(11) (A) No. 1 129 566

(45) ISSUED 820810

(52) CLASS 359-87

(51) INT. CL.^{3} G21C 13/00

(19) (CA) CANADIAN PATENT (12)

(54) CALANDRIA TANK OF PRESSURE TUBE TYPE NUCLEAR REACTOR

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(21) APPLICATION No. 335,232

(22) FILED 790910

(30) PRIORITY DATE Japan (110736/78) 780911

No. OF CLAIMS 4

ABSTRACT OF THE DISCLOSURE

A calandria tank constituted by a cylindrical barrel, upper and lower tube sheets attached to the calandria tank so as to close the upper and lower end openings of said cylindrical barrel and a plurality of calandria tubes each containing a pressure tube and a nuclear fuel and connected at its upper and lower ends to said upper and lower tube sheets, the space in the calandria tank being filled with heavy water. The cylindrical barrel is divided into an upper barrel section and a lower barrel section which are connected to each other by means of a connecting mechanism capable of absorbing the difference in the thermal expansion between the calandria tubes and the cylindrical barrel.

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BACKBROUND OF THE INVENTION

The present invention relates to the construction of calandria tank of a pressure tube type reactor using heavy water as the moderator.

The pressure tube type reactor is a nuclear reactor which makes use of heavy water as the moderator, and has the multiplicity of calandria tubes disposed in the heavy water. Heavy water or light water is circulated around the nuclear fuel contained each calandria tube so as to be heated and vaporized by the heat produced by the nuclear fuel.

The construction which constitutes the core of the nuclear reactor, containing the calandria tubes, heavy water and so forth is generally referred to as "calandrai tank". The calandria tank is usually constituted by a cylindrical barrel, and upper and lower tube sheets closing the upper and lower openings of the barrel. The aforementioned calandria tubes are fixed at their upper and lower ends to the upper and the lower tube sheets. The space around the calandria tubes and defined by the cylindrical barrel and the upper and lower tube sheets is filled up completely or filled to an appropriate level with the heavy water. Usually, the design is such that the heavy water or the light water flowing around the fuel in each calandria tube is introduced from the inlet and outlet feeder pipes connected to the ends of the pressure tube.

The calandria tank thus constructed is required to have a function to hold the heavy water, as well as the calandria tubes therein. For instance, a calandria tank having a height of about 5 m and a diameter of about 10 m is required to bear about 390 tons of heavy water and to support about 720 pieces of calandria tubes. For this reason, the cylindrical barrel and the upper and lower tube sheets of the calandria tank are made of a material having a sufficient mechanical strength and corrosion resistance, e.g. austenitic stainless steel.

On the other hand, the calandria tubes, which are disposed in the heavy water and containing the nuclear fuel, are made of a material which exhibits a small neutron absorption, i.e. a high neutron economy, e.g. zirconium alloy.

The austenitic stainless steel and the zirconium alloy have different coefficients of thermal expansion. Therefore, even if the calandria tubes are precisely installed in the calandria tank at the room temperature, a difference in thermal expansion of about 5 mm is caused between the calandrai tank barrel and the calandria tubes, provided that the height of the barrel and the length of the tubes are 5 m, in the operating condition in which the heavy water in the calandria tank is heated up to 80 to 90°C.

More specifically, since the austenitic stainless steel has a larger coefficient of thermal expansion than that of the zirconium alloy, a high tensile force is applied to each calandria tube at the points at which the latter is connected to the upper and the lower tube sheets, so that a high tensile stress is generated in these points. This poses a serious problem particularly in the case of the calandria tubes made of the zirconium alloy which has a rather inferior mechanical strength.

It is, therefore, necessary to take a suitable measure for naturally abosrbing the difference in thermal expansion between the cylindrical barrel of the calandria tank and the calandria tubes. An example of such a measure conventionally adopted is to form a thin-walled part in the tube sheets to absorb the difference in thermal expansion making efficient use of the diaphragm spring effect provided by such a thin-walled part. However, the tube sheet must have a thickness large enough to provide a sufficient strength at the portions where the calandria tubes are connected. For this reason, the reduction of the thickness of the tube sheet is allowed only at the peripheral portion of the latter. Should the case be so, the size of the tube sheet is impractically increased, although the difference in thermal expansion may be absorbed. In fact, in some cases, the radius of the tube sheet is increased by 1.5 to 2 m. This in turn incurs an increase of the amount of the heavy water which is expensive. Thus, the increment of the size of the tube sheet is quite disadvantageous from economical point of view. Taking the neutron economy into account, a distance of about 0.4 m between the outermost calandria tubes and the inner peripheral surface of the calandria tank barrel is enough for imparting the function of a neutron reflector to the heavy water. However, if the above-stated measure is taken, the aforementioned distance is as large as about 1.5 and 2 m, so that a considerable amount of heavy water is required additionally. The excessive amount of heavy water poses another problem that the quality of output control, which is made through increasing and decreasing the amount of heavy water in the calandria tank, is deteriorated in the aspect of the response characteristic and so forth.

It has been also proposed and actually used, as a measure which is taken in combination with or instead of the above-described measure, to reduce the diameter of the calandria tank only at its heightwise intermediate portion thereof such that the distance between the outermost calandria tubes and the inner peripheral surface of the calandria tank barrel is reduced to about 0.4 m as described before only at the portion of reduced diameter of the calandria tank barrel. By so doing, the calandria tank barrel itself exhibits a sufficient resiliency for absorbing the difference in thermal expansion. This measure, however, cannot provide remarkable improvement in the neutron economy over the first-mentioned measure, although it can considerably reduce the amount of heavy water contained by the calandria tank.

Most preferably, the calandria tank has a construction which can effectively absorb the difference in thermal expansion and in which the distance between the outermost calandria tubes and the inner peripheral surface of the calandria tubes and the inner peripheral surface of the calandria tank barrel is reduced to the minimum required distance of about 0.4 m over the entire length of the calandria tubes.

SUMMARY OF THE INVENTION

It is, therefore, an object of the invention to provide a calandria tank which can effectively absorb the difference in thermal expansion between the calandria tank barrel and the calandria tubes and which permits the reduction of the distance between the outermost calandria tubes and the inner peripheral surface of the calandria tank barrel to the minimum required distance.

According to the invention there is provided a calandria tank of a pressure tube type nuclear reactor, containing heavy water therein and having a plurality of calandria tubes each accomodating a nuclear fuel, said tank comprising: an upper barrel section having a cylindrical form with upper and lower end openings; a lower barrel section having a cylindrical form with upper and lower end openings, said upper end opening of said lower barrel section being positioned to oppose to said lower end opening of said upper barrel section at a suitable distance from and coaxially with the latter; an upper tube sheet attached to said upper barrel section so as to close said upper end opening of said upper barrel section, said calandria tubes being connected at their upper ends to said upper tube sheet; a lower tube sheet attached to said lower barrel section so as to close said lower end opening of said lower barrel section, said calandria tubes being connected at their lower ends to said lower tube sheet; and a connecting mechanism connecting said lower end opening of said upper barrel section and said upper end opening of said lower barrel section to each other in such a manner as to allow an axial movement of said upper and lower barrel sections to each other, wherein said connecting mechanism includes an aseismatic ring making a sliding contact with an inner surface of one of said upper and lower barrel sections and having elongated guide bores, said ring being attached to the other of said barrel sections, and protrusions attached to said barrel section making the sliding contact with said aseismatic ring, said protrusions engaging with said guide bores to prevent said aseismatic ring from moving in a circumferential direction and, further, allowing said aseismatic ring to move in the axial direction.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side elevational sectional view of a calandria tank in accordance with the invention;

Fig. 2 shows the detail of the portion

encircled by circule A in Fig. 1; and

Fig. 3 is a side elevational view of the portion of the calandria tank shown in Fig. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the invention will be described hereinunder with reference to Figs. 1 to 3.

The calandria tank 1 has a cylindrical lower barrel section 4, a cylindrical upper barrel section 5 disposed above the lower cylindrical barrel section 4 coaxially with the latter, a later-mentioned connecting mechanism 13 by means of which the aforementioned upper and lower barrel sections 4, 5 are connected to each other, a lower tube sheet 3 attached to the lower end opening of the lower barrel section 4 to close the lower end opening and an upper tube sheet 2 attached to the upper end opening of the upper barrel section 5 so as to close the upper end opening.

The connecting mechanism 13 which is shown in an oval frame A in Fig. 1 has a construction as shown in detail in Figs. 2 and 3.

A plurality of metal plates 12 are attached to the inner peripheral surface of the upper barrel section 5 near the lower end opening of the latter. Also, a plurality of metal plates 14 are attached to the inner peripheral surface of the lower barrel section 4 near the upper end opening, in vertical alignment with the metal plates 12. An aseismic ring 10 is attached to the metal plates 12, 14 coaxially with the tank barrels 4, 5, by means of the bolts 15, 16.

More specifically, the lower barrel section 4 and the ring 10 are connected to each other by means of two bolts 15 through each metal plate 14. In contrast to the above, the connection between the upper barrel section 5 and the ring 10 is achieved by means of the bolt 16 which is screwed into the metal plate 12 through an elongated bore 17 formed in the ring, such that the upper barrel section 5 and the ring 10 are displaceable relatively to each other in the vertical direction. A suitable gap is formed between the lower end opening of the upper barrel section 5 and the upper end opening of the lower barrel section.4. An annular metallic bellows 9 is disposed between these ends so as to bridge the above-mentioned gap. This bellows is welded at their upper and lower ends to the lower end of the upper barrel section 5 and to the upper end of the lower barrel section 4, respectively.

These metallic plates 12, 14, ring 10 and the bellows 9 in combination forms the connecting mechanism 13 for connecting the upper and lower barrel sections 5, 4 to each other. This connecting mechanism 13 is formed at an upper portion of the calandria tank. This arrangement is preferred because the bellows 9 is not subjected to the high pressure produced by the large amount of heavy water contained by the calandria tank 1. The above-mentioned constituents of the connecting mechanism 13 are made of austenitic stainless steel, as is the case of the barrel sections, so as to have a sufficient mechanical strength.

Outwardly projected metallic supporting flanges 18, 19 are welded to the outer peripheral surfaces of the barrel sections 4 and 5, respectively. A plurality of tie rods 11 each having threaded ends are received by bores formed in these flanges 18, 19. More specifically, each tie rod 11 is fixed at its lower end to the supporting flange 18 by means of nuts 20 and is loosely received by the bore 23 formed in the upper supporting flange 19. Lock nuts 21, 22 are screwed and fixed to the portions of the threaded upper end of the tie rod 11 above and below the supporting flange 19 at certain distances from the latter. The supporting flanges 18, 19 together with the tie rods 11 and nuts 20, 21, 22 in combination constitute a stopper which is generally designated at a numeral 24. A plurality of stopper 24 are disposed around the calandria tank barrel so as to limit the displacement of the barrel sections 4, 5 from each other. These stoppers provide minimum required displacement of the upper and lower barrel sections 5, 4 relative to each other, and effectively protect the ring 10 and the bellows 9 in case of an accident as will be mentioned later. The supporting flanges 18, 19 has annular forms extending radially outwardly from both barrel sections 4, 5. Although the supporting flanges 18, 19 may be substituted by a plurality of radial arms extending outwardly from each barrel sections 4, 5, the continuous flange-like form is preferred in order to obtain a sufficient mechanical strength.

A heavy water supplying pipe 7 and a heavy water discharging pipe 8 are attached to the lower barrel section 4 and open to the inside of the calandria tank 1. Also, the lower barrel section 4 is provided with a manhole pipe 6 for inspecting the inside of the calandria tank 1 or the internal structure.

A multiplicity of calandria tubes 25 made of a zirconium alloy, each containing nuclear fuel therein, are stretched between and connected to the upper and lower tube sheets 2, 3. The minimum required distance of about 0.4 m is preserved between the outermost calandria tubes 25 and the inner peripheral surface of the upper or lower barrel section 4, 5 imparting the function of a neutron reflector to the heavy water.

The calandria tank 1 of the invention having the described construction operates in the following manner.

As the reactor starts to operate, the light water circulated in the pressure tubes in calandria tubes 25 is heated by the heat generated by the fuel and is vaporized to become steam which is to be delivered to a steam turbine which is installed separately from the calandria tank 1. Meanwhile, heat is transmitted from the calandria tube 25 to the heavy water and further to the barrel sections 4, 5. As a result, the calandria tubes 25 and the barrel sections 4, 5 start to expand. Since the austenitic stainless steel has a larger coefficient of thermal expansion than that of the zirconium alloy as stated before, the barrel sections 4, 5 exhibit a thermal expansion which is about 5 mm greater than that exhibited by the calandria tubes 25, in case that the calandria tank 1 has aforementioned height and diameter.

More specifically, the lower barrel section 4 is expanded upwardly with its lower end fixed to the lower tube sheet 3, while the upper barrel section 5 is expanded downwardly with its upper end fixed to the upper tube sheet 2, and also the calandria tubes 25 are expanded upwardly with their lower ends fixed to the lower tube sheet 3. Since the upper tube sheet 2 is connected to the calandria tubes 25, the upper tube sheet 2 is allowed to move upwardly only by a distance corresponding to the thermal expansion of the calandria tubes 25. Therefore, the ring 10 is moved upward as the barrel section 4 expands axially, and slides with respect to the metallic plates 12 and the bolts 16. This sliding movement is allowed by the elongated bores 17 of the ring 10.

This sliding movement encounters a frictional resistance which constitutes the force applied to the juncture between the calandria tubes 25 and the tube sheets 2, 3. It is, therefore, possible to control the force applied to the juncture by suitably adjusting this frictional resistance. More practically, this can be achieved by adjusting the force at which the bolts 16 are tightened. In fact, it is possible to reduce the force applied to the juncture to such a low level as to just bear the weights of the upper tube sheet 2 and the upper barrel section 3, by reducing the frictional resistance substantially to zero. Also from this point of view, it is recommended to separate the calandria tank barrel at an upper part of the calandria tank 1.

The adjustment of the frictional resistance by the bolts 16, however, poses the following problem. Namely, the bolts 16 are likely to be rotated undesirably due to a vibration of the calandria tank 1 and repeated sliding movement of the ring 10, resulting in a change in the level of the frictional resistance. If the frictional resistances on some of the metallic plates 12 are changed, a distortion is caused between the surfaces of the metallic plates 12 and the ring 10 to hinder a smooth sliding movement of the ring. In order to obtain a uniform frictional resistance between all metallic plates 12 and the ring 10, it is considered to take an alternative measure which does not rely upon the bolts 16. For instance, it is possible to press the metallic plates 12 or movable pieces projected from the surface of the metallic plates 12 uniformly against the surface of the ring 10. This measure offers an additional advantage that the radial expansion of the ring 10 itself is conveniently absorbed by these springs allowing a wide selection of the material of the ring 10 independently of the material of the calandria tank barrel.

The axial expansion of the lower barrel section 4 is absorbed by the reduction of the distance between the upper and lower barrel sections 5,4 which appears as a compression of the bellows 9. When the temperature of the heavy water has reached a predetermined level, i.e. when the expansions of the barrel sections and the calandria tubes 25 have ceased, only the force exerted by the compressed bellows 9 is applied to the junctures between the tube sheets 2,3 and the calandria tubes 25. Strictly speaking, only the force which is obtained by substracting the aforementioned resistance form the compression force is applied to the junctures. If the frictional resistance is greater than the compression force, only the frictional resistance force is applied to the junctures, and it will be possible to reduce this force substantially to zero after the ceasing of the thermal expansions of the barrel sections 4,5 and the calandria tubes 25.

There is a change in the temperature of the heavy water at the starting, stopping and in the transient period of operation of the nuclear reactor. The bellows 9 expands and shrinks at each time of increase and decrease of the temperature of the heavy water. It is possible to nullify the force applied to the junctures between the calandria tubes 25 and the tube sheets 2, 3, as stated before, by allowing free expansion and shrinkage of the bellows 9. As a result of such an arrangement, however, a heavy repeating load is applied to the bellows 9 to considerably deteriorate the durability of the bellows 9. In addition, powders of metal are likely to be produced as a result of the frictional sliding movement of the metallic plates 12 and the ring 10 relative to each other. The powders of metal are then dispersed in the heavy water to adversely affect the heavy water cleaning device which is not shown. It is therefore necessary to minimize the stroke of expansion and shrinkage of the bellows 9. To this end, the stoppers 24 are provided in the described embodiment.

The rods 11 of the stoppers 24 are moved as the lower barrel section 4 is moved upward, so that the lock nuts 22 engaging the threaded part of the rods 11 are moved upward. As the rods 11 make an upward travel by a distance which has been calculated beforehand by various factors such as the length of the calandria tubes 25, length of the lower barrel section 4, temperature of the heavy water, coefficients of thermal expansion and so forth, the lower lock nuts 22 come into contact with the lower face of the supporting flange 19. Once the lower lock nuts 22 are brought into contact with the lower face of the supporting flange 19, no further compression of the bellows 9 takes place, so that the upward force caused by the thermal expansion of the barrel section 4 is directly applied to the junctures between the calandria tubes 25 and the tube sheets 2, 3. This force, however, is beforehand selected to be smaller than the force corresponding to the allowable stress in the junctures, so that no substantial problem is caused by the application of this force to the junctures. Namely, the distance between the lower lock nuts 22 and the lower face of the supporting flange 19 is so selected that the lock nuts 22 are brought into contact with the lower face of the supporting flange 19 only after the level of the axial expansion force caused by the barrel section 4 has been reduced to a sufficiently low level.

In an ordinary condition in which no external force is applied to the bellows 9, the upper and lower nuts 21, 22 clamp the supporting flange 19 therebetween so as to lock the barrel sections 4 and 5 against the movement relatively to each other, thereby to protect the bellows 9 and the ring 10 against any external force which would, for otherwise, cause a breakage of the bellows 9 and the ring 10 during the transportation of the calandria tank 1.

When an external force is applied to the calandria tank 1 after the installation of the latter due to an earthquake or the like, an oscillation of the tank 1 is caused particularly at the upper barrel section 5. This oscillation, however, is conveniently damped by the aseismic ring 10, so that oscillation of extremely large amplitude is prevented to protect the structures on the tube sheet 2, as well as the bellows 9.

In case of a bursting of the calandria tube 25 due to an abnormally high internal pressure, the pressure in the calandria tank 1 is also raised. This rise of the pressure in the calandria tank 1 is, however, an instantaneous one and is born mainly by the ring 10, because there is only a small gap preserved between the ring 10 and the barrel sections 4, 5. Even when the rise of pressure is so large as to cause an upward movement of the upper barrel section 5, such a movement is prevented by the upper lock nuts 21 which abut the upper face of the supporting flange 19, so that the pressure rise is prevented from developing to a serious accident.

A preferred embodiment of the invention has been described. In the described embodiment, the difference in thermal expansion between the calandria tubes 25 and the barrel sections 4, 5 is absorbed by the bellows 9. This, however, is not exclusive and the bellows 9 can be substituted by any construction or member which can absorb the difference in thermal expansion. For instance, provided that the ring 10 and the metal plates 12, 14 can have sufficient sealing performance, the metal plates 12, 14 may be formed as rings attached to the inner peripheral surfaces of the barrel sections 4, 5 over the entire circumference of the latter. In such a case, these rings make a sliding contact with the outer peripheral surface of the ring 10 over the entire circumference of the latter. This arrangement conveniently eliminates the necessity of the bellows 9, and is effective in preventing the internal pressure from leaking to the outside even in case of accident such as the aforementioned accidental rise of the internal pressure of the calandria tank 1.

Also, the invention does not exclude a combined use of the above-described sealing construction and the bellows 9.

Such a combined use ensures a better and longer effect, overcoming the deterioration of the sealing power of the above-stated sealing construction due to a long use.

From the foregoing description, it will be apparent that the difference in thermal expansion between the calandria tubes 25 and the barrel sections 4, 5 is effectively absorbed thanks to the division of the calandria tank 1 barrel into upper and lower barrel sections 5, 4, which in turn permits to reduce the distance between the outermost calandria tubes 25 and the inner peripheral surface of the calandria tank barrel 1 to the minimum required distance of about 0.4 m over the entire axial length of the latter. In consequence, amount of heavy water contained by the calandria tank 1 is very much decreased as compared with that in the conventional calandria tank 1 of the kind described.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A calandria tank of a pressure tube type nuclear reactor, containing heavy water therein and having a plurality of calandria tubes each accomodating a nuclear fuel, said tank comprising:

an upper barrel section having a cylindrical form with upper and lower end openings;

a lower barrel section having a cylindrical form with upper and lower end openings, said upper end opening of said lower barrel section being positioned to oppose to said lower end opening of said upper barrel section at a suitable distance from and coaxially with the latter;

an upper tube sheet attached to said upper barrel section so as to close said upper end opening of said upper barrel section, said calandria tubes being connected at their upper ends to said upper tube sheet;

a lower tube sheet attached to said lower barrel section so as to close said lower end opening of said lower barrel section, said calandria tubes being connected at their lower ends to said lower tube sheet; and

a connecting mechanism connecting said lower end opening of said upper barrel section and said upper end opening of said lower barrel section to each other in such a manner as to allow an axial movement of said upper and lower barrel sections to each other, wherein said connecting mechanism includes an aseismatic ring making a sliding contact with an inner surface of one of said upper and lower barrel sections and having elongated guide bores, said ring being attached to the other of said barrel sections, and protrusions attached to said barrel section making the sliding contact with said aseismatic ring, said protrusions engaging with said guide bores to prevent said aseismatic ring from moving in a circumferential direction and, further, allowing said aseismatic ring to move in the axial direction.

2. A calandria tank of pressure tube type nuclear reactor as claimed in claim 1, wherein said connecting mechanism is provided at an upper portion of said calandria tank.

3. A calandria tank of pressure tube type nuclear reactor as claimed in claim 1, wherein a stopper is provided for limiting the relative axial movement of said upper barrel section and said lower barrel section.

4. A calandria tank of pressure tube type nuclear reactor as claimed in claim 3, wherein said stopper includes:

a first supporting member projected outwardly from outer periphery of said upper barrel section;

a second supporting member projected outwardly from outer periphery of said lower barrel section;

rods fixed to one of said first and second supporting members and loosely engaging the other; and

lock nuts screwed to the threaded part of portion of said rod loosely engaged by said the other of said first and second supporting members and positioned above and below said the other of said first and second supporting

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members, the distances between said the other of said first and second supporting members and said lock nuts being adjustable.

FIG. 1

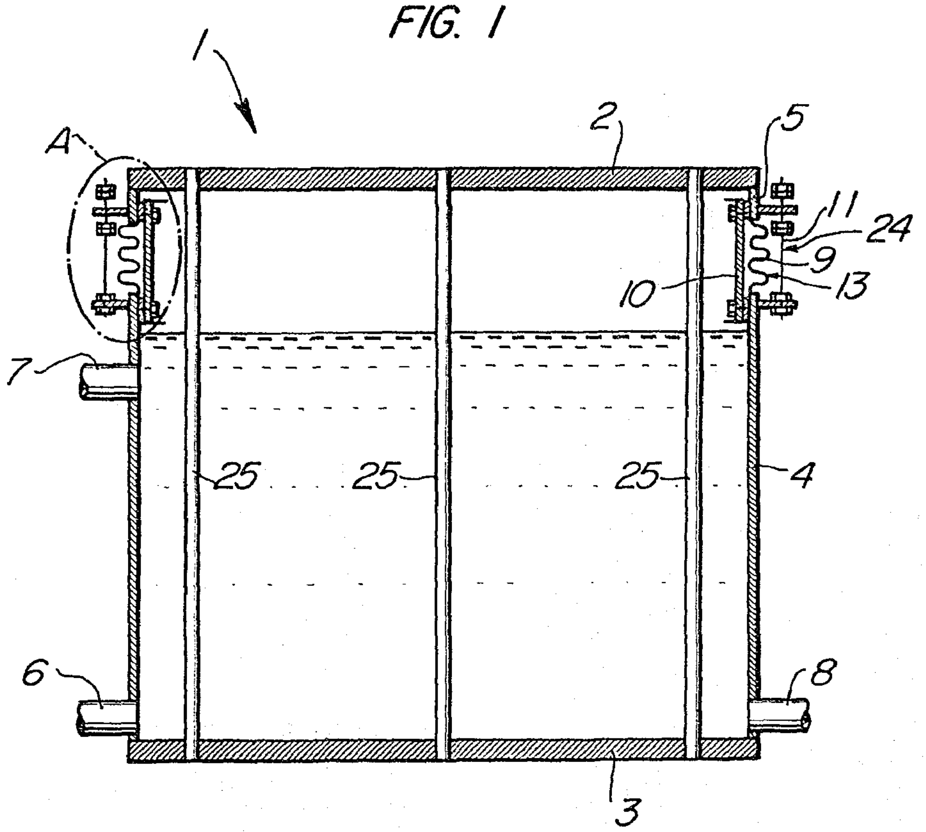

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FIG. 2

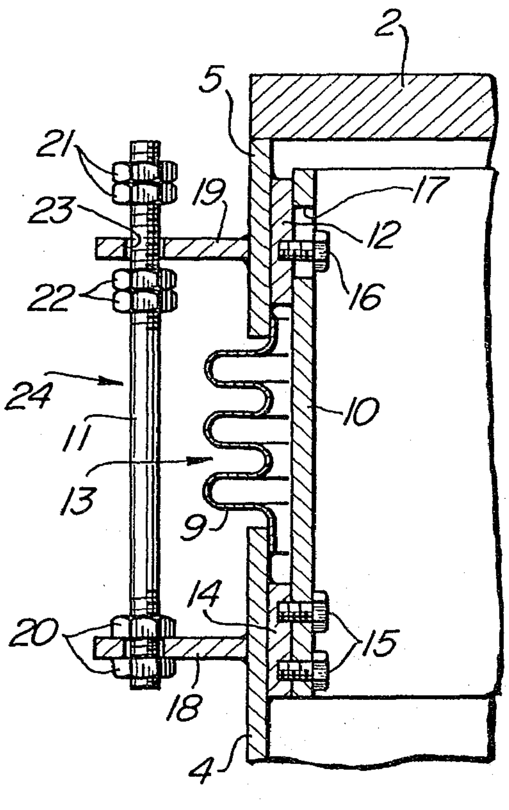
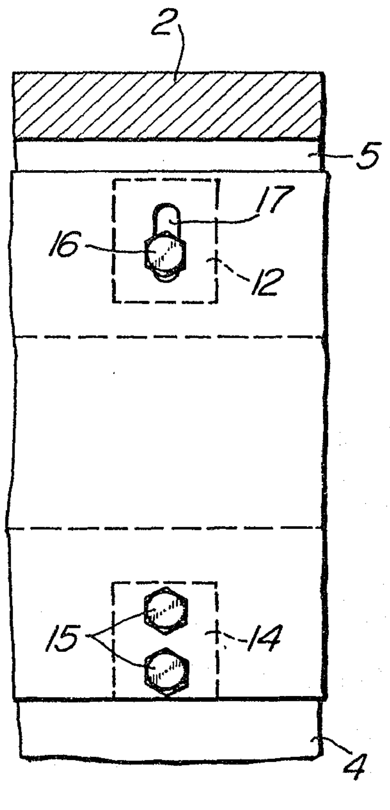


FIG. 3



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