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Attorney Docket No. 96155

INFLATABLE STRUCTURE

STATEMENT OF GOVERNMENT INTEREST

[0001] 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.

CROSS REFERENCE TO OTHER PATENT APPLICATIONS

[0002] Not applicable.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0003] The present invention relates to inflatable structures and more specifically to an inflatable bridge structure for spanning over gaps in a terrain.

(2) Description of the Prior Art

[0004] There exists a need for the availability of spanning structures, which can be easily transported by a hiker or other lone traveler and can be quickly erected for providing access across gaps in a trail. Lightweight structures using inflatable components can provide ease of transport and quick erection.

[0005] A number of prior art devices teach bridge-like construction with flexible, inherently buoyant ways for carrying items such as vehicles on water. However, such known construction is generally heavy, difficult to transport, expensive to manufacture and cannot be quickly moved and erected. Additionally, the reliance on buoyancy to support the loads placed on such structures make them ill suited for traversing crevasses, steep gullies, and other gaps in terrain where a spanning structure would not contact water.

[0006] Other prior art devices teach inflatable structures for spanning across gaps in terrain. However, in order to provide sufficient strength, such structures rely on compression members, such as steel plates, and tension members, such as steel rods, both of which add considerable weight to the structures, making them difficult for a lone traveler to transport.

[0007] To provide adequate strength, other prior art devices rely on tube-like members that are filled with foam plastic material, which solidifies in the members. Once used, however, such structures would no longer be portable, as the tube-like members would then be rigidly extended.

[0008] Still other prior art devices utilize casings divided into multiple compartments by flexible partition walls, with each compartment having an inflatable bag therein. When inflated, the bags each bear against their respective partitions to form the bearing member. The use of partitioned casings and multiple bags makes such structures heavy and cumbersome for a lone traveler to transport. A different approach to providing a lightweight, portable, inflatable, spanning structure is needed for use by a lone traveler.

SUMMARY OF THE INVENTION

[0009] It is therefore a general purpose and primary object of the present invention to provide a spanning structure, which can be easily transported by a hiker or other lone traveler and can be quickly erected for providing access across gaps in a trail.

[0010] The object of the present invention is attained by providing lightweight inflatable components, which, when inflated, form elongated tubes that span the gap or gaps in the trail. Multiple elongated tubes can be encased by a lightweight netting, such that the tubes act in concert to support the required weight across the gap.

[0011] In one embodiment, a an inflatable spanning structure for bridging a gap comprises at least two inflatable members forming elongated tubes when inflated, said tubes having a length sufficient to span the gap; and a membrane encasing the at least two inflatable members, the membrane acting to cause the inflatable members to act in concert when supporting a load.

[0012] In one variation, the members are connected together along the length of the members. The members may be fused together during fabrication of the members. Alternately, the members may comprise mechanical fasteners along the length of the members for connecting the members together during erection of the structure. The mechanical fasteners may comprise complementary hook and loop fastening strips.

[0013] In another variation, the structure comprises three upper inflatable members placed side-by-side forming an upper portion of the structure; two lower inflatable members forming a lower portion of the structure, each placed beneath a point where two of the upper inflatable members contact each other such that each lower inflatable member is in contact with two of the upper inflatable members, the lower inflatable members; wherein the membrane encases the upper and lower inflatable members.

[0014] The diameter of the upper inflatable members is greater than the diameter of the lower inflatable members. The members may be connected together along their lengths. In one variation, the members are fused together during fabrication of the members. In another variation, the members comprise mechanical fasteners along their length for connecting the members together during erection of the structure. The mechanical fasteners may comprise complementary hook and loop fastening strips.

[0015] In another variation, the inflatable members are fabricated of a laminate material having a tensile strength greater than 5000 pounds per square inch. The laminate material may be a mylar-tin-mylar laminate. The membrane may be fabricated of a netting material, which may be a nylon netting.

[0016] In one embodiment, a system for bridging over a gap in a trail may utilize an inflatable spanning structure. The system may comprise three upper inflatable members forming elongated tubes when inflated, the tubes having a length sufficient to span the gap and being placed side-by-side to form an upper portion of the structure; two lower inflatable members, each lower inflatable member placed beneath a point where two of the upper inflatable members contact each other, such that each lower inflatable member is in contact with two of the upper inflatable members, the lower inflatable members forming a lower portion of the structure; fittings on said members for inflating said members; a hand operated pump connecting to said fittings; and a membrane encasing the upper and lower inflatable members such that the upper and lower inflatable members act in concert when supporting a load.

[0017] In one variation, the upper and lower inflatable members may be fabricated of a mylar-tin-mylar laminate having a tensile strength greater than 5000 pounds per square inch. The membrane may be fabricated of a nylon netting material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] A more complete understanding of the invention and many of the attendant advantages thereto will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

[0019] **FIG. 1** shows an isometric view of inflatable spanning members forming a bridge over a gap in a trail;

[0020] **FIG. 2** shows a cross-sectional view of the spanning members of **FIG. 1**, taken at line **2-2** of **FIG. 1**;

[0021] **FIG. 3** is a cross-sectional view of an alternative configuration of spanning members; and

[0022] **FIG. 4** shows calculations for a sample cylindrical spanning member;

[0023] **FIG. 5** shows calculations for a sample, pressurized, cylindrical spanning member;

[0024] **FIG. 6** shows an empirical deflection assessment; and

[0025] **FIG. 7** shows property and deflection tables for exemplary configurations of spanning members.

DETAIL DESCRIPTION OF THE INVENTION

[0026] Referring now to **FIG. 1**, there is shown a spanning structure **10** providing access across a gap **11** in a trail **13**. For illustration purposes and without limitation, spanning structure **10** is shown as being formed of three members **12** in the shape of elongated tubes. Members **12** are shown spanning gap **11** adjacent each other, with the length, **L**, of members **12** being greater than the width, **w**, of gap **11**. The number, configuration and cross-sectional shape of members **12** may be varied to suit the loads to be carried and the gaps to be spanned by structure **10**. Preferably, members **12** can have a curvilinear cross-sectional shape to avoid stress concentrations.

[0027] Each member **12** has a fitting **14** for use in inflating the member. In order to conserve weight, fitting **14** may be suitable for use with portable pump **16**, such as a hand operated bicycle pump. Electric or battery operated pumps and commensurate fittings **14** may also be used where portability, weight and power availability are not considerations. Once the gap in the trail is traversed, the members can be retrieved and deflated using fittings **14**.

[0028] **FIG. 2** is a cross-sectional view of spanning structure **10** taken at line **2-2** of **FIG. 1**. Members **12** are illustrated as ellipsoid in cross-section, having their major axes **X-X** generally horizontal. By presenting a more horizontally oriented upper surface as compared to other cross-sectional shapes having more rounded upper surfaces, such an ellipsoid shape may help in traversing structure **10**. However, as previously noted, other cross-sectional shapes can be contemplated.

[0029] For configurations having multiple members **12**, members **12** can be encased in membrane **18**, such that members **12** act in concert to support the required weight across gap **11**. For clarity, membrane **18** is not illustrated in **FIG. 1**. Preferably, but not for limitation, membrane **18** can be fabricated as a netting so as to lower the overall weight of structure **10**. For ease of assembly and erection, multiple members may be connected together at their tangent points (**tp**). The connection may be mechanical, such as hook and loop fastening material, or the members can be fused together during fabrication.

[0030] **FIG. 3** illustrates an alternative configuration of a spanning structure **10'**, wherein members **12'** form an upper portion of structure **10'** and two smaller members **20** form a lower portion. Smaller members **20** are each located beneath the point where members **12'** contact one another such that each smaller member **20** contacts two members **12'**. Smaller members **20** thus provide additional support at the areas where members **12'** contact one another and add additional stability to structure

10′. In a manner similar to structure **10** of **FIG. 2**, members **12′** and smaller members **20** can be encased in membrane **18′**.

[0031] **FIG. 4** provides calculations for a sample cylindrical member having a diameter of 12 inches and a wall thickness of 0.05 inch. Values for area, **A**, section modulus, **S**, moment of inertia, **I**, and modulus of elasticity, **E**, are shown. Using beam formulas as known in the art and a factor of safety **F** = 1.25, the maximum moment, **M**, and deflection, **δ**, are shown for a beam of length **L** consisting of three such members with a load **P** = 250 pound (lb) at its center. The calculated deflection of 176.52 inches is clearly unsatisfactory. However, the above calculations do not take into account that the members are pressurized.

[0032] **FIG. 5** provides calculations for pressurized members, or vessels. The diameter and wall thickness are as shown in **FIG. 4**. For the pressure values listed in **FIG. 5** (P_0, P_i, P_t), the calculated hoop (σθ), axial (σ**a**) and bending (σ**b**) stresses are as shown. Pressure and stress values are given in pounds per square inch (psi). It is noted that the membrane described with relation to **FIGS. 2** and **3** is not shown in **FIG. 5** for clarity.

[0033] As previously noted, the members must be sufficiently strong to support the anticipated loads, yet lightweight such that they may be easily carried. For illustration and not limitation, an exemplary member can be fabricated of a mylar-tin-mylar laminate material. The maximum stress values ($\sigma_{y\ Tin}$, $\sigma_{y\ Mylar}$, $\sigma_{y\ Combined}$) and allowable hoop (**Sθ**), axial (**Sa**) and bending (**Sb**) stresses for the material are as shown in **FIG. 5**. For the three-member configuration of **FIG.2**, the calculated deflection for pressurized mylar-tin-mylar members is 14.1 inches.

[0034] **FIG. 6** illustrates the calculations of empirical deflection assessment from a prototype. Using the results shown in **FIG. 6**, **FIG. 7** provides property and deflection tables for four alternative configurations of spanning members each of length **L** = 24 feet and supporting a weight **Wt** = 312.5 pounds, which includes the weight of the members (**Wt_p**, **Wt_5** and **Wt_6**). The configuration labeled "Primary" in **FIG. 7** corresponds with the three-member configuration of **FIG. 2** (**Table 1**). The configuration labeled "Alternate 1" in **FIG. 7** corresponds with the five-member configuration of **FIG. 3** (**Table 2**). The configuration labeled "Alternate 2" in **FIG. 7** includes the five-member configuration of **FIG. 3** with an additional smaller member located between the two, outer, smaller members (**Table 3**).

[0035] In **Tables 1-3**, the diameter of the larger members is taken at twelve (12) inches. The diameter of the smaller members in both **Table 2** and **Table 3** is taken at six (6) inches. In addition, **Table 4** lists properties and the deflection for the configuration of "Alternate 1", wherein the diameter of the smaller members is taken at five (5) inches versus the six (6) inch diameter of the smaller members of **Table 2**, while the diameter of the larger members in **Table 4** remains at twelve (12) inches.

[0036] With the exception of the "Primary" configuration (**Table 1**) in **FIG. 7**, the deflections listed are all less than ten (10 inches). Such deflections can be well tolerated when traversing a trail gap, such as that shown in **FIG. 1**.

[0037] What has thus been described is a spanning structure that can be easily transported by a hiker or other lone traveler and quickly erected for providing access across gaps in a trail. Inflatable components form elongated members that can span the gaps. Preferably, the members are ovoid or circular in cross-section when inflated.

[0038] To conserve weight, the members can be fabricated of a laminated mylar material, preferably a mylar-tin-mylar laminate. Such materials are known to those in the art as being lightweight yet having high tensile strength, as shown in **FIG. 5**. To provide adequate strength to support a traveler, multiple members can be used. Multiple members can be encased in a lightweight membrane such that the tubes act in concert to support the required weight across the gap. Preferably, the membrane can be fabricated of nylon netting, such as is known in the art for providing barricades along trails.

[0039] One such configuration of multiple members includes three members, each twelve inches in diameter, placed side-by-side to form an upper portion of a spanning structure. Two smaller members, each five inches in diameter, form a lower portion, with each one being placed beneath a point where two of the upper members contact each other. The smaller members each contact two of the upper members.

[0040] When inflated to pressures in the range of from 30 psi to 40 psi, such a configuration of encased multiple members can support loads of over three hundred pounds while spanning over twenty feet. A small, lightweight pump, suitable for use by a lone traveler, can be used to inflate the members via compatible fittings on the members.

[0041] Obviously many modifications and variations of the present invention may become apparent in light of the above teachings. For example, the cross-sectional shape can be modified to suit fabrication techniques. In addition, different configurations of multiple members, as indicated in **FIG. 7**, may be contemplated. Differing materials including, but not limited to, may be used in fabrication of the members or membrane.

[0042] It will be understood that many additional changes in details, materials, steps, and arrangements of parts which have been described herein and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

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INFLATABLE STRUCTURE

ABSTRACT OF THE DISCLOSURE

A spanning structure can be easily transported by a hiker or other lone traveler and quickly erected for providing access across gaps in a trail. Lightweight, inflatable components form elongated tubes that span such gaps. A small, lightweight pump, suitable for use by a lone traveler, can be used to inflate the tubes. The tubes can be fabricated of a laminated mylar material, preferably mylar-tin-mylar. Multiple tubes can be encased in lightweight netting such that the tubes act in concert to support the required weight across the gap. Preferably, the netting can be fabricated of a nylon material. In one prototype configuration, three tubes placed side-by-side form an upper portion of the spanning structure. Two smaller tubes, each one placed beneath a point where two of the upper tubes contact each other, form a lower portion. The smaller tubes each contact two of the upper tubes.

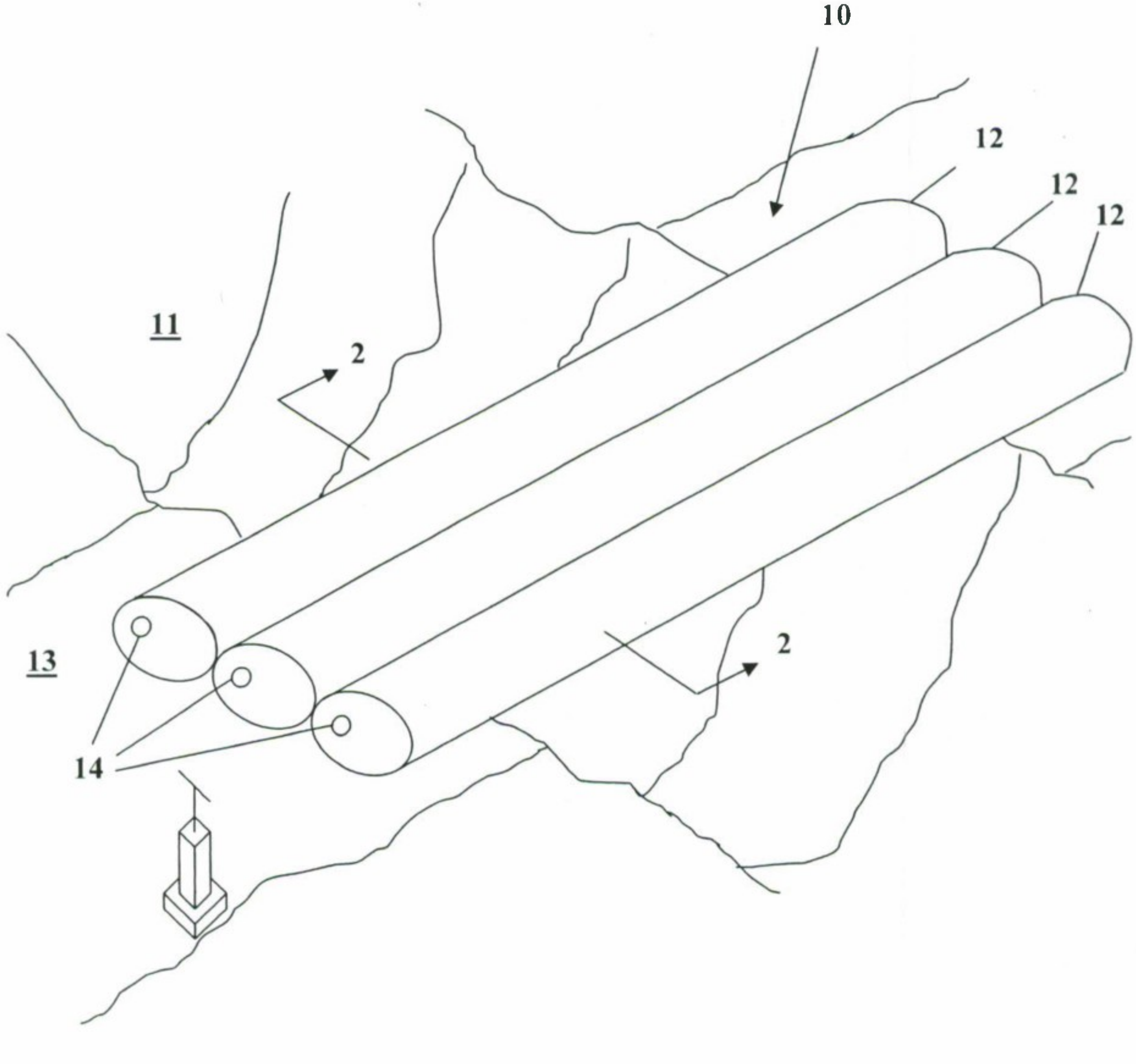


FIG. 1

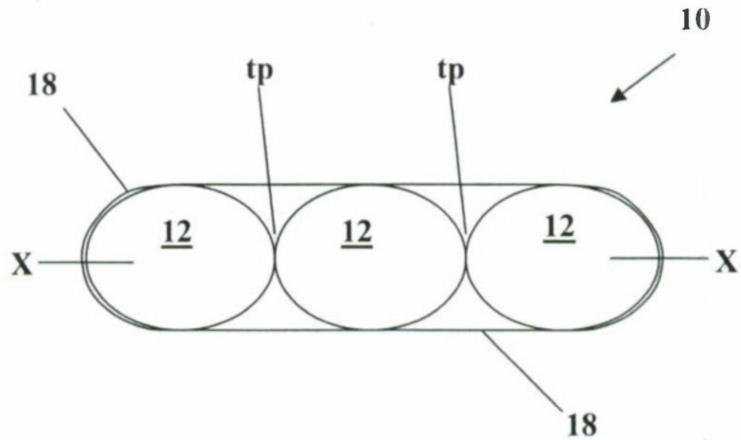


FIG. 2

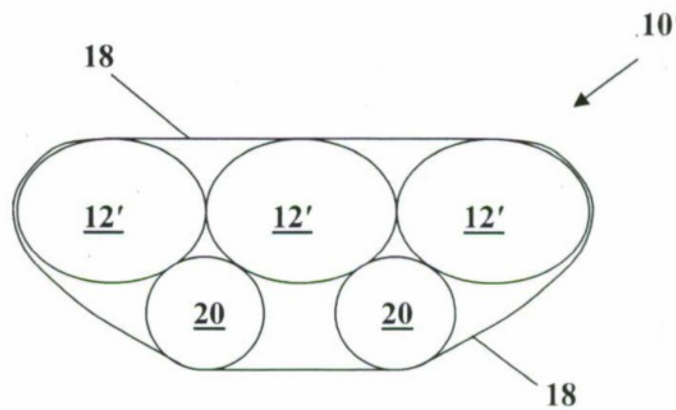
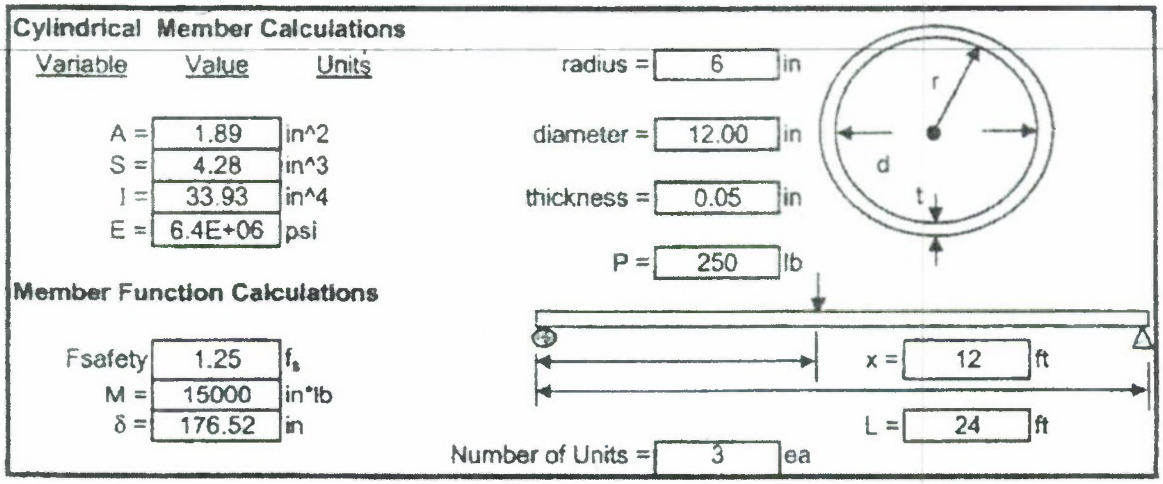
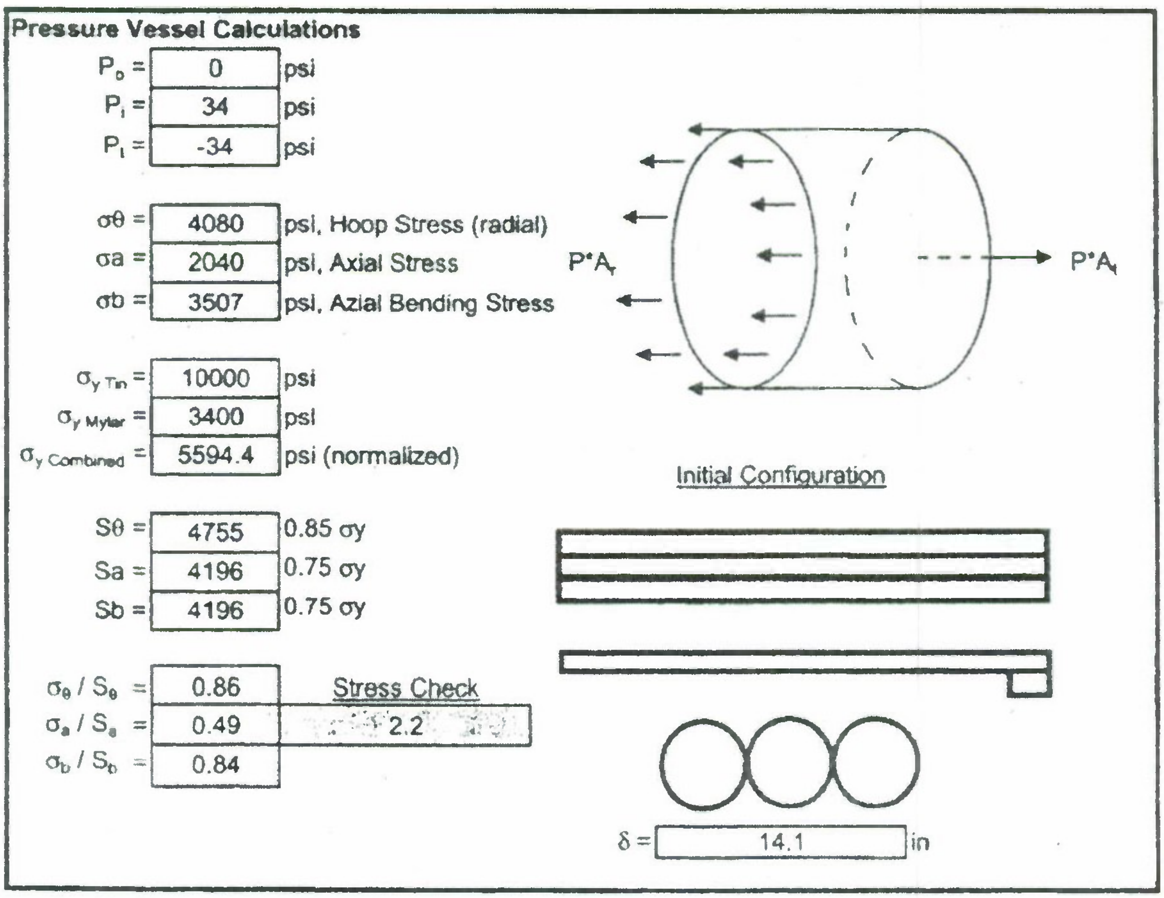


FIG. 3

FIG. 4



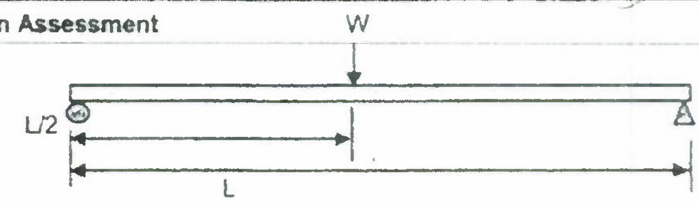
Cylindrical Member Calculations
Variable
Value
Units
A = 1.89 in^2
S = 4.28 in^3
I = 33.93 in^4
E = 6.4E+06 psi
radius = 6 in
diameter = 12.00 in
thickness = 0.05 in
P = 250 lb
r
d
t
Member Function Calculations
Fsafety 1.25 fs
M = 15000 in*lb
δ = 176.52 in
x = 12 ft
L = 24 ft
Number of Units = 3 ea



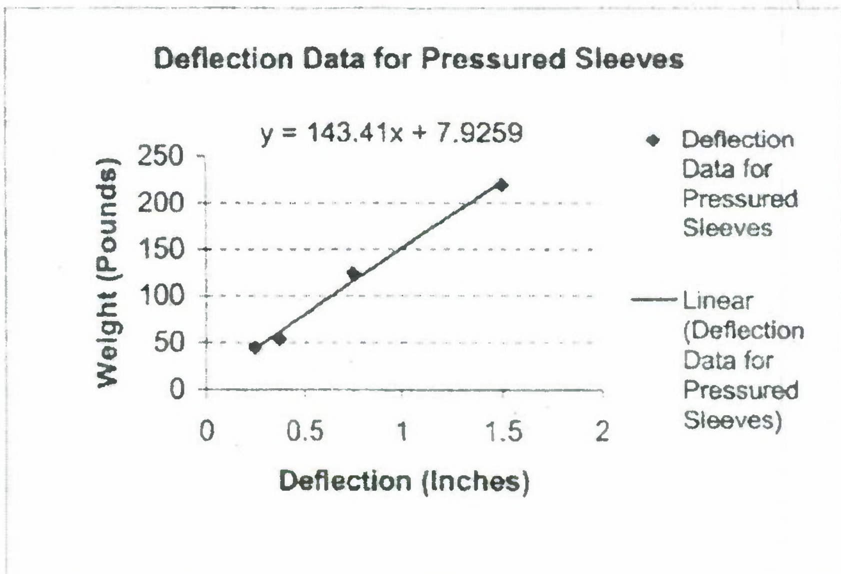
Pressure Vessel Calculations
Po = 0 psi
Pi = 34 psi
Pt = -34 psi
σθ = 4080 psi, Hoop Stress (radial)
σa = 2040 psi, Axial Stress
σb = 3507 psi, Azial Bending Stress
σy Tin = 10000 psi
σy Mylar = 3400 psi
σy Combined = 5594.4 psi (normalized)
Sθ = 4755 0.85 σy
Sa = 4196 0.75 σy
Sb = 4196 0.75 σy
σθ / Sθ = 0.86
σa / Sa = 0.49
σb / Sb = 0.84
Stress Check
2.2
P*Ar
P*Ai
Initial Configuration
δ = 14.1 in

FIG. 5

Empirical Deflection Assessment from Prototype



		deflection	Weight	Flexural Rigidity (EI)	
Deflection Equation		1.5	220	3.38E+05	
		0.75	125	3.84E+05	
δ=PL^3/48*EI		0.375	54	3.32E+05	EI=PL^3/48*δ
L =	48	0.25	45	4.15E+05	
			EI Average =	3.7E+05	
			EI =	2.9E+05	(Reduced by t_s)
			Estimated E with Calculated I =	8.7E+04	(Thin Film Effects)



Extrapolated Deflection Value Using Empirical Data

$\delta = PL^3/48{*}EI$

	EI as Constant	EI as Calculated	E as Extrap'd	
δ=	141.2	0.2	1.4	in

FIG. 6

Configuration Specific Calculations

Total Wt = 312.5

$\sigma_{y\ Combined}$ = 5594.4 psi (normalized)

Alternate No. 1	Alternate No. 2	Primary

Table 2

Alt 1, 6-inch Sub Tubes

A_{12} =	1.89	in^2
A_6 =	0.95	in^2
I_{12} =	33.93	in^4
I_6 =	4.24	in^4
C_{12} =	1.63	in
C_6 =	4.87	in
I_t =	471.61	in^4
δ=	3.8	in

Table 3

Alt 2, 6-inch Sub Tubes

A_{12} =	1.89	in^2
A_6 =	0.95	in^2
I_{12} =	33.93	in^4
I_6 =	4.24	in^4
C_{12} =	2.25	in
$C_{6,1}$ =	3.35	in
$C_{6,2}$ =	6.75	in
I_t =	803.73	in^4
δ=	2.2	in

Table 1

Primary Configuration

A_{12} =	1.89	in^3
I_{12} =	33.93	in^4
I_t =	101.79	in^4
δ=	17.7	in

Alt 1, 5-inch Sub Tubes

A_{12} =	1.89	in^2
A_5 =	0.79	in^2
I_{12} =	33.93	in^4
I_5 =	2.45	in^4
C_{12} =	1.30	in
C_5 =	4.70	in
I_t =	280.46	in^4
δ=	6.4	in

Table 4

Material ρ =	0.002	lb/in^2
Unit Wt $_p$ =	17.6	lb
Unit Wt $_5$ =	24.9	lb
Unit Wt $_6$ =	26.4	lb

RECOMMENDATION: Pursue full-scale prototype demonstrator for Alternate 1 using 5-inch substructure support tubes.

FIG. 7