

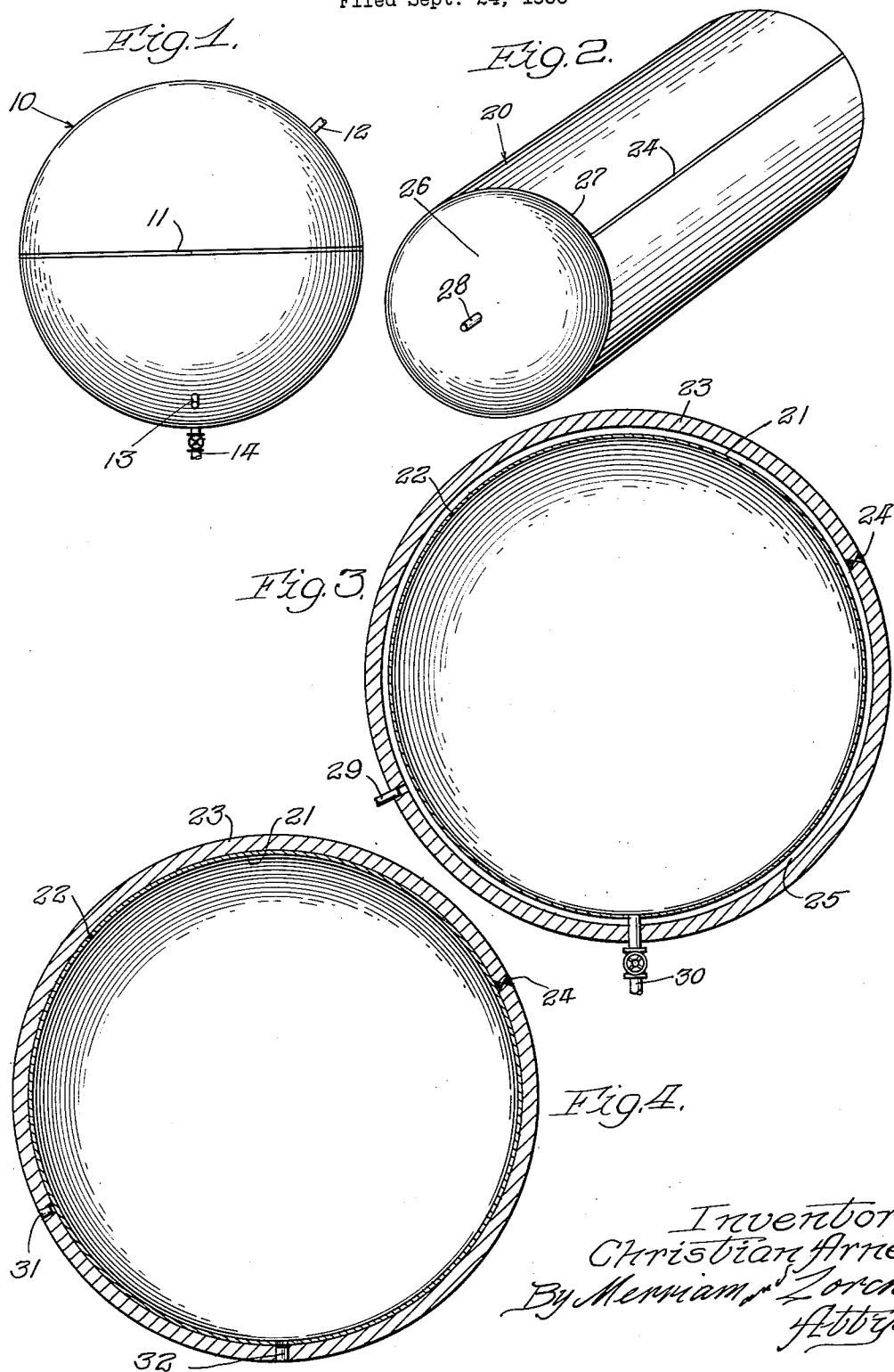
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METHOD OF PRODUCING LINED VESSELS

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METHOD OF PRODUCING LINED VESSELS
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This invention relates to a method of lining vessels and vessels so produced.

It is frequently desirable to provide vessels which have material of one characteristic on the interior and material of a different characteristic on the exterior. For example, it may be desirable to have a stainless steel liner for protection against corrosion, chemical attack, and the like on the inside and a carbon steel shell, which serves as a backing member, on the outside.

In abandoned Zick and Arne application, Serial No. 477,022, filed December 22, 1954, there is a description of a method of producing a lined vessel in which the yield point of the liner is lower than the yield point of the shell.

The present invention contemplates a method of lining a vessel in which the materials of the liner and shell have substantially the same, or different, yield points and involves the application of controlled pressure and temperature conditions.

In one method of carrying out my invention, a liner is properly inserted and positioned inside the shell. For ease of assembly, the outside diameter of the liner should be slightly less than inside diameter of the shell. The liner is then expanded into contact with the shell by the use of internally applied pressure while the shell and liner are at substantially the same temperature. Air between the liner and shell may be expelled during this operation through a vent in the shell. The shell is expanded, not to its yield point or anywhere near it, but elastically expanded within its elastic limit; the liner is thus stressed to a greater point than the shell. The stress of the shell is carried up to the percentage of the yield point usually allowed in testing.

The liner may then be pre-stressed so as to be placed under compression in order to place and maintain the liner into close contact with the shell. This may be accomplished by maintaining the internal pressure and (a) lowering the temperature of the liner while the temperature of the shell is maintained constant or (b) heating the shell while keeping the temperature of the liner constant. The maintenance of pressure within the vessel tends to prevent the liner from moving away from shell or vice versa during this temperature adjustment, and causes the metal liner to exceed its elastic range of deformation and flow plastically, that is, beyond its yield point, and remain in contact with the shell. When the pressure is reduced and the lined shell is subjected to atmospheric conditions, the shell and the liner will eventually reach the same temperature, but they will still stay in contact with each other.

In cases wherein the thickness of the liner is comparatively small in proportion to its radius, the liner is less able to withstand being pre-stressed into compression since the liner would tend to buckle when the internal pressure is released. In such cases, a vacuum should be maintained between the liner and the shell in order to pull the liner out against the shell and keep the liner from buckling. In some instances it will be sufficient to block off the vent after air has been expelled between the liner and shell. In other instances, depending on the proportions of the tank, the air must be removed until a sub-atmospheric pressure is established. The air may be removed by a vacuum pump, steam jet ejector, or by an absorbent placed in a tank which is connected to the

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vent. A monometer may be inserted through the shell in order to control the sub-atmospheric pressure.

The cooling of the liner may be accomplished by using gas pressure and blowing into the vessel a quantity of gaseous nitrogen or carbon dioxide at high pressure and low temperature.

Heating the shell may be accomplished by using liquid pressure, using the liquid to keep the liner cold, and surrounding the shell with an envelope or spray of hot water or hot oil or hot air.

When either of the above procedures for adjusting the temperature is employed, my method will be effective if the temperatures mentioned are the average temperatures of the shell and liner, respectively. In neither case will there be a sharp break in temperature between the shell and the liner. Therefore, the time element is not critical and the process is not difficult to control.

In some instances, the liner may be positioned against the shell by increasing the internal pressure of the liner and/or by maintaining a vacuum between the liner and shell, and the liner may then be stressed beyond its elastic limit by the atmospheric temperature so that it plastically maintains contact with the shell.

Thus, my method, briefly, is directed to a method of forming a multilayer vessel with materials having substantially the same, or different, yield points which comprises forming the vessel with a liner placed inside a shell, applying internal pressure of an amount less than that required to yield the shell beyond its elastic limit to deform the liner into contact with the shell but preventing the shell from elastically stretching beyond its elastic limit, adjusting the temperature of the liner and shell so that the shell is at a higher average temperature than the liner and the liner expands plastically against the shell or, if desired, permitting the temperature of the shell and the liner to reach the same desired predetermined temperature, and releasing the internal pressure under such conditions that the liner will not buckle or materially deform. My method is also directed to the maintenance of a vacuum between the liner and shell in combination with or in place of applying internal pressure to the liner.

In carrying out the method of the invention there is established a temperature differential in which the average temperature of the shell is higher than the average temperature of the liner. The absolute temperature level existing in either the shell or the liner during the establishment of this temperature differential is unimportant. Thus, for purposes of the invention, it is immaterial, for example, whether the shell alone is heated to a temperature above ambient or the liner alone is cooled to a temperature below ambient, or if both the shell and the liner are heated or cooled to different temperatures, provided that the desired differential in temperature is created. Such temperature differential will cause expansion of the shell relative to the liner, thus permitting additional plastic expansion of the liner. It should be noted in this respect that contraction of the liner, as by cooling, is in effect relative expansion of the shell.

My method of lining vessels may be used in the forming of many forms of vessels. Two diagrammatic structures are shown in the accompanying drawings for illustrative purposes, one being a sphere and the other a cylinder.

In the drawings:

FIGURE 1 shows a perspective view of a spherical vessel;

FIGURE 2 is a perspective view of a cylindrical vessel;

FIGURE 3 is an enlarged cross section through the cylindrical vessel of FIGURE 2 showing the vessel be-

fore the application of the pre-stressing operation herein involved; and

FIGURE 4 is a view similar to FIGURE 3 after completion of my pre-stressing method.

The assembly shown in these drawings comprises a liner positioned in a shell.

In forming the sphere 10 shown in FIGURE 1, a lower hemispherical liner section may be inserted into a lower hemispherical shell section which contains a sufficient amount of water so as to permit the lower liner section to float in spaced relationship thereto. The water permits the liner to be readily rotated within the shell during fabrication of the vessel; the water should be removed prior to application of my pre-stressing method. An upper hemispherical liner section having a manhole with an inwardly projecting lip may then be positioned above the lower liner section and the two sections may be welded together along the external seam formed by their adjoining edges. An upper hemispherical shell section having a manhole with an outwardly projecting lip is positioned in place above the lower shell section so that its manhole is aligned with the manhole in the upper liner section. A welder may then enter the liner through the aligned manholes, and the liner may be rotated within the shell so that the internal seam formed by the adjoining edges of the upper and lower shell sections may be welded. In order to assure a well-sealed vessel, the external seam 11 of the upper and lower shell sections should also be welded. The manholes should then be suitably sealed. A vent 13 is shown positioned in the shell so as to provide an outlet for the air in the annular space between the liner and shell; if desired, this vent may also be used for maintaining a vacuum between the liner and shell. Pressure inlet 12 and a valve drain 14 communicate with the confines of the liner and project beyond the vessel.

The cylindrical tank 20 shown in FIGURES 2 and 3 may be formed by constructing a cylindrical shell section having a cylinder with a longitudinally extending welded seam 24, and a circular end plate welded on both its sides along its marginal edge to one end of the cylinder. The shell section may then be positioned so that it rests on the end plate. A liner may be formed by constructing a cylindrical liner section having a longitudinally extending welded seam 22 and opposed circular end plates externally welded to the ends of the cylindrical liner section. The liner may be inserted inside the upwardly extending shell, and the remaining circular end plate should be externally welded to the upper circular edge of the shell. A vent 29 is shown fitted to the vessel so as to provide an outlet for the air in the annular space 25 between the liner and shell and for maintaining a vacuum between the liner and shell. Pressure inlet 28 and valve drain 30 communicate with the interior of the liner. FIGURE 4 shows the liner 21 positioned inside the shell 23 after my pre-stressing method has been completed; sealing plugs 31 and 32 seal the vent and drain, respectively.

Obviously, the above-described vessels, as well as other suitable vessels, may be fabricated by other methods.

The shell may be formed of carbon steel and the liner may be constructed of stainless steel or a thin sheet of stainless steel bound to a thicker sheet of carbon steel by a cladding process such as described in U.S. Patent No. 2,713,196. If desired, other analogous structural materials may be used.

After the vessel assembly has been completed but prior to my pre-stressing method, internal pressure may be applied to the liner by introducing liquid into the interior of the vessel through the pressure inlet while venting air between the shell and liner to the atmosphere. When desired, the liquid may be slowly withdrawn through a valve drain or outlet provided at the bottom

of the vessel, thus releasing the internal pressure effected by the liquid.

A cylindrical vessel having a stainless steel liner 0.25 inch thick, a carbon steel shell 0.75 inch thick, an internal liner diameter of about 48 inches, and an overall length of about 20 feet may be pre-stressed in accordance with the following procedure which serves to illustrate my method of producing a vessel comprising a liner and shell having substantially the same yield point.

An internal pressure is applied to the vessel while the temperature of the liner and shell are about 100 degrees F.; this pressure is at first resisted by the liner only, but the pressure is increased until the liner yields and goes into contact with the shell. Air between the shell and liner is expelled through a vent in the shell. The conditions are now:

Internal pressure	-----p.s.i.	416
Shell stress	-----	0
Shell temperature	-----° F.	100
Liner stress	-----p.s.i.	40,000
Liner temperature	-----° F.	100

The pressure is then increased so that the liner yields, beyond its elastic limit, an additional amount and the shell elastically expands. The conditions are now:

Internal pressure	-----p.s.i.	1,160
Shell stress	-----p.s.i.	24,000
Shell temperature	-----° F.	100
Liner stress	-----p.s.i.	40,000
Liner temperature	-----° F.	100

If the process ended here and the internal pressure was released, the liner would contract elastically more than the shell and the liner would not be tightly positioned inside the shell. It would then take a pressure of 166 p.s.i. to bring the liner in contact with the shell again, and at high pressures, the liner would be subject to a stress of 16,000 p.s.i. more than the shell. This would soon distort or destroy the liner.

When steel is heated so that its normal (e.g., unrestricted) expansion is restrained, it develops a stress which is about 200 p.s.i./° F. for carbon steel and 300 p.s.i./° F. for stainless steel.

If it is desired that the liner, when just in contact with the shell, should have a stress not of 16,000 p.s.i. tension, but 2,000 p.s.i. compression, the liner must be yielded an additional 18,000 p.s.i. To accomplish this, the liner may be yielded by reducing its temperature 60° F. (e.g., 18,000 p.s.i. ÷ 100 p.s.i./° F.). Therefore, with the pressure unchanged, the temperature of liner should be cooled a total of 60° F. to a temperature 40° F. The conditions are now:

Internal pressure	-----p.s.i.	1,160
Shell stress	-----p.s.i.	24,000
Shell temperature	-----° F.	100
Liner stress	-----p.s.i.	40,000
Liner temperature	-----° F.	40

When the pressure is released and the liner heats up to 100° F., the conditions will go through the following stages:

(a) Liner Just in Contact With the Shell

Shell stress	-----p.s.i.	0
Shell temperature	-----° F.	100
Liner stress	-----p.s.i.	0
Liner temperature	-----° F.	93

(b) Pre-Stress Condition

Shell stress	-----p.s.i.	+500
Shell temperature	-----° F.	100
Liner stress	-----p.s.i.	-1500
Liner temperature	-----° F.	100

The same yielding of the liner may be accomplished, if desired, by maintaining the temperature of the liner

constant and heating the shell a total of 90° F. (e.g., 60° F. × 300 p.s.i./° F. + 200 p.s.i./° F.) to 190° F.

If the liner thickness is 0.125 inch and has an internal diameter of 50 feet, the liner would buckle when the internal pressure is released. Therefore, in accordance with my method, a vacuum is maintained between the liner and shell during the application of internal pressure, the controlled temperature variation, and the release of the internal pressure.

As mentioned above, my invention contemplates the use of a liner and shell constructed of metals having different yield points such as an ammonium nitrate tank (for example, 100 feet in diameter and 30 feet high) having a steel shell and an aluminum liner.

My method must obviously take into consideration the temperature at which the vessel is to be used so that the liner will be in contact with the shell at this temperature.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

What is claimed is:

1. The method of forming a multilayer vessel assembly comprising a liner and a shell which comprises adjusting the effective internal pressure of the assembly so that the liner expands plastically into contact with the shell while the shell is expanded only within its elastic limit; establishing a higher average temperature in the shell than the average temperature in the liner in order to cause relative expansion of the shell and allow further plastic expansion of said liner while maintaining said internal pressure; and releasing said internal pressure and allowing the temperatures of said liner and shell to equalize, whereby the elastic return of the shell is at least equal to that of the liner so that the liner remains in contact with the shell in the unpressured condition of the assembly.

2. The method of claim 1 wherein said pressure release and temperature equalization are carried out under such conditions that the liner does not buckle.

3. The method of claim 1 wherein said pressure and temperature equalization are carried out while maintaining a vacuum between the liner and the shell.

4. The method of claim 1 wherein said effective internal pressure of the assembly is created solely by maintaining a vacuum between the liner and the shell.

5. The method of claim 1 wherein said effective internal pressure of the assembly is created solely by increasing the internal pressure of the liner.

6. The method of claim 1 wherein said higher average temperature is established by heating the shell to a higher average temperature than the liner.

7. The method of claim 1 wherein said higher average temperature is established by cooling the liner to a lower average temperature than the shell.

8. The method of forming a multilayer vessel which comprises forming the vessel with a liner positioned inside a shell; applying internal pressure to the liner to deform the same plastically into contact with the shell while expanding the shell only within its elastic limit; selectively controlling the temperature of the liner and the shell so that the shell is at a higher average temperature than the liner while maintaining said internal pressure to cause relative expansion of the shell and allow further plastic expansion of said liner; and releasing said pressure and allowing the temperatures of the shell and the liner to equalize under such conditions that the liner does not buckle.

9. The method of claim 8 wherein said pressure release and temperature equalization are carried out while maintaining a vacuum between the liner and the shell.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,064,344

November 20, 1962

Christian Arne

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 49, for "100" read -- 300 --.

Signed and sealed this 30th day of April 1963.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents