United States Patent [19]

Okamoto

[11] **3,926,332**

[45] **Dec. 16, 1975**

[54] **SEALING STRUCTURE FOR A LIQUID STORAGE VESSEL HAVING A FLOATING HEAD**

[75] Inventor: **Chikashi Okamoto,** Yokkaichi, Japan

[73] Assignee: **Nippon Kakokicompany, Limited,** Tokyo, Japan

[22] Filed: **Dec. 10, 1973**

[21] Appl. No.: **423,532**

[30] **Foreign Application Priority Data**

Feb. 14, 1973 Japan.............................. 48-17497

[52] **U.S. Cl.** **220/226;** 220/216; 220/222; 277/226; 277/229

[51] **Int. Cl.**^{2}..................... **B65D 87/20;** B65D 87/18

[58] **Field of Search**............. 220/26 R, 26 S, 26 SA, 220/216–227; 277/34.3, 226, 229, 232

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Primary Examiner—John Petrakes
Attorney, Agent, or Firm—Haseltine, Lake & Waters

[57] **ABSTRACT**

A sealing structure for use in a liquid storage vessel such as an oil storage tank having a floating head or roof, the sealing structure comprising a hollow resilient core of generally loop form, which core has a substantially arcuate cross section and is allowed to contract or expand in cross section when subjected to stress when the floating head is moved relative to the body of the vessel.

6 Claims, 4 Drawing Figures

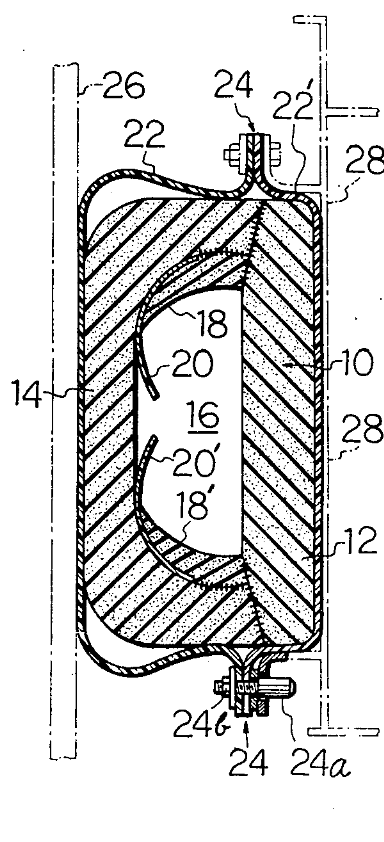


Fig. 1

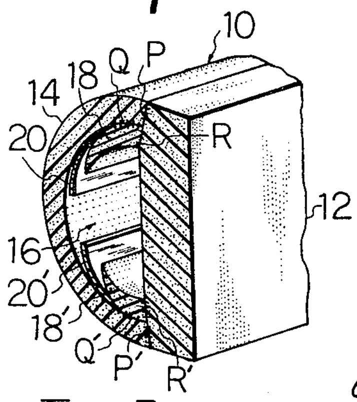


Fig. 3

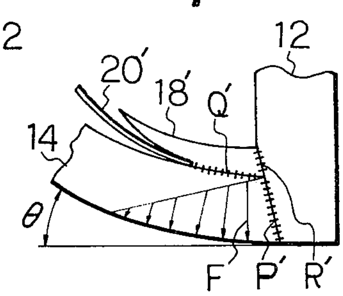


Fig. 2

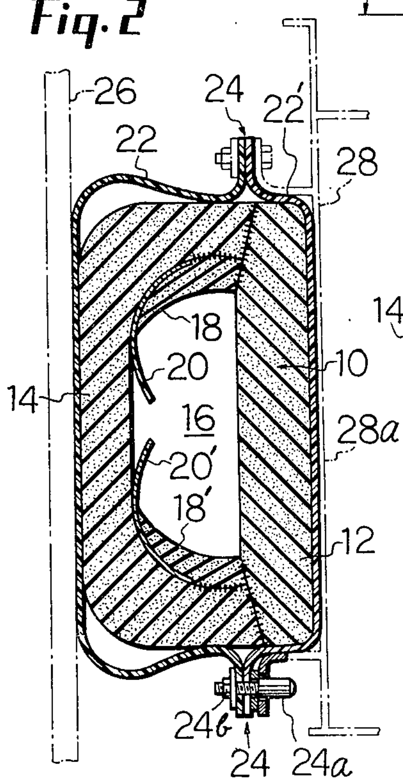
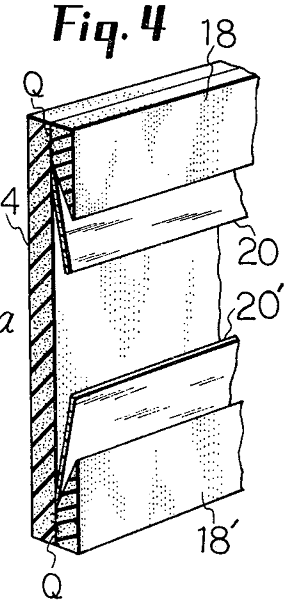


Fig. 4



SEALING STRUCTURE FOR A LIQUID STORAGE VESSEL HAVING A FLOATING HEAD

The present invention relates generally to a liquid storage vessel with an unsecured top and specifically to an aboveground gas-tight oil storage tank having a floating head or roof. More specifically, the present invention is concerned with a sealing arrangement to be used in the oil storage tank of the particular type for hermetically sealing the tank between the tank body and the floating head.

Gas-tightness and durability are essentials of oil storage tanks and accordingly the principal requirements for the sealing arrangement of the oil storage tank of the described type are a uniform and constant pressure between the tank body and the floating head, responsiveness to the movement of the floating head relative to the tank body, and resistance to wear and abrasion resulting primarily from the friction between the contact surfaces of the tank body and the sealing structure. If the sealing pressure between the tank body and the floating head is deficient, gaps may be produced between the inner peripheral surface of the tank body and the rim of the head although the sealing structure may be subject to lesser wear and abrasion that will result in a prolonged service life of the sealing structure. Oil vapor will therefore escape and, in some cases, oil itself may leak from the tank through such gaps, causing not only a considerable amount of loss of the stored oil but the danger of a conflagration or explosion if a spark happens to be produced in the neighborhood of the leaks as in the event of an earthquake. If, conversely, the sealing pressure is excessive, complete sealing of the tank may be achieved and the relative movement between the tank body and the floating head may be accommodated to satisfactorily by the sealing arrangement but the wear and abrasion of the sealing structure will be accelerated resulting in a shortened service life of the sealing arrangement. Other important requirements for the sealing arrangement for the oil storage tank of the described type include: resistance to an undue stress which may be imparted to the sealing structure as a result of upward and downward movements or sways of the floating head; configurations adapted to match the geometry of the tank and to be readily installed into a working position; and simple, economical and robust construction.

A variety of sealing arrangements have thus far been proposed with a view to meeting these requirements, but none of the arrangements has succeeded in satisfying all of such requirements. The present invention contempletes provision of an improved sealing structure which is capable of meeting all the above mentioned requirements.

It is, accordingly, an object of the present invention to provide an improved sealing structure for use in a liquid storage vessel having a floating head so as to achieve complete sealing between the body and the floating head of the vessel.

It is another object of the invention to provide an improved sealing structure for a liquid storage vessel of the described type wherein the sealing pressure exerted between the tank and the floating head of the vessel is maintained satisfactorily uniform and constant substantially irrespective of the position of the floating head relative to the body of the vessel.

It is still another object of the invention to provide an improved sealing structure for use in a liquid storage vessel of the described type which structure is highly responsive to upward and downward movements or sways of the floating head relative to the body of the vessel so that the floating head is at all times maintained in a balanced position relative to the vessel body.

It is still another object of the invention to provide an improved sealing structure for use in the liquid storage vessel of the described type, the sealing structure having sufficient resistance to wear and abrasion that will assure a prolonged service life of the sealing structure.

It is still another object of the invention to provide an improved sealing structure for a liquid storage vessel of the described type, wherein the sealing structure is sufficiently resistant to undue stress which may be imparted to the structure as a result of upward and downward movements of the floating head relative to the body of the vessel.

It is still another object of the invention to provide an improved sealing structure for use in a liquid storage vessel of the described type, which structure is adapted to be readily installed in a working position in the vessel.

It is still another object of the invention to provide an improved sealing structure which is adapted for use specifically in a liquid storage vessel of the described type and which is simple and robust in construction and economical to manufacture.

It is, thus, a general object of the present invention to provide an aboveground gas-tight liquid storage vessel having a floating head which is hermetically sealed from the body of the vessel by an improved sealing arrangement adapted to provide increased gastightness and durability of the storage vessel as a whole and accordingly enhanced assurance of safety required under any local regulations for the prevention of a conflagration or explosion of the vessel in the event of an earthquake or any other disaster.

In accordance with the present invention, these and other objects are accomplished in a sealing structure comprising a resilient core including an elongated inner core member having a substantially rectangular cross section and substantially parallel inner and outer longitudinal surfaces and an elongated outer core member having a substantially arcuate cross section projecting outwardly away from the outer longitudinal surface of the inner core member and substantially parallel upper and lower longitudinal ends respectively secured to the upper and lower longitudinal ends of the outer longitudinal surface of the inner core member, the outer core member being initially fromed as a substantially flat strip and being thereafter forcibly deformed into a configuration having the aforesaid arcuate cross section, and a flexible covering member which hermetically encloses the core therewithin and which is adapted for being slidably pressed partly between the inner longitudinal surface of the inner core member and an outer peripheral surface of the floating head and partly between the projecting outer longitudinal surface of the outer core member and and inner peripheral surface of the liquid storage vessel. The core may further include upper and lower resilient elongated members having respective upper and lower longitudinal ends respectively secured to upper and lower longitudinal portions of the outer longitudinal surface of the inner core member and respective outer longitudinal surfaces which are secured at their upper and lower end portions to upper and lower end portions, respectively, of the inner longitudinal surface of the outer core member, the resilient elongated members having respective lower and upper free longitudinal end portions which are spaced apart from each other and which are at least in part resiliently forced against the inner longitudinal surface of the outer core member. By preference, the core may still further include upper and lower intermediate strips of resilient material which are at least partly in slidable contact between the upper and lower longitudinal surface of the inner core member and outer surfaces of the lower and upper free longitudinal end portions of the upper and lower resilient elongated members, respectively, and which have respective upper and lower longitudinal end portions respectively secured to the weld between the outer core member and the upper resilient elongated member and the weld between the outer core member and the lower resilient elongated member.

The inner and outer core members and the upper and lower resilient elongated members are preferably formed of a foam thermoplastic resin such As, for example, polyurethane while the upper and lower intermediate strips may be formed of any one of the known thermoplastic resins.

The features and advantages of the sealing structure according to the present invention will become more apparent from the following description of the invention taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a fragmentary perspective view partially in cross section, of a core forming part of a preferred embodiment of the sealing structure according to the present invention;

FIG. 2 is a cross sectional view of the embodiments of the sealing structure which is in a condition installed in an oil storage tank having a floating head;

FIG. 3 is a fragmentary cross sectional view of the core of the sealing structure in the installed condition; and

FIG. 4 is a fragmentary perspective view showing partially in cross section, the configuration of part of the core of the sealing structure which is spread out into the form of an endless belting so as to show a process which may be used to obtain the formation illustrated in FIG. 1.

Reference will now be made to the drawings, first to FIG. 1 in which the core forming part of the sealing structure according to the present invention is shown to be in a free or relaxed condition. As illustrated, the core, designated in its entirety by reference numeral **10**, includes an inner elongated core member **12** and an elongated outer core member **14.** The inner core member **12** has a substantially rectangular cross section and accordingly substantially parallel inner and outer surfaces. The outer core member **14**, on the other hand, extends along the outer surface of the inner core member **12** and has a substantially semicircular or arcuate cross section which projects outwardly away from the outer surface of the inner core member **12.** A closed cavity **16** having a substantially semicircular cross section is thus formed between the outer surface of the inner core member **12** and the inner surface of the outer core member **14.** The outer core member **14** is bonded or otherwise secured at its upper and lower longitudinal ends to upper and lower longitudinal ends, respectively, of the outer surface of the inner core member **12**, as indicated at P and P′ in FIG. **1.** The core **10** further comprises a pair of, upper and lower, internal wedge members **18** and **18′** which extend along upper and lower portions, respectively, of the inner surface of the outer core member **14.** The upper internal wedge member **18** is bonded or otherwise secured at an upper end portion of its outer surface to an upper end portion of the inner surface of the outer core member **14** as indicated at Q and is further secured at its upper longitudinal end to the upper end portion of the inner surface of the inner core member **12** as indicated at R. Likewise, the lower internal wedge member **18′** is secured at a lower longitudinal end portion of its outer surface to a lower end portion of the inner peripheral surface of the outer core member **14** as indicated at Q′ and is further secured at its lower longitudinal end to the lower end portion of the inner surface of the inner core member **12** as indicated at R′. These upper and lower internal wedge members **18** and **18′** have lower and upper free end portions, respectively, which are at least in part resiliently forced against the inner surface of the outer core member **14** and which are spaced apart from each other in vertical directions By preference, the lower and upper free end portions of the upper and lower internal wedge members **18** and **18′**, respectively, are reduced in thickness toward their ends so that each of the wedge members **18** and **18′** has a generally wedge-shaped cross section which is curved over the inner surface of the outer core member **14** as shown. The inner and outer core members **12** and **14** and the internal wedge members **18** and **18′** are formed of light-weight resilient plastic material such as foamed thermoplastic material a typical example of which is polyurethane foam.

The core **10** having the construction above described may be placed in use as is but, for the reasons to be explained, the core may further comprise, as shown, a pair of, upper and lower, intermediate strips **20** and **20′**, respectively, of a flexible plastic material which is preferably heterogeneous to the material forming the members **12, 14, 18** and **18′**. The upper intermediate strip **20** is interposed between the upper portion of the inner surface of the outer core member **14** and the outer surface of the free end portion of the upper internal wedge member **18** and is bonded or otherwise secured at its upper longitudinal end to the weld line between the outer core member **14** and the upper internal wedge member **18.** Likewise, the lower intermediate strip **20′** is interposed between the lower portion of the inner surface of the outer core member **14** and the outer surface of the free end portion of the lower internal wedge member **18′** and is bonded or otherwise secured at its lower longitudinal end to the weld line between the outer core member **14** and the lower internal wedge member **18′**. The intermediate strips **20** and **20′** are thus partly in slidable contact between the inner surface of the outer core member **14** and the outer surfaces of the free end portions of the upper and lower strips **20** & **20′**, respectively intermediate strips. The **20** and **20′** are herein shown as projecting beyond the free ends of the internal wedge members **18** and **18′**, respectively, but, where desired, they may be substantially coextensive with or concealed benind the internal wedge members **18** and **18′**.

FIG. **2** illustrates a sealing structure incorporating the core **10** having the above described construction. The core **10** is enclosed or wrapped in flexible covering members **22** and **22′** which are securely connected together by suitable fastening means 24 which are shown as comprising a clamping nut 24*a* and a bolt 24*b*. The covering members 22 and 22' are usually formed of rubber coated cloth.

The sealing structure thus arranged is mounted on an oil storage tank which is shown in phantom in FIG. 2 as consisting of a tank body 26 and a floating head 28. The tank body 26 stores therein oil or any other liquid of, usually, an inflammable property and the floating head 28 floats on the surface of oil. To permit movement of the floating head 28 relative to the tank body 26, the head 28 has a rim 28*a* which is so sized as to provide an appropriate allowance between the inner peripheral surface of the tank body 26 and the rim 28*a* of the head 28. The core 10 of the sealing structure should therefore be so arranged that, when the core is in a free or relaxed condition which is free from stress, the overall width of the core or, in other words, the distance between the inner surface of the inner core member 12 and the outer end of the outer core member 14 is significantly larger than the amount of clearance between tank body 26 and the floating head 28. When the sealing structure is to be placed in a working position, the core 10 complete with the covering members 22 and 22' is forced between the inner peripheral surface of the tank body 26 and the rim 28*a* of the floating head 28 so that the outer core member 14 is caused to contract toward the outer surface of the inner core member 12 against the resiliency of the material forming the loop portion 14. The outer surface of the outer core member 14 is consequently partly flattened and is tightly pressed against the inner peripheral surface of the tank body 26 through the covering member 22 while the inner surface of the inner core member 12 is fast on the rim 28*a* of the floating head 28 through the other covering member 22'. Under these conditions, the upper and lower internal wedge members 18 and 18' are tightly forced toward the internal surfaces of the outer core member 14 across the upper and lower intermediate strips 20 and 20', respectively, thereby adding to the forces that act to press the outer core member 14 against the inner peripheral surface of the tank body 26.

When the outer core member 14 has its top portion flattened and contracted toward the inner surface of the inner core member 12, the upper and lower end portions of the outer core member 14 are deformed to create certain angles θ between the outer surfaces of the particular portions of the outer core member 14 and horizontal planes at the upper and lower ends of the inner core member 12 as seen in FIG. 3 so that the upper and lower portions of the outer core member 14 are forcefully urged upwardly and downwardly, respectively, as indicated by arrows F in FIG. 3. The forces F will provide sufficient resistance to upward and downward deformation of the core and to bending or compressive stresses imparted to the core as a result of the movement of the floating head 28 relative to the tank body 26. Such resistance will be reinforced by the forces which are exerted by the upper and lower internal wedge members 18 and 18' which press the upper and lower portions of the outer core member 14 partly upwardly and downwardly respectively, and partly outwardly of the inner core member 12. Substantially uniform sealing pressure is achieved in this manner at all times by the core 10 irrespective of the position of the floating head 28 relative to the tank body 26.

When the core 10 is in the contracted condition above described and especially when the core is subjected to stresses created by the movement of the floating head 28 relative to the tank body 26, the free end portions of the internal wedge members 18 and 18' will be moved relative to the outer core member 14. Such movement of the internal wedge members 18 and 18' is facilitated by means of the upper and lower intermediate strips 20 and 20' which are in slidable engagement with both the inner surface of the outer core member 14 and the outer surfaces of the free end portions of the upper and lower internal wedge members 18 and 18', respectively. When, thus, the outer core member 14 is deformed under stress, the inner surface of the outer core member 14 and the outer surfaces of the internal wedge members 18 and 18' are moved in opposed directions relative to the intermediate strips 20 and 20' and, since, the wedge members 18 and 18' are urged against the intermediate strips 20 and 20', the inner surface of the outer core member 14 and the outer surfaces of the free end portions of the internal wedge members 18 and 18' are caused to slide on the opposite surfaces of the intermediate strips 20 and 20', respectively. The outer core member 14 is in this manner prevented from being subjected to undue stresses when the core member 14 is moved or deformed relative to the internal wedge members 18 and 18'.

Members 12, 14, 18 and 18' are first formed separately each in a flat strip form and are thereafter secured to each other, in a manner illustrated in FIG. 4. The outer core member 14 of flat strip form has width which is so selected to provide a desired radius of curvature when deformed into a configuration having an arcuate cross section shown in FIG. 1. A pair of wedge members 18 and 18' each of the flat strip form are then secured at Q and Q', respectively, to the upper and lower longitudinal end portions of the inner surface of the outer core member 14. The internal wedge members 18 and 18' have free end portions which are reduced in thickness toward their respective ends and which are appreciably spaced apart from the inner surface of the outer core member 14 as illustrated. A pair of relatively thin strips 20 and 20' are then interposed between the inner surface of the outer core member 14 and the outer surfaces of the respective free end portions of the wedge members 18 and 18', respectively. The strips 20 and 20' are secured to the welds between the outer core member 14 and the wedge members 18 and 18' so as to be loosely sandwiched between the ring-shaped member 14 and the free end portions of the wedge-shaped members 18 and 18'. The outer core member 14 complete with the wedge members 18 and 18' and the strips 20 and 20' attached thereto is then forcibly deformed outwardly into a configuration having a generally arcuate cross section and the outer core member 14 and the wedge members, 18 and 18' are secured at their respective upper and lower edges to upper and lower longitudinal end portions of an outer surface of an inner core member 12.

What is claimed is:

1. A sealing structure for use in a liquid storage vessel having a floating head, said sealing structure comprising a core including an elongated inner core member of elastic material having a substantially rectangular cross section and substantially parallel inner and outer longitudinal surfaces and an elongated outer core member of elastic material having a substantially arcuate cross

section projecting outwardly away from the outer longitudinal surface of the inner core member, said outer core member having substantially parallel upper and lower longitudinal ends respectively secured to the upper and lower longitudinal ends of the outer longitudinal surface of the inner core member to form a continuous cavity throughout the length of said core, said outer core member being initially formed separately from said inner core member as a substantially flat elongated strip and being thereafter forcibly deformed into a configuration having said arcuate cross section, and a flexible covering member hermetically enclosing said core therewithin and slidably pressed between the inner longitudinal surface of said inner core member and an outer peripheral surface of said floating head and partly between the projecting outer longitudinal surface of said outer core member and an inner peripheral surface of said liquid storage vessel.

2. A sealing structure as claimed in claim **1**, in which said core further includes upper and lower resilient elongated members having respective upper and lower longitudinal ends respectively secured to upper and lower longitudinal portions of the outer longitudinal surface of said inner core member and respective outer longitudinal surfaces which are secured at their upper and lower end portions to upper and lower end portions, respectively, of the inner longitudinal surface of said outer core member, said resilient elongated members having respective lower and upper free longitudinal end portions which are spaced apart from each other and which are at least in part resiliently forced against the inner longitudinal surface of said outer core member.

3. A sealing structure as claimed in claim **2**, in which said core further includes upper and lower intermediate strips of resilient material which are at least partly in slidable contact between the upper and lower longitudinal portions, respectively, of the inner longitudinal surface of said inner core member and outer surfaces of said lower and upper free longitudinal end portions of said upper and lower resilient elongated members, respectively, and which have respective upper and lower longitudinal end portions respectively secured to the junction between the outer core member and said upper resilient elongated member and the junction between the outer core member and said lower resilient elongated member.

4. A sealing structure as claimed in claim **2** in which the free end portions of said upper and lower resilient elongated members are reduced in thickness toward their respective lower and upper ends to form a wedge-shape.

5. A sealing structure as claimed in claim **2** in which said inner and outer core members and said upper and lower elongated members are formed of foam thermoplastic material.

6. A sealing structure as claimed in claim **5** in which said foam thermoplastic material is polyurethane foam.

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