EXPANSION TANK WITH DECOUPLED SINGLE FLEXIBLE DIAPHRAGM

BACKGROUND OF THE INVENTION

Expansion tanks are known for use in flow systems for controlling flow of liquid under varying pressures. Generally, expansion tanks comprise a substantially cylindrical housing terminated on each end by a substantially hemispherical or isotensoid dome. In some cases, the cylindrical housing may be shortened or absent, such that the entire shape is comprised of the two domes. The housing and domes further contain a bladder-type diaphragm that divides areas of a liquid and a pressurized gas. For a general discussion of expansion tanks and bladder-type diaphragms, see U.S. Pat. No. 4,784,181 to Hilverdink entitled “Expansion Tank with a Bladder-Type Diaphragm”.

In expansion tanks, it is critical to maintain a liquid and gas-tight barrier between the liquid and pressurized gas, as well as the outside environment. Any leakage between gas and liquid, or gas and outside, will cause the tank to stop working until it is recharged and may also cause permanent damage to the tank. This gas tight barrier must also be capable of flexing and bending and maintaining integrity through continuous changes in temperature and pressure, making material selection and seal joint design an integral part of overall tank performance.

Two general approaches to making this barrier have traditionally been used. For example, a first approach, as described in, among others, U.S. Patent 7322488, and 7303091, “Expansion tank with double diaphragm”, includes a “double diaphragm bladder” secured to the interior of a tank. The bladder comprises a non-flexible diaphragm having a peripheral edge and a flexible diaphragm having a peripheral edge. The peripheral edges of the non-flexible diaphragm and the flexible diaphragm are sealed together with a ring clamp, or by heat sealing.

This provides an excellent leak-proof seal. Most important in this design, the movement of the diaphragm in operation is decoupled from the outer, cylindrical housing and domes. Therefore, when the pressure differential between the water and air sections of the tank changes, and the diaphragm moves or is stretched, it does not pull on the walls of the cylinder. This approach, however has the disadvantage that it uses additional parts, including the large non-flexible diaphragm, along with corresponding additional fabrication steps, which adds both materials and manufacturing costs when compared to the second approach.

The second approach to the air-water barrier that is generally used is described in US Patents 7,671,754 Sensor for detecting leakage of a liquid; 5,368,073 Hydro pneumatic Pressure Vessel Having an Improved Diaphragm Assembly;5,484,079 Hydro pneumatic Filament Wound Pressure Vessel; and 7,216,673 Non Metallic Expansion Tank With Internal Diaphragm and Clamping Device for Same. In this design, the diaphragm is directly coupled to the outer wall of the dome or cylindrical housing by either adhesive bonding or a mechanical clamping mechanism. While this second approach has a reduced number of parts compared to the first approach that was described, attaching the diaphragm directly to the wall of the tank is a fundamentally flawed design: as the pressure differential between the water and air sections of the tank changes and the diaphragm moves and stretches, the diaphragm pulls on the attachment point to the vessel wall. It is well known by those skilled in the art that thin-walled, large diameter cylinders and spheres, are very poor in collapse conditions; by pulling inwards on the wall of the tank, it is possible to collapse portions of the tank construction. Just as importantly, it is well known by those skilled in the art that the bond strength between the dissimilar materials of construction of the tank can be very low; the force exerted by the diaphragm on the tank can cause delamination between different layers, such as the diaphragm (which is, typically, an elastomer or flexible thermoplastic), the outer wall (which is, typically, a rigid thermoplastic shell), or the fiber reinforcement (which is, typically, fiberglass in a thermoset). It can also cause interlaminar failure of the fiber reinforcement itself. So, by coupling the diaphragm directly to the wall, permanent, catastrophic failure of the tank can result.

Therefore, there is a need for a design and assembly method of an expansion tank that incorporates a single diaphragm with leak-proof seals, which minimizes the number of parts and steps in manufacturing, yet decouples the diaphragm from the cylindrical housing and domes.

SUMMARY OF THE INVENTION

In this invention, an expansion tank with an improved diaphragm seal is provided. This expansion tank includes a seal for the joint between the flexible and non-flexible diaphragms that combines the function of both the non-flexible diaphragm and the cylindrical- and/or dome-shaped tank into a single part. This is achieved by the providing of a novel seal support, for the seal between the flexible and non-flexible diaphragms, or for the seal between the flexible diaphragm and the tank wall, in the case where there is no non-flexible diaphragm, that prevents collapse, delamination, or tearing of the tank components. This reduces the number of parts and manufacturing steps, and improves the long term performance of the tank, including under collapse conditions caused by loads from the movement of the diaphragm.

In this invention, at least one rigid or semi-rigid dome that is substantially hemispherical, or a shape that is otherwise suitable as an mandrel for the reinforcement filament winding, especially and most preferably, the winding of isotensoidal structures, is joined to a substantially cylindrical section, or directly to a second dome, or another shape that is otherwise suitable as a mandrel for filament winding, including winding of isotensoid structures, to produce a gas-andfluid-tight layer; this may also provide a mandrel, or form, around which fiber-reinforcement may be wound, including isotensoidal reinforcement. More generally, it is understood that isotensoidal filament winding provides the most effective structural reinforcement for thin walled tanks. The particular shapes described in this patent are those most commonly used for water tanks, but other shapes, such as toroidal shapes can also be used as isotensoidal mandrels. It must also be noted that in many situations isotensoidal filament reinforcement is not necessary, such as when operating at lower pressure differences, providing thicker, and thus stronger, tank walls or winding filaments that are not isotensoidal. This invention is effective without regard to the use of isotensoidal technology.

In accordance with this invention, one of the segments forming the thin-walled pressure tank, e.g., a dome-shaped or cylindrical section, further comprises an extension lip, extending inwardly substantially near the junction of two of the sections. This extension lip may be made from the same material as the tank, e.g., dome-shaped or cylindrical tank segment, or may be part of a separate circumferential connector interconnecting two of the sections of the tank wall. The extension lip provides a joining surface on which the flexible diaphragm can be sealably connected to a nonflexible diaphragm, or if there is only one diaphragm, directly to the tank wall; the sealing connection is achieved by techniques known to those skilled in the art, such as adhesive bonding, solvent welding, thermal welding, clamping or the like, or by similar techniques that may be developed in the future.. Critical to this design, the extension lip is of sufficient length and modulus of elasticity, so that when the diaphragm is stretched, and thus pulls against the lip, the extension lip deflects without substantially affecting the body of the tank. This deflection allows the diaphragm's collapse load to be substantially decoupled from the tank outer wall, e.g., of the dome- or cylindrical-shaped section of the tank.

In another preferred embodiment, the lip is formed as part of a substantially stiff clinch ring which may be connected between two of the tank segments, e.g., between the cylindrical wall and a dome, of the outer tank wall, or to the interior surface of one of the sections, or overlapping the two sections, e.g., cylindrical and dome-shaped, and their junction line. The latter can provide additional structural support to the tank, or additional rigidity to the end of the extension lip, to further prevent structural collapse of the outer tank walls as a result of stress from the diaphragm, in either its expanded or collapsed conditions, by further isolating the tank walls from the diaphragm movements. The lip is preferably circumferential, extending inwardly from the clinch ring circumference, or from the wall surface, and is sealingly joined to the flexible diaphragm by any known means. In another embodiment, a portion of the length of the lip can be formed having a thinner cross-section, so as to allow for deflection of the lip at lower stresses from the diaphragm.

Critical to these designs, the deflectable extension lip forming the seal for the diaphragms, is connected to, but substantially mechanically and structurally decoupled from, the dome-and/or-cylinder-shaped tank, or mandrel, for forming the tank body.

BRIEF DESCRIPTION OF THE DRAWING

The invention is described with reference to the several figures of the drawing, in which,

FIG. 1 is a schematic cross-section of a diaphragm tank according to an embodiment of the invention, representing the tank charged with air pressure and the space below flexible diaphragm being empty of water;

FIG. 1A is an expanded view of the schematic cross-section of a diaphragm tank in

[redacted];

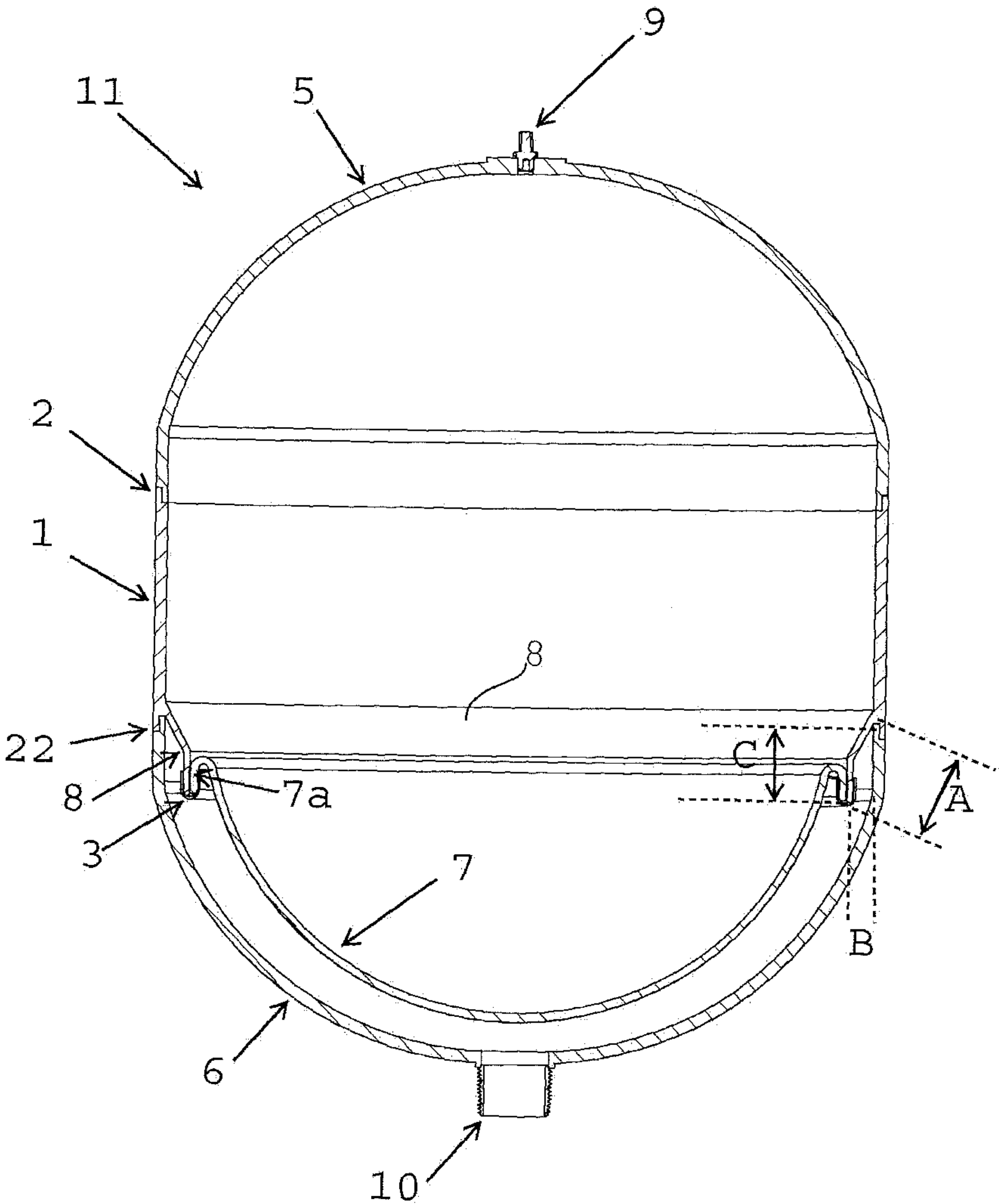

FIG. 1

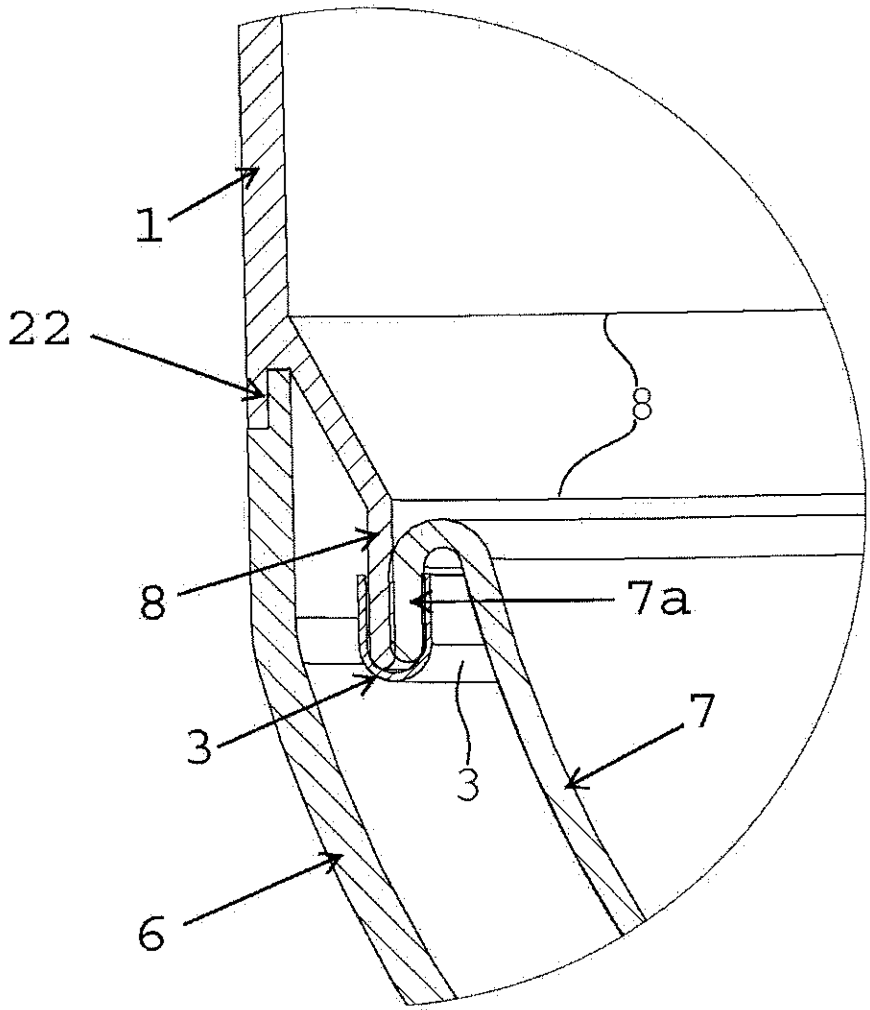

FIG 1A