United States Patent

Andersson

[15] **3,653,434**

[45] **Apr. 4, 1972**

[54] **CYLINDRICAL PRESSURE VESSEL**

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[22] Filed: **May 14, 1969**

[21] Appl. No.: **824,563**

[30] **Foreign Application Priority Data**

May 17, 1968 Sweden....................................6755/68

[52] **U.S. Cl.**..**165/169,** 220/3
[51] **Int. Cl.**...**F28f 3/12**
[58] **Field of Search**.......................................165/169; 220/3

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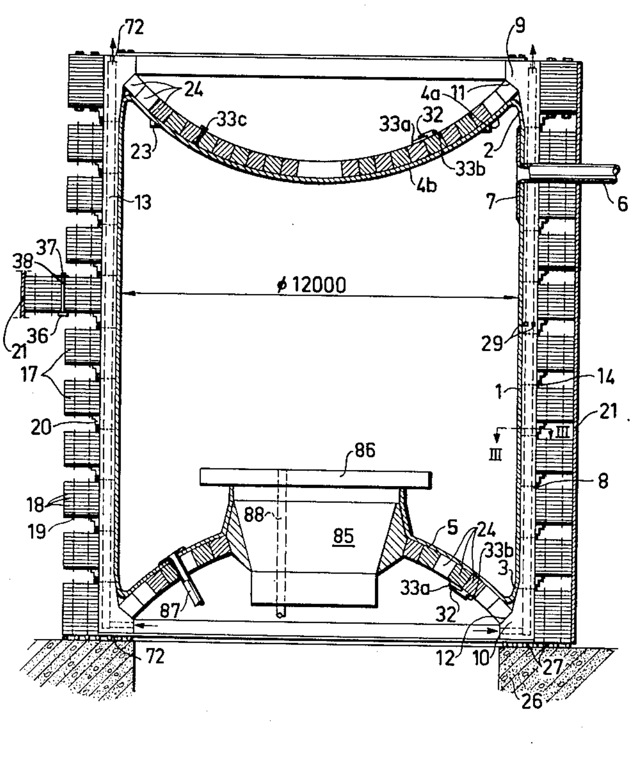
Attorney—McGlew and Toren

[57] **ABSTRACT**

A pressure vessel consists of a comparatively thin-walled container and a pressure-resistant construction supporting the container. The pressure-resistant construction comprises girders extending longitudinally, and annular members extending circumferentially around the girders. The girders have top and bottom shoulders to engage top and bottom walls.

13 Claims, 12 Drawing Figures



Patented April 4, 1972 3,653,434

7 Sheets-Sheet 1

Fig.1

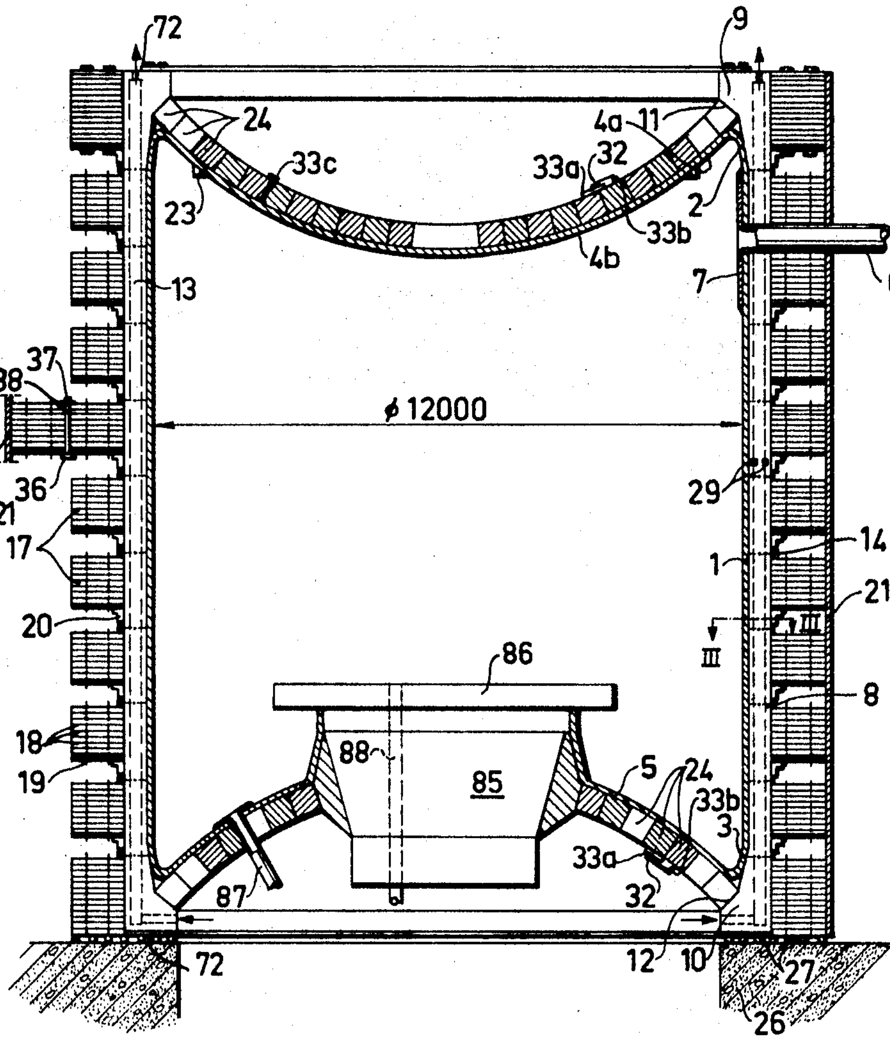


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Fig. 2

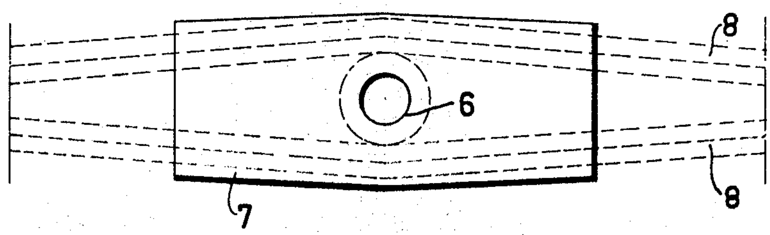

Fig. 3

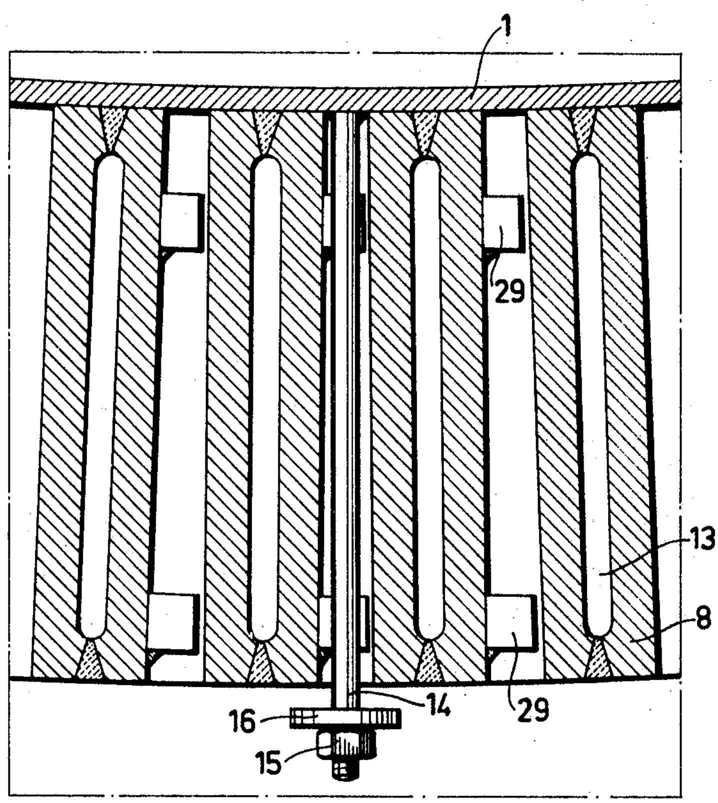

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Fig. 4

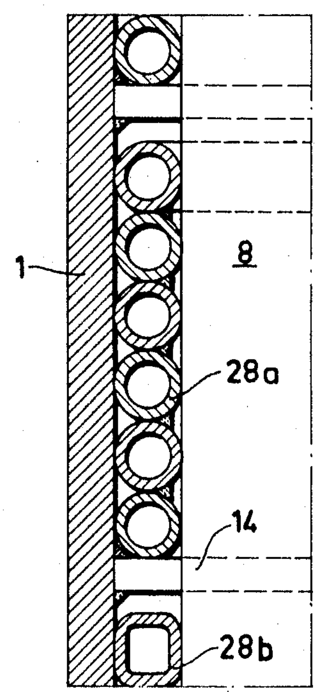

Fig. 5

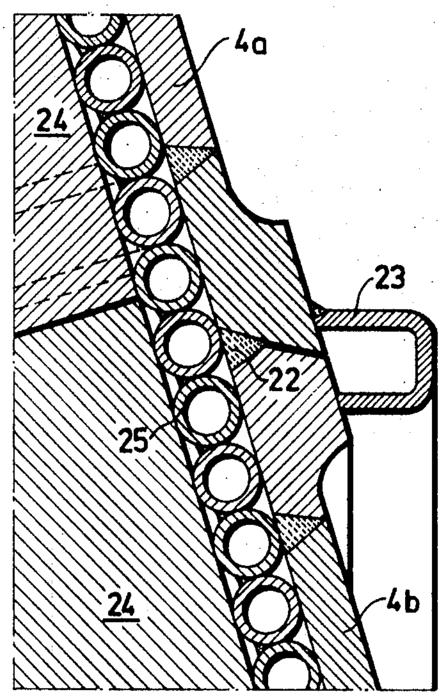

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Fig. 6

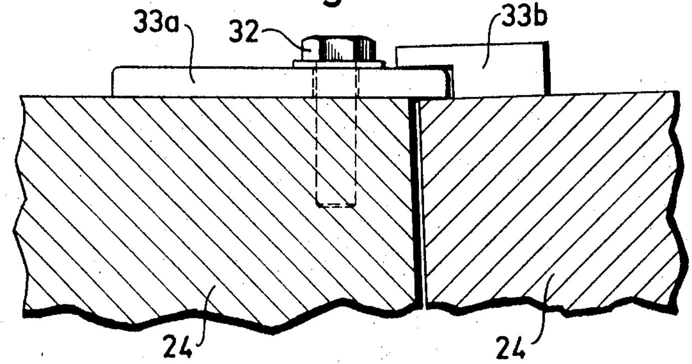

Fig. 9

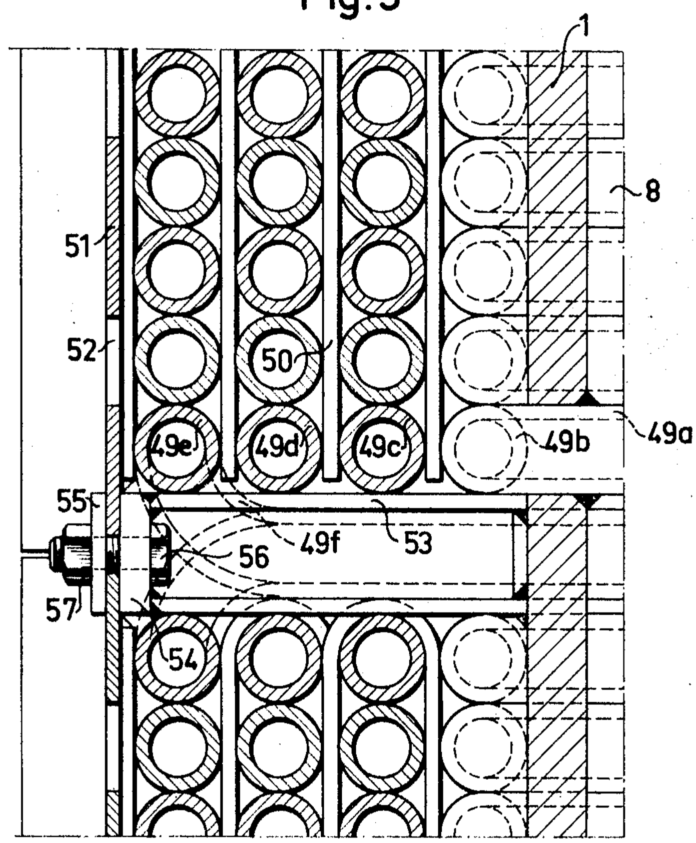

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Fig. 7

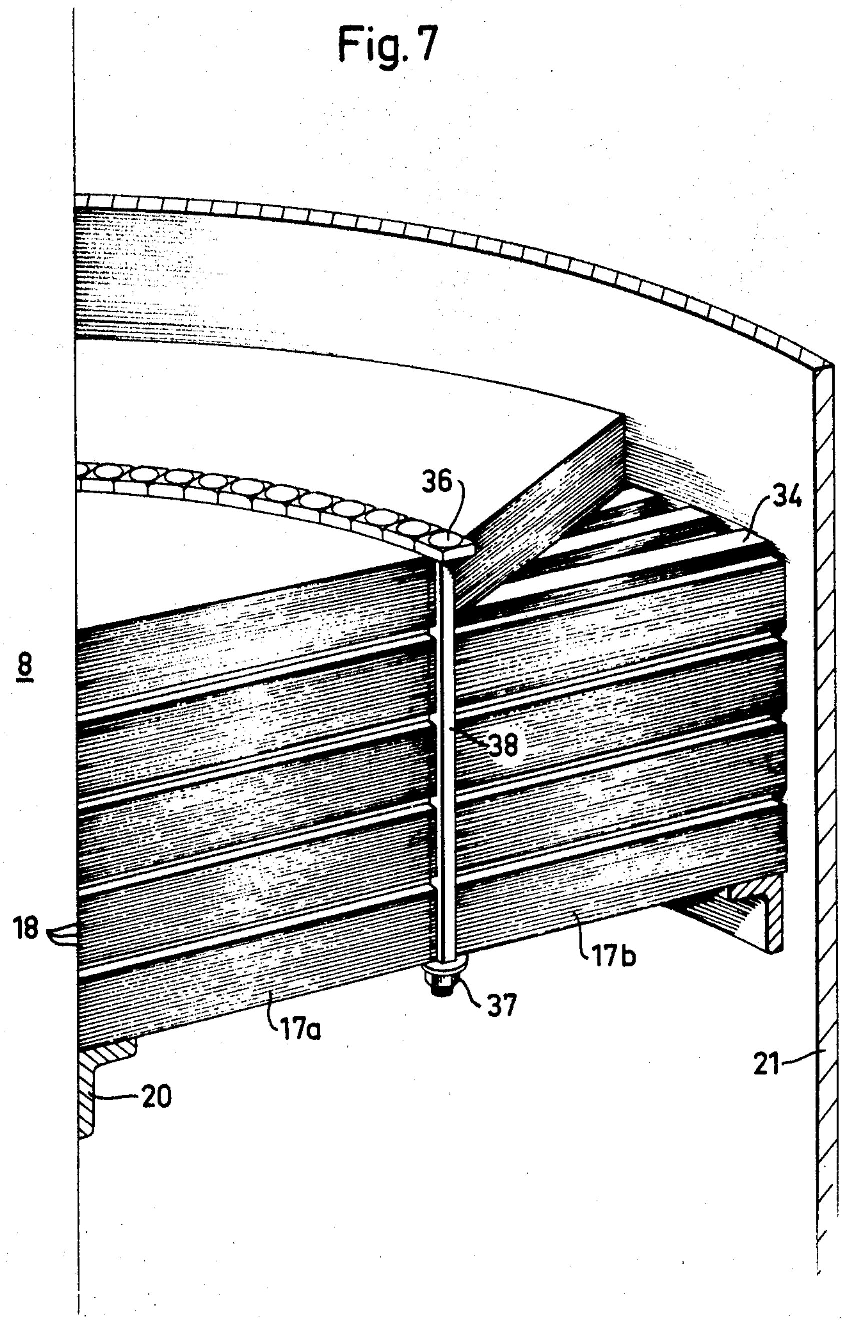

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Fig. 8

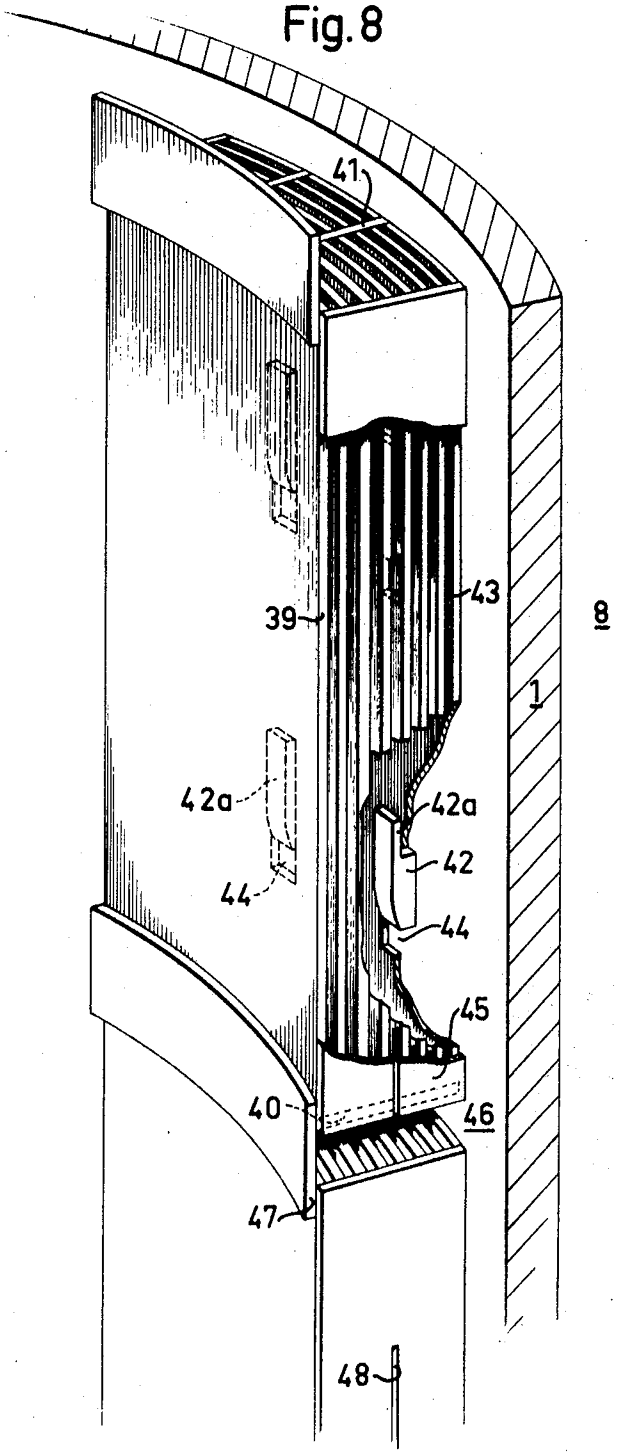

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Fig. 10

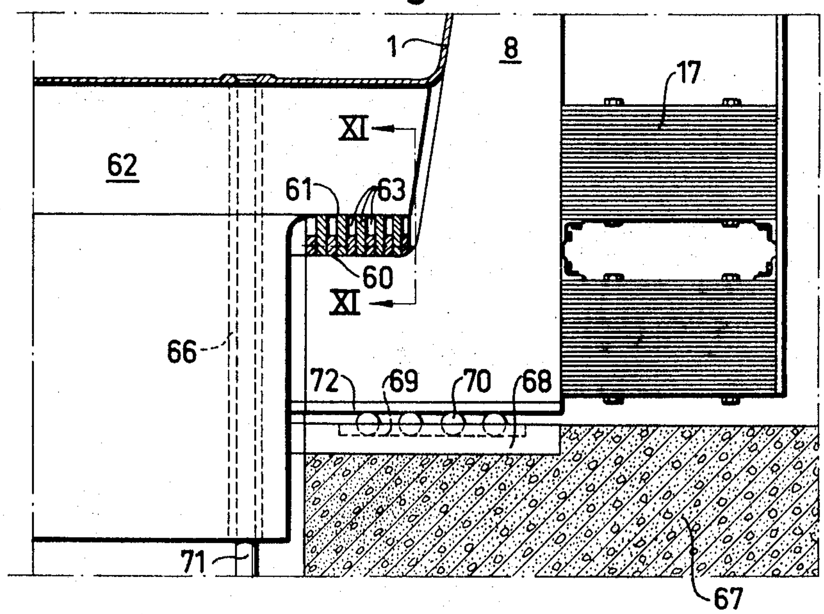


Fig. 11

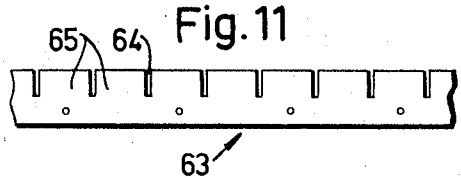
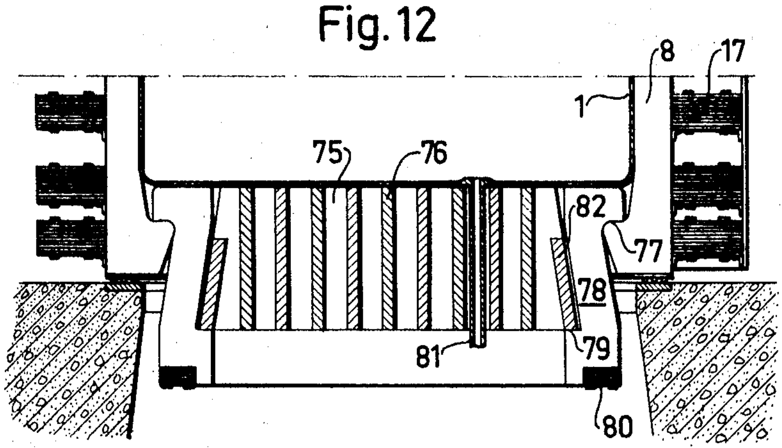


Fig. 12



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CYLINDRICAL PRESSURE VESSEL

The invention relates to a cylindrical pressure vessel, particularly a pressure vessel with a large diameter intended for high internal pressure and a high temperature. The pressure vessel according to the invention is specifically intended to be used as pressure vessel for a nuclear reactor where maximum safety is absolutely necessary, especially if the nuclear energy plant is to be located within, for instance, a town district. Pressure vessels having thick walls and considerable dimensions are both complicated to manufacture and cumbersome to transport from the place of manufacture to the place of use, even if they are manufactured in two or three parts which are then welded together on the site. The object of the invention is primarily to produce an absolutely safe pressure vessel which can be assembled on the site and which consists of several relatively small parts which can be handled fairly easily. The pressure vessel should also be safe against earthquakes. A second object of the invention is to avoid the use of large forged parts and instead enable the use of comparatively thin steel components manufactured by rolling, such as girders and steel plate.

The pressure vessel according to the invention comprises a comparatively thin-walled cylindrical container and a pressure-resistant construction outside this container, and is characterised in that the pressure-resistant construction comprises a plurality of girders running in the longitudinal direction of the pressure vessel and provided at their ends with shoulders facing inwardly to cooperate with pressure-resistant end walls, and annular elements which surround the girders and hold them together.

The cylindrical container forms the gastight or watertight part of the pressure vessel. It is given relatively thin walls and can therefore be transported to the site where it is to be used in several parts which can be welded together on the site.

The wall of the container is supported by the longitudinal girders. These may suitably have a rectangular cross section and be placed radially to provide maximum rigidity. The distance between two adjacent girders is chosen with respect to the thickness of the wall of the container so that this is not pressed out between two girders. The girders are suitably provided with channels for a coolant. Alternatively, coils for coolant can be arranged between the wall of the container and the girders.

The girders, which take up the axial pressure in the pressure vessel, are held together by annular elements which take up the radial pressure. The annular elements can be made of cast or forged steel, but it is suitable if they are made of stacks of metal rings held together by bolts. Each metal ring may consist of two or more sections and two adjacent rings are positioned so that the joints do not cover each other. The surface of the metal rings should be so coarse or rough that the rings cannot slip on each other. Alternatively, the rings may be provided with depressions which fit into each other. The annular elements may be placed close together or somewhat spaced depending on the magnitude of the radial pressure and the rigidity of the longitudinal girders.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following the invention will be further described with reference to the accompanying drawings.

FIG. **1** shows an axial cross section through a pressure vessel according to the invention, intended as pressure vessel for a nuclear reactor.

FIG. **2** shows a detail of the pressure vessel according to FIG. **1**.

FIG. **3** shows a section along the line III—III in FIG. **1**.

FIG. **4** illustrates a method of cooling the pressure-resistant construction according to one embodiment of the invention.

FIG. **5** shows a detail of the upper end wall of the pressure vessel according to FIG. **1**.

FIG. **6** shows a detail of an alternative embodiment of the upper end wall of the pressure vessel.

FIG. **7** illustrates an embodiment of the annular elements of the pressure vessel.

FIG. **8** illustrates a heat insulation to be placed on the interior wall of the pressure vessel.

FIG. **9** illustrates cooling means to be placed on the interior wall of the pressure vessel.

FIG. **10** is a cross-sectional view of the bottom portion of an embodiment of the invention.

FIG. **11** is a cross-sectional view along line XI—XI of FIG. **10**.

FIG. **12** is a cross-sectional view of the bottom portion of another embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The pressure vessel according to FIG. **1** has a relatively thin-walled cylindrical container **1**. The top and bottom of the container wall have conically narrowing parts **2** and **3**. The container has upper and lower end walls **4** and **5** curving inwards. A tube **6** is connected to the container wall, and the part **7** of the wall situated nearest the tube **6** has greater thickness than the rest of the container.

The upright container **1** is surrounded by vertically placed girders **8** having a rectangular cross section. The girders are placed radially with their widths extending in relation to the pressure vessel. The width of the girders should preferably be at least four times their thickness. At the top and bottom the girders **8** are provided with parts **9**, **10**, welded on, which abut the conical parts **2**, **3** and are provided with inwardly directed shoulders **11**, **12**. The girders are provided with channels **13** for a coolant. These channels **13** are formed by the girders consisting of two halves which are welded together, as shown in FIG. **3**. Spacers **29** prevent twisting of the girders **8**.

In order to ensure that the container **1** will not buckle inwards, certain parts of the container wall are welded to rods **14**, extending between two adjacent girders and provided with a nut **15** and washer **16** at the outer ends so that there is some clearance between the washer and the outer surface of the girders.

The girders **8** are completely rectilinear with the exception of the girders situated close to the tube **6**. Nearest the tube **6** the girders are bent aside as shown in FIG. **2**. The increased distance between the girders which thus arises is compensated by providing the container wall **1** with a reinforced part **7**.

The girders **8** are surrounded by annular elements **17**. One such element **17** consists of a number of metal rings **18** held together by bolts **19**. The elements **17** situated nearest the top and bottom ends of the pressure vessel are taller or have an axial dimension larger, than the other elements since the radial forces here are greatest. The annular elements **17** are somewhat spaced from each other. In order that they will be held in position even in pressureless state, they are supported by brackets **20** which are attached to the girders **8**.

The annular elements **17** are attached to a metal sheath **21**. The purpose of this is to prevent the elements **17** twisting in relation to each other.

The upper end wall **4** of the cylindrical container **1** consists of two parts, a peripheral part ***4a*** and a central part ***4b***, which are joined together by a weld **22**, see FIG. **5**. When the pressure vessel is to be opened the weld **22** is ground away, and in order to collect the grindings an annular container **23** is arranged beneath the welding seam.

Above the end wall **4** tubes **25** are arranged close together for a coolant, see FIG. **5**. Above these tubes is a pressure-resistant construction consisting of concentric rings **24**, the outermost rings abutting the inwardly facing shoulder **11** on the girders. The rings **24** have such a wedge-shaped cross section that they form an inwardly domed end wall. When the pressure vessel is under pressure, therefore, the rings will be subjected only to pressure stresses. In order to facilitate assembly and disassembly, at least the outermost of the rings **24** are suitably made in two or more sections. These sectioned rings can easily be removed by first pressing down the pressure-resistant construction somewhat, which is easy as the relatively thin-walled container 1 is yielding. Each pair of two adjacent rings 24 are interconnected by means of a first locking member 33*a* engaging a recess formed by a second locking member 33*b* on the adjacent ring, see FIG. 6. The first locking member 33*a* is fastened to the ring 24 by means of a screw 32, and can easily be loosened when the rings 24 are to be disengaged. The rings can also be interconnected by means of a bolt 33*c* having a head and a nut, see FIG. 1.

The lower end wall of the pressure vessel is also partially built up of rings 24 in a similar manner. The central part of the end wall consists of a solid steel body 85, supporting a platform 86. This platform 86 is intended to support certain parts of the nuclear reactor, primarily the reactor core. Since the reactor itself does not form any part of the present invention, it will not be described further. A cooling fluid and other facilities may be supplied to the reactor through pipes 87 extending through the rings 24 and through pipes 88 extending through the steel body 85 and the platform 86.

The lower end wall may alternatively be made in one piece if it is not considered necessary to open it.

The pressure vessel rests on a concrete base 26, rollers 27 being arranged between the base and the lower ends of the girders 8, and if desired also between the base and the underside of the lowest ring 17, in order to permit radial expansion.

FIG. 4 illustrates an alternative method of cooling the pressure vessel. Tubes 28 for a coolant are arranged close to each other between the wall of the container 1 and the girders 8. The tubes may have a circular cross section 28*a* or, for example, a square cross section 28*b*. If particularly effective cooling is desired, this cooling can be combined with the cooling of the girders 8 which is illustrated in FIGS. 1 and 3.

For very high pressures in the pressure vessel, when wide rings 17 are required, an outer ring can be shrunk onto the shown rings 17 so that a more uniform distribution of strain is obtained in the composite ring.

FIG. 7 illustrates an annular member which can withstand a very high internal pressure, and which can be cooled so as to be useful in combination with a high temperature nuclear reactor. The annular member consists of an inner annular member 17*a* and an outer annular member 17*b*. The inner and outer members are separated by spacers in the form of bolts 38 having a head 36 and a nut 37. The sheet metal rings of each annular member are placed into groups, with axially adjacent groups being separated by spacers 34. A comparatively large surface is exposed to the air, because of the channels formed by the spacers 34 and 38. If desired, a forced cooling can be effected by means of a gaseous or liquid coolant which is forced to flow through these channels.

FIG. 8 illustrates a heat insulation to be placed on the interior wall of the comparatively thin-walled container 1. The heat insulation consists of a plurality of sheet-metal plates 39, welded to a plate 40 which forms a bottom, and also welded to two plates 45 forming side walls. The upper portions of the plates 39 are spaced apart by means of spacing members 41. Slots 48 have been provided in the bottom and side wall plates to facilitate a heat expansion. The plate 39 close to the container wall 1 has openings 44 of a size sufficient for receiving holders 42 welded to the container wall 1. When mounting the heat insulation the holders 42 are inserted into the openings 44, the fingers 42*a* of the holders being inserted into the space 43 between two adjacent plates 39. An auxiliary plate 47 is fastened to the top of each heat insulating member, so as to cover the space 46 between two axially adjacent insulating members.

FIG. 9 illustrates cooling means on the inside of the comparatively thin-walled container 1. The cooling means comprises a plurality of cooling tubes 49, each tube having an inlet portion 49*a* extending through the container wall 1, four spiral portions 49*b*–49*e*, and an outlet portion 49*f* extending through the container wall 1. The four spiral portions 49*b*–49*e* are spaced apart by means of spacing members 50. A wall 51 having openings 52 supports the cooling tube portions 49*e*. The wall 51 is fastened to the container wall 1 by means of supporting members 53, 54, a washer 55, and a bolt 56 and nut 57. The supporting members 53, 54 also carry the weight of a group of cooling tubes, for instance 40 cooling tubes. The coils of the topmost tube of such a group of tubes support the spacing members 50.

The heated fluid in the reactor reaches the cooling tubes 49 through the openings 52. If water is supplied through the inlet tube 49*a* it will boil during its passage, through the four spiral portions 49*b*–49*e*, and will leave as steam through the outlet tube 49*f*. Consequently, the cooling means also serves as a steam generator.

FIGS. 10 and 11 illustrate an alternative embodiment of the bottom of the pressure vessel. The lower portion of the girder 8 has a horizontal shoulder 60 which supports a plurality of supporting members 63, which engage a shoulder 61 on the bottom 62 of the pressure vessel. Each supporting member 63 consists of an annular member, part of which is illustrated in FIG. 11. The annular member 63 has a plurality of vertical slots 64. The tongues 65 between each pair of adjacent slots 64 provide a minor degree of resiliency, and therefore the supporting members 63 allow a small radial movement between the shoulders 60 and 61, owing to thermal expansion and contraction, for instance. The concrete base 67 is provided with an annular steel support member 68, containing a plurality of radial grooves 69, viz one groove 69 for each girder 8. Each groove 69 contains a plurality of steel balls 70, supporting an annular plate 72 which is fastened to the bottom ends of the girders 8, thus allowing a radial movement between the girders 8 and the base 67. The annular plate 72 also prevents the girders 8 from twisting. The annular plate 72 may be divided into a plurality of sections. A plurality of tubes 71, for instance cooling fluid tubes, extend through vertical openings 66 in the bottom 62.

The embodiment illustrated in FIG. 12 has a bottom consisting of a plurality of vertical metal plates 75, interconnected by means of spacing members 76, fastened to the plates 75 by welding. A conical member 82 extends circumferentially around the bottom. Circumferential member 82 is supported on shoulders 79 on a plurality of suspending members 78 which are carried by shoulders 77 on the lower ends of the girders 8. An annular member 80 holds the suspending members 78 together. A plurality of tubes 81, for instance cooling fluid tubes, extend vertically through the bottom. When it is desired to remove the bottom, the bottom is first lifted a few millimeters, the annular member 80 is removed, the suspending members 78 are swung aside so that the circumferential member 82 goes clear of the shoulders 79, and the bottom is now lowered and removed from the pressure vessel.

What is claimed is:

1. Cylindrical pressure vessel comprising, in combination, a comparatively thin-walled cylindrical container having pressure-resistant end walls; and a pressure-resistant construction embracing said container; said pressure-resistant construction comprising a plurality of girders extending longitudinally of said pressure vessel and formed with shoulders at their ends facing radially inwardly to cooperate with said pressure-resistant end walls; said girders having rectangular cross sections and their widths being substantially larger than their thicknesses; said girders being oriented with their widths extending radially in relation to said pressure vessel; annular elements surrounding said girders and retaining said girders in position; and annular plates secured to the ends of said girders, each girder being connected to each angular plate by at least two fastening elements preventing the girders from twisting.

2. Cylindrical pressure vessel according to claim 1, characterized in that the girders (8) are provided with channels (13) for a coolant.

3. Cylindrical pressure vessel according to claim 1, characterised in that the annular elements (17) consists of a number of metal rings (18) placed one on top of the other and held together by bolts (19).

4. Cylindrical pressure vessel as claimed in claim **3**, in which the metal rings (**18**) are arranged in groups separated by spacers (**34**), for the purpose of increasing the surface exposed to the air.

5. Cylindrical pressure vessel as claimed in claim **3**, in which a first annular element (**17***a*) is surrounded by a second annular element (**17***b*), spacers (**38**) being arranged between the two annular elements for the purpose of increasing the surface exposed to the air.

6. Cylindrical pressure vessel according to claim **1**, characterized in that the annular elements (**17**) are connected by a metal sheath (**21**) to prevent them from twisting in relation to each other.

7. Cylindrical pressure vessel according to claim **1** in which at least one tube (**6**) is connected to the side wall (**1**) of the cylindrical container, characterized in that the tube (**6**) extends between two adjacent annular elements (**17**) and between two adjacent girders (**8**) which are bent aside to provide space for the tube (**6**), the side wall (**1**) of the container having a reinforced section (**7**) close to the tube (**6**).

8. Cylindrical pressure vessel according to claim **1**, characterized in that the lower part of the vertical girders (**8**), and the underside of the lowest ring (**17**), rest on rollers or balls (**27, 70**) in order to permit radial expansion.

9. Cylindrical pressure vessel according to claim **1**, characterized in that the pressure-resistant construction for the end walls (**4**) consists of concentric ring members (**24**) having such a wedge-shaped cross section that they form an inwardly domed end wall.

10. Cylindrical pressure vessel according to claim **9**, characterized in that said concentric ring members are formed by cooperating ring sections; and locking members interconnecting adjacent ring sections.

11. Cylindrical pressure vessel as claimed in claim **1**, in which the lower portion of each girder (**8**) has a horizontal shoulder (**60**) which supports a plurality of supporting members (**63**), which engage a shoulder (**61**) on the bottom (**62**) of the pressure vessel, said supporting member (**63**) having a plurality of vertical slots (**64**), whereby the supporting members (**63**) allow a small radial movement between the shoulders (**60**) and (**61**).

12. Cylindrical pressure vessel as claimed in claim **1**, in which a shoulder (**77**) on the lower portion of the girders (**8**) carries a plurality of suspending members (**78**), said suspending members (**78**) having a shoulder (**79**) carrying the bottom end wall of the pressure vessel.

13. Cylindrical pressure vessel as claimed in claim **12**, in which said suspending members are supported on said girders for swinging movement radially of the vessel, and a retaining ring embracing the lower ends of said suspending members and retaining the same in a position carrying said bottom end wall, said retaining ring being removable to provide for outward swinging of the bottom ends of said suspending members to permit removal of said bottom end wall from said pressure vessel.

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