspective cross sectional illustration showing the manner in which an inflatable structural member, constructed in accordance with the concepts shown in FIGURE 1, may be stored on a reel and fed from the reel in the rigid state.

FIGURE 11 is a cross sectional plan view through the centre of the reel in FIGURE 10 which shows details of a rotary fluid coupling whereby a fluid may be fed from an external source to a passageway in the centre of the shaft.

FIGURE 12 is a cross sectional view along the lines 12—12 of FIGURE 11, which shows details of the end fitting which is attached to the drum and the means whereby the fluid may be fed from the passageway in the centre of the shaft to the inflatable structural member.

Before proceeding with the detailed description of my invention I would like to explain the underlying principle.

It is a well known law of mechanics that any structural member which is thin, that is one which has most of the material near the neutral surface of flexure, is flexible in this surface relative to a member which has the same amount of material which is located further from the neutral surface. For instance, a strip of material is supple or flexible in its wider neutral surface of flexure, but relatively rigid in its thinner neutral surface of flexure.

The basic concepts of my invention centre about a practical method of disposing load carrying elements near the surface of flexure when it is desired to have a flexible member which may be reeled for convenience, and away from the neutral surface of flexure when it is desired to have a rigid member for carrying compressive load.

There are several ways of disposing the elements to achieve the desired result. Inflation is used as the disposal means in all the embodiments, which have been illustrated.

The basic concept of my invention may be understood with reference to FIGURES 1 and 2. Only a sufficient portion of an inflatable structural member 1 is illustrated to show the essential features. In its simplest form it consists of: erecting means comprising one or more resilient

elements, or strips, such as 2 and 11 shown; element, or strip, connecting means 3, whereby the elements or strips are connected to each other; sealing means for preventing the escape of fluid from the member when it is inflated which, in the embodiment of FIG. 1, include the element connecting means 3 and the sealant between the end of the tube and the projection 10 of the end fitting; and inflating means which generally include all the means necessary for providing a flow of fluid to and from the member for inflating and deflating it.

Describing the above cited means in greater detail, the resilient elements 2 and 11 may be made of any resilient strips of material, such as steel, plastic or fiberglass, which can dish as shown in FIG. 2 without taking a permanent set, and which will return to the flat state shown in FIG. 1 when the member is deflated. The element, or strip, connecting means 3 may comprise a tube of supple material, such as rubber, or synthetic organic compounds and the means for fastening the elements to the tube which may be done by bonding, cementing, riveting or combinations thereof. If a tube is used, fastening of the elements thereto is necessary to insure the elements will dish when the member is inflated. It will be appreciated that although the element connecting means are shown as comprising a tube, this is more for reasons of convenience than necessity, since functionally all that is necessary is that the elements be connected, which can be done by local joints at the edges. The sealing means are broadly defined as the means which prevent escape of fluid from the member when it is inflated. It will be appreciated that this may include a variety of techniques and processes well known in industry. For instance, if the member is fastened to an end fitting 5, as shown in FIG. 1, sealants are required where the tube 3 is fastened to the projection 10 of the end fitting. Furthermore, if the element connecting means 3 comprise say, intermittent bonds, rather than a continuous tube, a sealant is required at the joining edges of the elements. In most applications the member will be provided with an end fitting 5 having a projection 10 to which the elements may be secured by such means as rivets 4. Such an end fitting also provides suitable means for connecting inflating and deflating means to the threaded end 8. The end fitting may also be provided with means, such as the hole 6, to which external loads may be conveniently connected by means of a yoke.

Although the other end of the member is not shown, it will be evident that it may consist of any type of enclosure which prevents the fluid fed into the member from escaping, depending on the particular application intended for the member. The element connecting means 3 could envelop the ends of the elements is an application such as a fishing pole. In applications where the member is intended to be used as a column, the other end of the member could be indentical to the end which is shown.

Although FIG. 1 illustrates how one external load may be connected to one end of the member, it will be appreciated that any number of possible connections for this purpose could be provided. For instance, the member could have two end fittings of the type shown in FIG. 1, along with special clamps at several places along the member, or internally threaded rivets attached to one of the elements, and projecting through the tube wall.

It will also be appreciated that the member illustrated may be used as a basic component of composite structures, such as those cited in the preamble of this application.

Describing now the operation of the embodiment shown in FIGURES 1 and 2, it will be seen that when the member is in the deflated state shown in FIG. 1, it is also flexible. This is the case because the elements 2 and 11 overlie each other and hence are disposed close to the horizontal neutral surface of flexure containing the neutral axis X—X. The member may be regarded as permanently rigid in the vertical neutral surface of flexure containing the neutral axis Y—Y, since most of the material is relatively far away from this neutral surface. The member

may be made rigid in both surfaces by feeding a liquid or gas through the passageway 9 in the direction of the arrow 7. The fluid pressure will inflate the member to the cross sectional shape shown in FIG. 2. It will be appreciated that the member then is in a rigid state since the elements then are disposed away from the neutral surface of flexure. In the rigid state, the member may function as a structural member, or a component of a device, or machine, since it is capable of carrying tensile, compressive, or flexural loads. The member may be made flexible again by relieving the fluid pressure. The elasticity of the elements returns the member to the state shown in FIG. 1. In some applications where tubes with thick walls are required, the deflation process may be improved by the application of a vacuum. However, since the tube is preferably moulded to conform to the flexible state, it will tend to return to this state when the applied pressure is relieved.

It will be appreciated that, although the member is shown inflated to a circular cross section, this need not be the case. By varying the thickness of the elements, or inflation pressure, a variety of shapes is attainable.

The second embodiment of my invention is shown in FIGURES 3 and 4. This is the preferred embodiment for applications where only light loads have to be carried. In principle, this embodiment is very similar to the embodiment of FIGURES 1 and 2, which has been described. However, the erecting means may comprise a number of elements 12 which are imbedded in the wall of the inflatable means 13. It will be noted that the inflatable means 13 also serves as the element connecting means and must be moulded to conform to the flexible state shown in FIG. 3 to ensure the member will return to the flat configuration when deflated. In this respect this embodiment differs from that of FIG. 1 where the resilient elements 2 and 11 restore the member to the flexible state after it has been deflated. However, it will be noted that, if only one element is used, which is as wide as the inflatable means, then the design could be such that the element itself would restore the member to the flexible state. It will also be noted that wire elements could be used in place of the flat elements 12 shown. The member may also terminate in an end fitting 5, as shown in FIG. 1.

The principle of operation is identical to that described in connection with the first embodiment. When the member is inflated it assumes, in the limit, a cross sectional shape shown in FIG. 4, and when the member is deflated the moulded inflatable means restore it to the flat, and hence flexible, state of FIG. 3.

The third embodiment of my invention is shown in FIGURES 5 and 6. It will be apparent that the construction of the member differs from that of the member of FIGURES 1 and 2 in that the element connecting means include the hinges 16 and 17, by means of which the elements 14 and 15 are joined at the longitudinal edges. The sealing means are shown as comprising a tube 18 of supple material whose main purpose is to prevent the escape of fluid past the hinges. Although these means are shown as consisting of a tube which envelops the elements, in their simplest form they may only be rubber or other sealant caulked locally in the area of the hinges.

It will be appreciated that by using element connecting means in the form of hinges, as shown in FIG. 5, rather than in the form of a tube 3, of FIG. 1, the load carrying capacity of the member may be substantially improved. Since there is severe stress in the element connecting means when the member is inflated, the use of hinges also permits thicker elements to be used than can be used with element connecting means in the form of supple material, as in FIGURES 2 and 4.

It will be noted that, although the member of FIG. 5, only shows two elements 14 and 15, any number may be provided.

The fourth embodiment of my invention is shown in FIGURES 7 and 8. It will be seen that the sealing means

23 comprise a tube situated between the resilient elements 19 and 20, which are joined by element connecting means comprising the hinges 21 and 22. Again, although the sealing means 23 are shown as comprising a tube, they, in the simplest form, may be rubber or other sealant placed locally in the area of the hinges, although a tube is less likely to develop leaks after repeated use.

It will be mentioned here that if the sealing means 23 of FIG. 8 comprise a tube it is not necessary to bond, or cement, the tube to the elements 19 and 20, which is unlike the embodiment of FIG. 5, where the sealing means 18, if in the form of a tube, must be fastened to the elements 14 and 15 to ensure the elements dish as shown in FIG. 6 when the member is inflated.

A simple application of an inflatable structural member is shown in FIG. 9. This figure illustrates a hose 31 with a nozzle 30. The construction of the hose shown is identical to that of the member shown in FIG. 1 and includes erecting means comprising elements 27 and 28, element connecting means comprising a supple tube 26 and the bonding, by means of which the elements are fastened to the tube, and sealing means which, along with the tube 26, include any sealant preventing escape of fluid from the member. The hose is fastened to the nozzle by means of the clamp 24 and fastener 25.

Although the erecting means are shown as comprising two elements 27 and 28, it will be apparent that only one element is necessary, although such a hose is not as rigid as one using two or more elements.

The hose shown in FIGURE 9 is in the flexible state and may be reeled on a drum if desired. If the free end of the hose is connected to a fluid supply the hose will inflate to the cross sectional shape shown in FIG. 2 if the fluid is under sufficient pressure. The hose is then rigid and will remain so even when the fluid leaves the nozzle provided that the fluid in the hose is maintained at sufficient pressure.

There are numerous possible applications for a hose of this type. It could conveniently be used by a fire fighter or ease the refuelling problem between aircraft in flight.

A basic application of an inflatable structural member is shown in FIG. 10. This shows the member 34 being fed from a reel in the rigid state in the direction of the arrow 58. The member is of the same type shown in FIG. 1, but any of the other members illustrated in FIGURES 3, 5 and 7 could also be used.

The member 34 consists of two end fittings 32 and 50, the latter being shown in FIG. 12, and a main body which essentially consists of erecting means comprising the elements 53 and 54, element connecting means comprising a supple tube 52 and bonding by means of which the elements are fastened to the tube, and sealing means which, along with the tube 52, include any sealant preventing escape of fluid from the member.

The end fitting 50 is retained to the wall of the drum 60 of the reel by means of the retainer 55. An external load may be connected to the end fitting 32 by means of a yoke bolted through the hole 33.

The reel essentially consists of a housing 57, a drum 60 and shaft 59. The drum is journalled in the housing by means of bearings 40 and is attached to the shaft by means of spokes 56.

An external fluid supply required for inflating the member is fed into the reel at the connection 47 of the rotary coupling 42 shown in FIG. 11. The fluid passes through the passageway 41 in the shaft, the hose 49 and the passageway 51 in the end fitting to the interior of the inflatable structural member. By means of the rotary coupling the member may be inflated or deflated while the reel is operated.

There are numerous types of couplings available on the market which could be used for this purpose. The one shown is for illustrative purposes only. In consists of an annulus 48, two O-rings 45 and 46 of a material such as rubber and retainers 43 and 44, and the threaded inlet

47, already referred to. It will be evident that a hose with a fitting may be connected to the threaded inlet 47 and that the hose and rotary coupling remain stationary while the shaft 59 is rotated.

Although the reel operating means is not shown it will be apparent that a crank or motor may be attached to the square end of the shaft 39.

When a fluid supply is connected to the rotary coupling, only the protruding portion of the inflatable structural member 34 inflates and becomes rigid. The portion of the member on the drum does not inflate to any appreciable extent since the elements 53 and 54 do not readily yield to a double curvature.

By means of the rollers 35 and 37, which are journalled on the pins 36 and 38 respectively, the inflatable structural member may be fed with ease in any desired direction from the reel. These rollers also provide the means whereby external leads imposed on the fitting 32 may be reacted by the housing 57.

The member may be reeled onto the reel while the protruding portion is in a rigid state. This is the case because the curvature of the drum forces the member to deflate as the drum is being rotated by means attached to the square end 39 of the shaft.

It will be appreciated that a device of the type described can be used as a component of many devices and machines. For instance, the member 34 shown could, with miner modification, be the pole of a fishing reel. By using an end fitting of the type 5 illustrated in FIG. 1, in place of end fitting 32, the device could be used as a refuelling line which may be fed from one aircraft to another. The device could also be used as a linear actuator in applications where space limitations prohibit the use of hydraulic cylinders, commonly used for such a purpose. The device could also be used as the structural component of a door which may be reeled out of the way, or as an extendable boom.

Since the invention described has manifold applications and numerous modifications may be made thereto, all within the spirit and scope of the invention, it is intended that the description and drawings are to be interpreted as illustrative only and not in any limited sense and that only such limitations should be placed upon my invention as are specifically contained in the definition thereof or expressed in the following claims.

What I claim as my invention is:

1. An inflatable structural member, of the type described, such as a hose or boom, which is flat and flexible when deflated and erectly rigid when inflated, at least including, in combination, an inflatable tube, erecting means whereby said inflatable structural member is made erectly rigid when said inflatable tube is inflated, said erecting means comprising at least one resilient strip of stiff resilient material, such as metal or plastic, which is normally flat and oriented parallel to the longitudinal axis of said tube and is proportioned with respect to thickness and width such that it will dish transversely and become erectly rigid when said tube is inflated and, by virtue of its resilience, restore said inflatable structural member to a flat state when deflated, strip connecting means connecting said strip to said inflatable tube such that said strip is compelled to dish transversely when said tube is inflated, two end fittings, one at each end of said inflatable structural member, said strip being connected to said end fittings, and inflating means for inflating and deflating said tube.

2. The inflatable structural member of claim 1, in which said erecting means comprise two resilient strips which are connected to said tube and overlie each other when said inflatable tube is deflated and are dished outwardly from each other to an erectly rigid state when said tube is inflated.

3. An inflatable structural member, of the type described, such as a hose or boom, which is flexible and flat when deflated and erectly rigid when inflated, including,

in combination, erecting means whereby said inflatable structural member may be made erect, said erecting means comprising at least two stiff resilient strips of about equal width which are in a normally flat and flexible state and in an overlying relationship when said inflatable structural member is deflated and, by virtue of their resilience, restore said inflatable structural member to a flat state when deflated, said resilient strips being dished from each other to a rigid state when said inflatable structural member is inflated, two end fittings, one at each end of said inflatable structural member, said resilient strips being attached to said end fittings, hinge means connecting said strips to each other along their longitudinal edges, sealing means for retaining fluid within said inflatable member when inflated, and inflating means for inflating and deflating said inflatable structural member.

4. A device of the type described, including linear actuators, extendable booms and extendable antennas, said device including, in combination, an inflatable structural member and storage means for storing said inflatable structural member in a flexible state and projecting it in an erectly rigid state and cantilever manner to enable loads to be carried therewith, said storage means including a reel on which said inflatable structural member may be reeled and to which it is attached, said reel compelling the portion of said inflatable structural member thereon to be deflated while the portion projecting from said storage means is in an erectly rigid state when inflated, guide and support means for guiding and supporting the cantilever projected portion of said inflatable structural member, means for housing and supporting said reel, means for inflating and deflating said inflatable structural member, and means for operating said reel to thereby vary the length of the projected portion of said inflatable structural member, said inflatable structural member being normally flat and flexible when deflated and erectly rigid when inflated, and restorably flat of its own accord after it has been deflated, said inflatable structural member including, in combination, an inflatable tube, erecting means whereby said inflatable structural member is made erectly rigid when inflated, said erecting means comprising at least one stiff resilient strip, which is normally flat and oriented parallel to the longitudinal axis of said tube and is proportioned with respect to width and thickness such that it will dish transversely and become erectly rigid when said tube is inflated, and by virtue of its resilience, restore said inflatable structural member to a flat state when deflated, and strip connecting means for connecting said strip to said inflatable tube such that said strip is compelled to dish transversely when said inflatable tube is inflated.

5. The device of claim 4, in which said erecting means comprise two resilient strips which overlie each other when said tube is deflated and are dished outwardly from each other to an erectly rigid state when said inflatable tube is inflated.

6. A device of the type described, including linear actuators, extendable booms and extendable antennas, said device including, in combination, an inflatable structural member and storage means for storing said inflatable structural member in a flexible state and projecting it in an erectly rigid state and cantilever manner to enable loads to be carried therewith, said storage means including a reel on which said inflatable structural member may be reeled and to which it is attached, said reel compelling the portion of said inflatable structural member thereon to be deflated while the portion projecting from said storage means is in an erectly rigid state when inflated, guide and support means for guiding and supporting the cantilever projected portion of said inflatable structural member, means for housing and supporting said reel, means for inflating and deflating said inflatable structural member, and means for operating said reel to thereby vary the length of the projected portion of said inflatable structural member, said inflatable structural member being normally flat and flexible when deflated and erectly rigid when inflated and restorably flat of its own accord after it has been deflated, said inflatable structural member including, in combination, an inflatable tube, erecting means whereby said inflatable structural member may be made erectly rigid, said erecting means comprising at least two stiff resilient strips which are in a normally flat and flexible state and overlying relationship when said inflatable structural member is deflated and, by virtue of their resilience, restore said inflatable structural member to a flat state when deflated, said resilient strips being dished from each other to an erect state when said inflatable structural member is inflated, two end fittings, one at each end of said inflatable structural member, said resilient strips being attached to said end fittings, hinge means connecting said strips to each other along their longitudinal edges, and sealing means for retaining fluid within said inflatable structural member when inflated.

References Cited

UNITED STATES PATENTS

1,104,508	7/1914	Huthsing	138—119 X
2,063,843	12/1936	Jensen	137—355.2
2,212,128	8/1940	Richter	137—557
2,297,150	9/1942	Hunter	52—2
3,084,961	4/1963	Merriman	285—242
3,298,142	1/1967	Isaac	52—2

FOREIGN PATENTS

660,254	11/1951	Great Britain.

HENRY T. KLINKSIEK, *Primary Examiner.*