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(54) **Tube-in-shell heat exchangers**

(57) A tube-in-shell heat exchanger wherein the tube bundle has a central spine 1 (shown as tubular) extending longitudinally through the shell 20. The spine carries a series of longitudinally spaced bracing grids (shown as comprising parts 5, 6 and 8) for bracing the tubes 7 apart. The

grids are resiliently mounted on the spine so that differential thermal expansion of one group of tubes relative to other groups of tubes and structure can be accommodated without inducing severe thermal stress. As shown, the resilient mounting of a grid on the spine 1 is by an annular spring 11 and brackets 12 and 13.

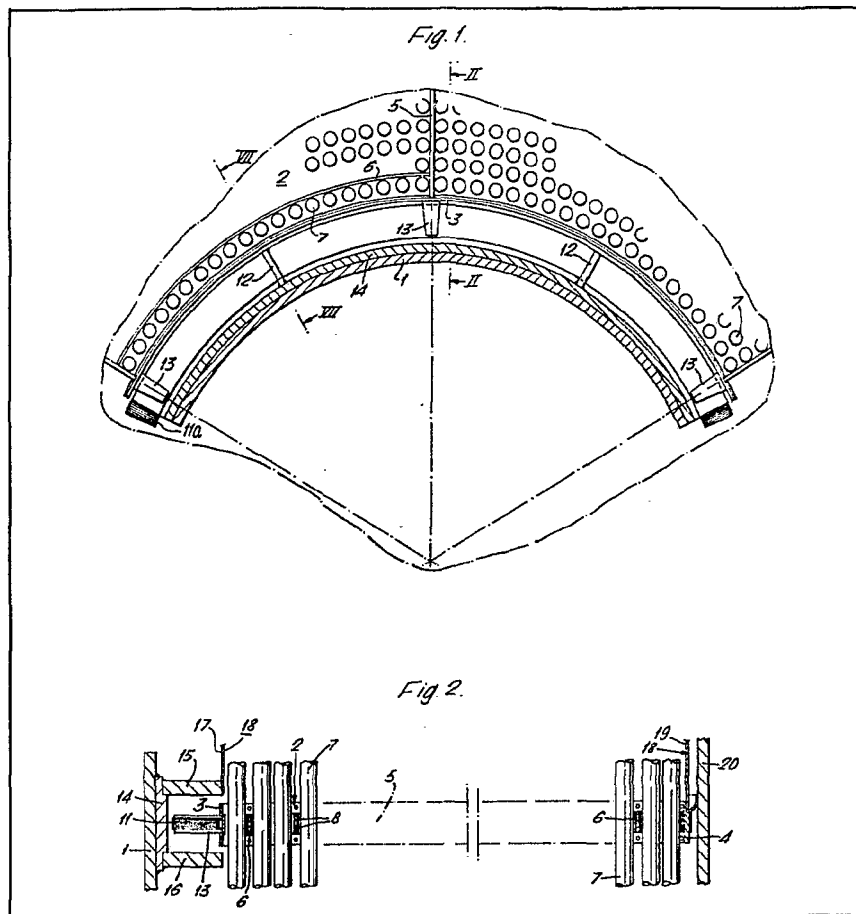


Fig. 1.

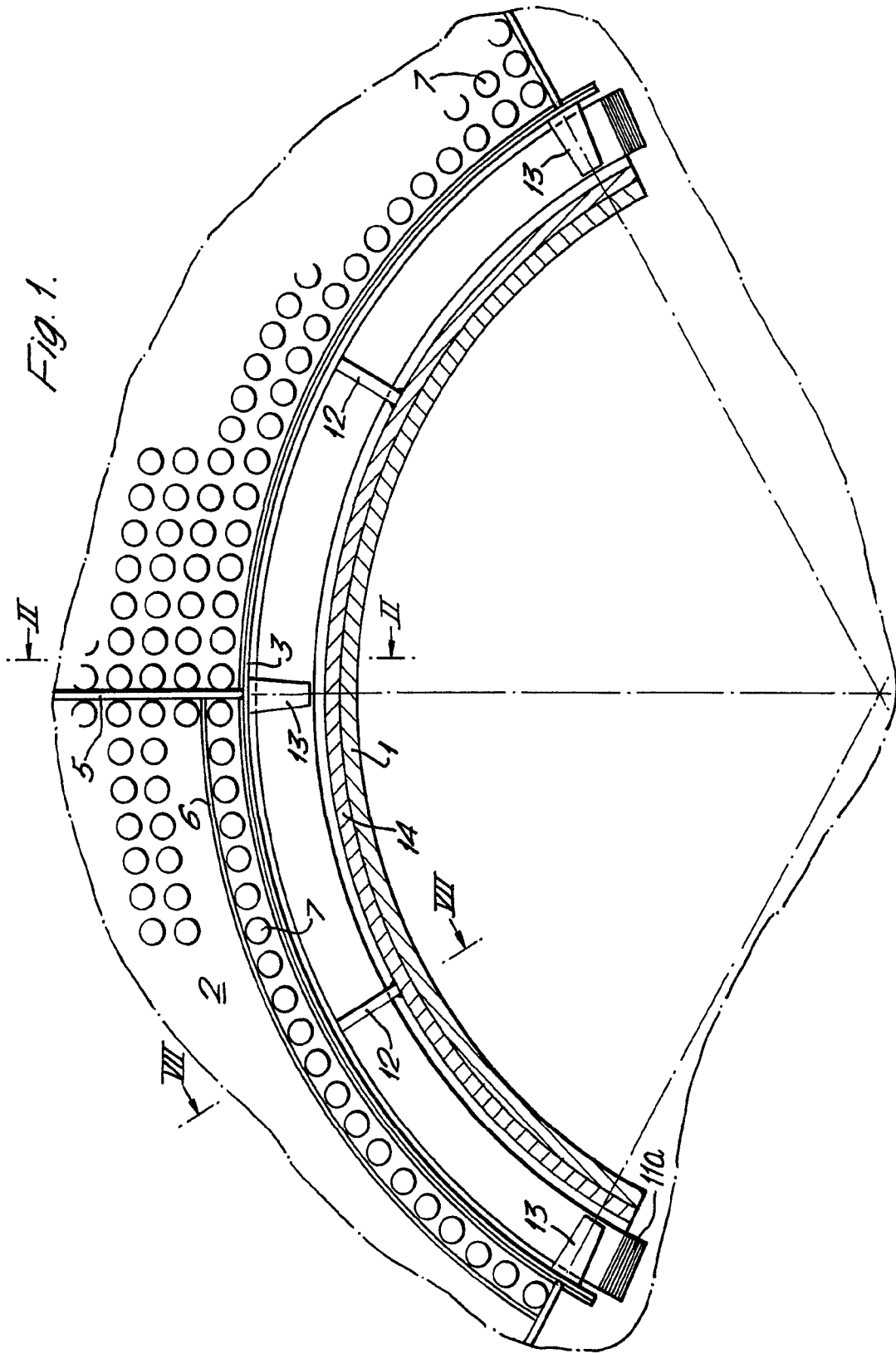


Fig. 2.

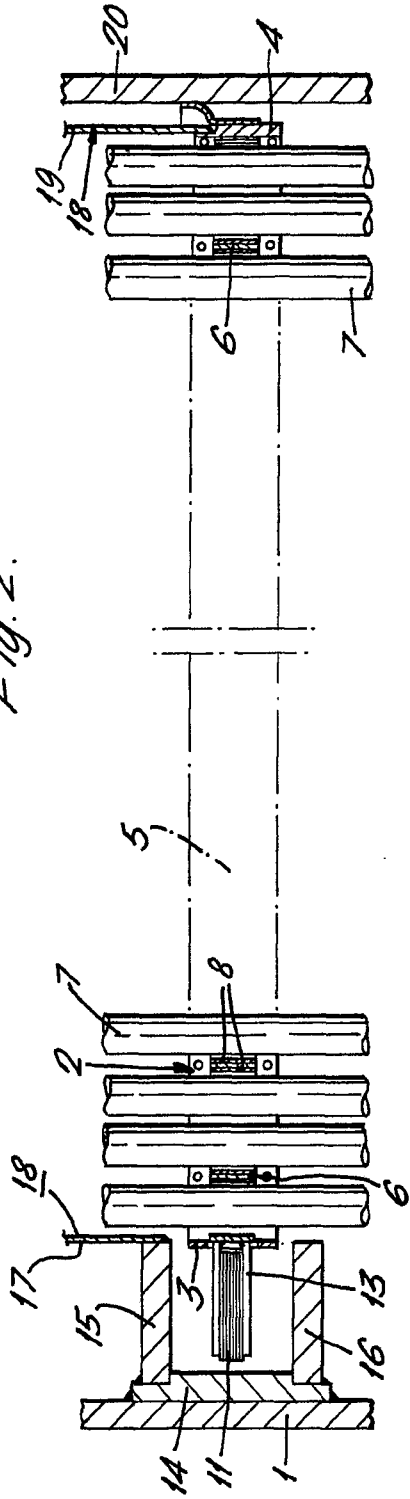
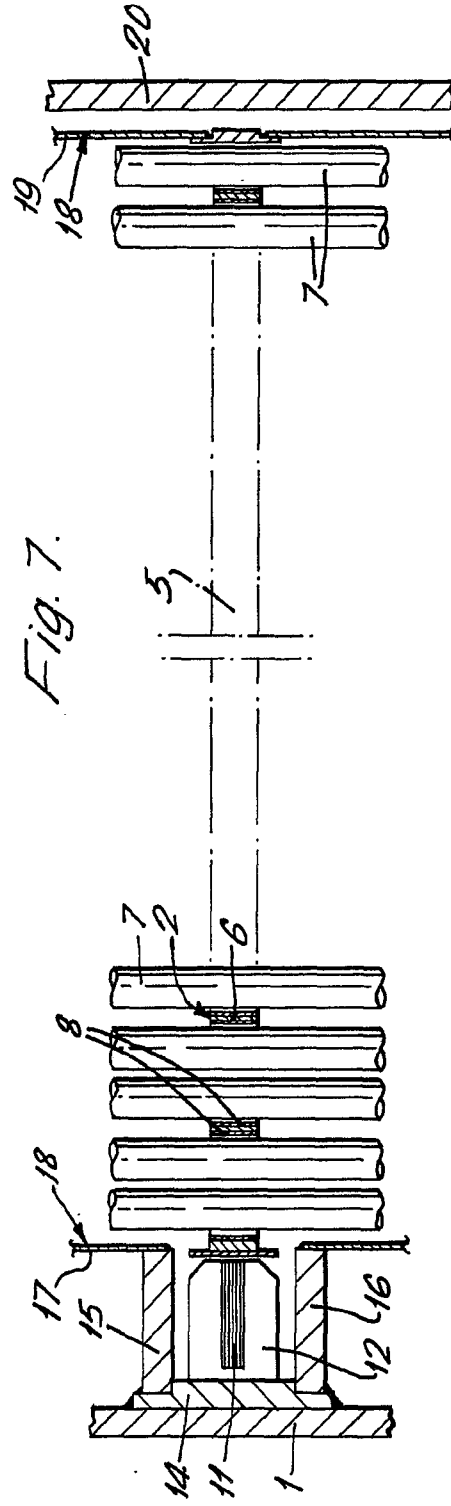


Fig. 7.



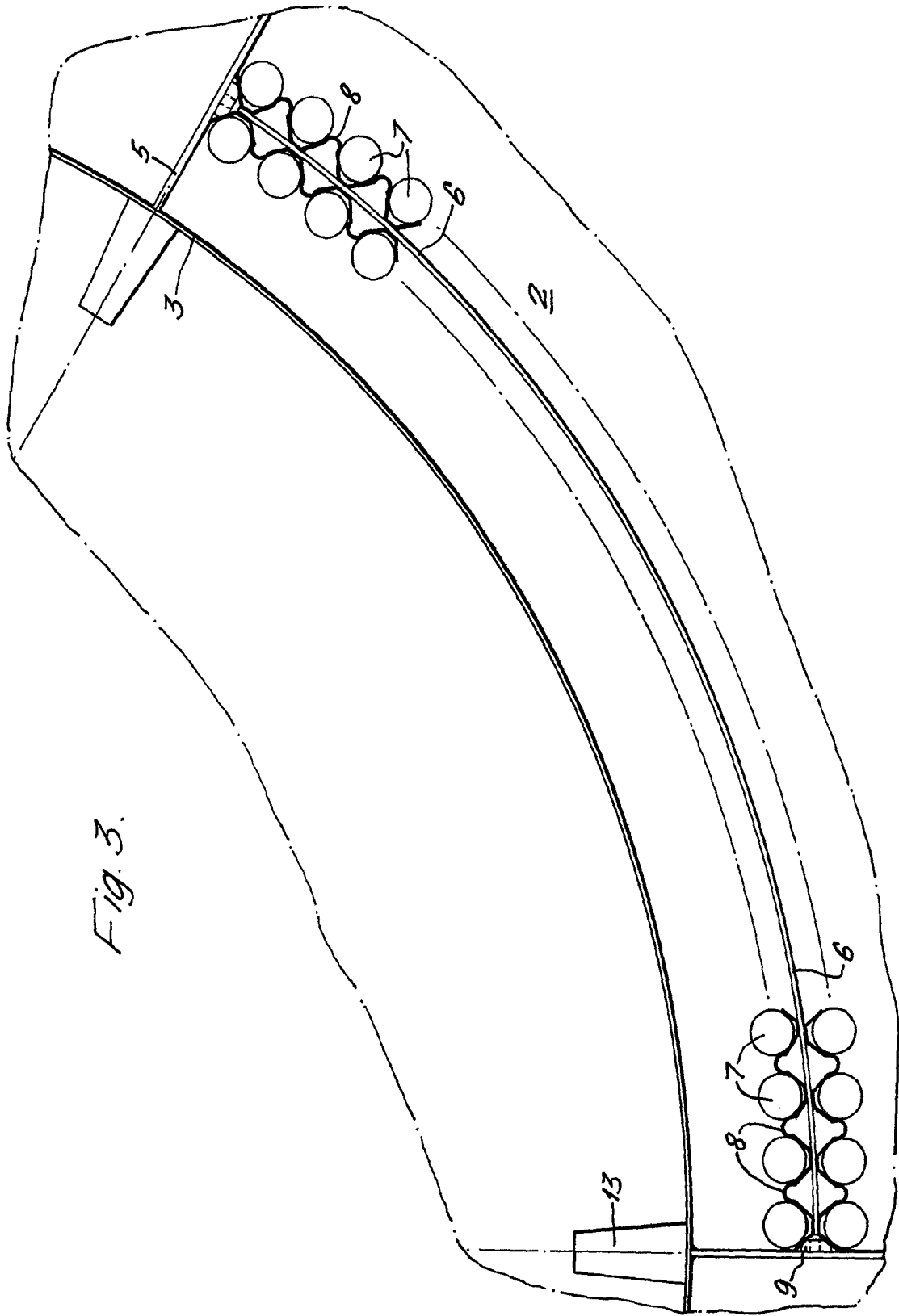


Fig. 3.

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Fig. 4.

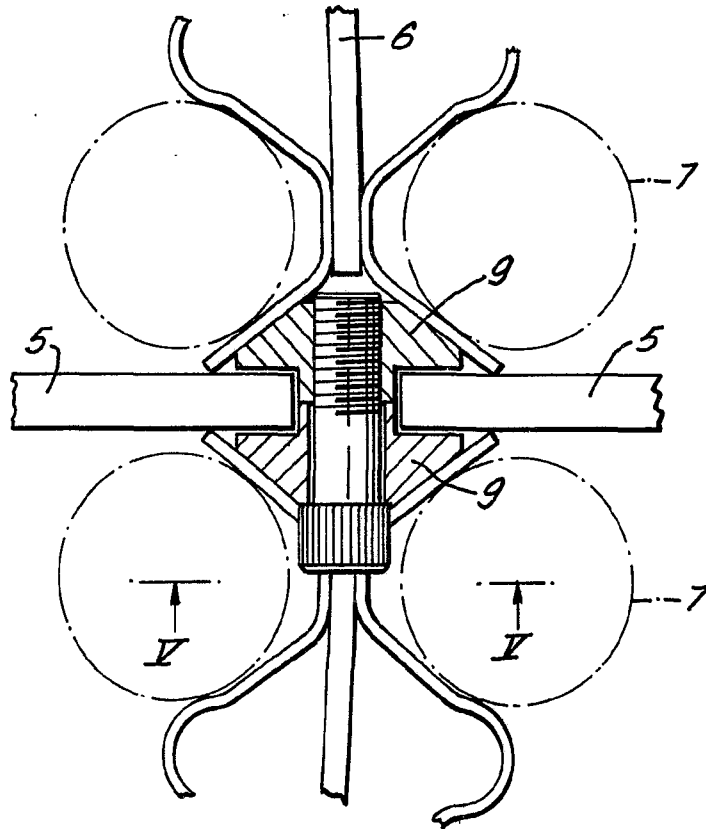


Fig. 5.

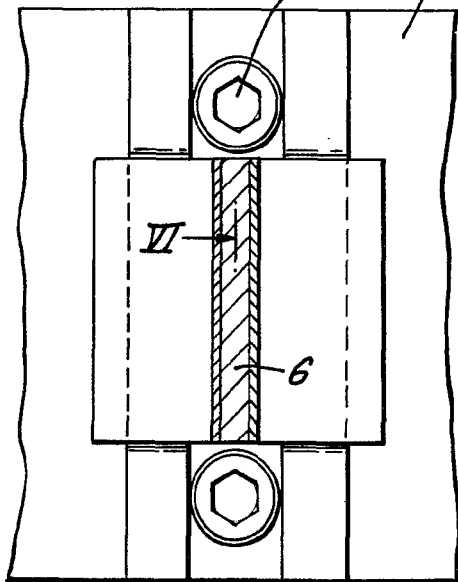


Fig. 6.

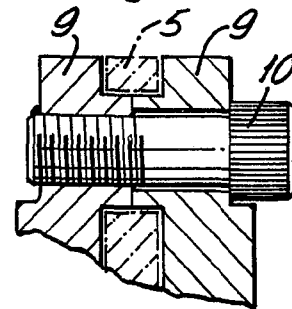
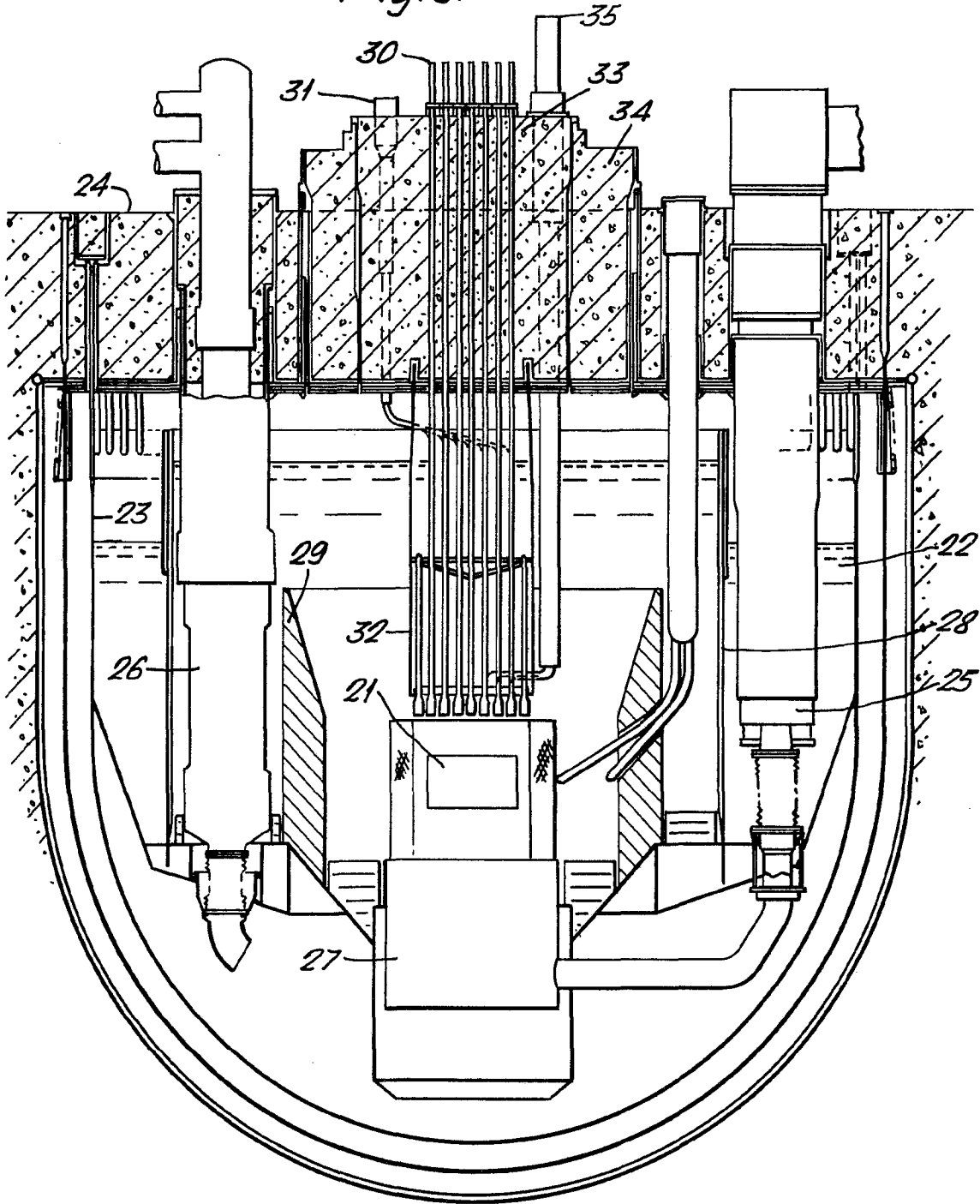


Fig. 8.



SPECIFICATION

Tube-in-shell heat exchangers

This invention relates to tube-in-shell heat exchangers and is directed towards intermediate heat exchangers for use in liquid metal cooled fast breeder nuclear reactor constructions.

A tube-in-shell heat exchanger comprises a closed shell housing a bundle of heat exchange tubes which pass through the shell by way of a transverse tube sheet or sheets. In use a first fluid flows through the shell in heat exchange with a second fluid flowing through the tubes. In one kind of tube-in-shell heat exchanger used as an intermediate heat exchanger in a liquid metal cooled fast breeder nuclear reactor constructions, the tubes being elongate and extending between opposed tubes sheets incorporate expansion bends and therefore are subject to severe vibration due to fluid flow through the shell. One expedient to prevent vibrational movement is to support the tubes transversely by a series of longitudinally spaced grids of which successive grids radially displace the tubes from their nominal in-line positions in opposed directions in order to strain the tubes. However, tube support provided by this expedient can be too rigid, and the differential movement of the tubes relative to the other parts of the structure thereby induces severe stress.

According to the invention in a tube-in-shell heat exchanger wherein the heat exchange tubes are arranged in a bundle and braced transversely by a longitudinal series of spaced grids, the grids are resiliently supported from a central spine of the tube bundle. The resilient supports provide flexibility in the mountings of the tube bundle on the central spine so that groups of heat exchange tubes can be longitudinally displaced relative to the spine and to adjoining groups of tubes to accommodate differential linear thermal expansion.

In a preferred construction of heat exchanger the spine has an annular series of radially outwardly extending forked brackets and each grid has an annular series of radially inwardly extending forked brackets, each bracket of one annular series being interposed between two neighbouring brackets of the other annular series, and there is a resilient annular member disposed to interengage each forked bracket.

In a liquid metal cooled fast breeder nuclear reactor construction of the kind comprising a nuclear fuel assembly submerged in a pool of coolant in a primary vessel, and a tube-in-shell intermediate heat exchanger according to the invention, the intermediate heat exchanger comprises a bundle of heat exchange tubes having a central spine extending longitudinally through the shell and a series of longitudinally spaced transverse grids resiliently mounted on the central spine within the shell and disposed to provide transverse support for bracing the tubes apart, successive grids displacing the tubes from their nominal in-line positions in opposed directions, resilient mountings for the grids on the central

spine each comprising an annular series of brackets rigidly secured to the spine, the brackets each having a pair of radially outwardly extending forked arms, a complementary annular series of forked brackets having radially inwardly extending arms rigidly secured to a grid, each bracket of one series being interposed between two neighbouring brackets of the complementary series, and a resilient annular member disposed transversely to the spine in engagement with the forked arms of both complementary series of brackets.

A construction of tube-in-shell heat exchanger embodying the invention is described by way of example with reference to the accompanying drawings of which

Figure 1 is a fragmentary cross-section,

Figure 2 is a fragmentary elevation in section on line II—II of Figure 1,

Figure 3 is a fragmentary plan view of a tube bracing grid,

Figure 4 is a fragmentary cross-sectional view of a detail of the grid shown in Figure 3 and drawn to a larger scale,

Figure 5 is a fragmentary sectional view on line V—V of Figure 4,

Figure 6 is a fragmentary side view on line VI—VI of Figure 5,

Figure 7 is a fragmentary elevation in section on line VII—VII of Figure 1, and

Figure 8 is an elevation in section of a liquid metal cooled fast breeder nuclear reactor.

The tube-in-shell heat exchanger shown in the drawing is for use in a nuclear reactor construction to effect heat exchange between a primary liquid sodium coolant flowing through the tubes and a secondary liquid sodium coolant flowing through the shell. The shell is generally cylindrical and the tubes arranged in a bundle extend substantially parallel to the longitudinal axis of the shell and are secured at their ends to transverse tube sheets. The bundle of tubes has a central tubular spine and to provide transverse support for the heat exchange tubes there is a series of longitudinally spaced grids. Referring now to Figure 1 there is shown a segment of the heat exchanger wherein is depicted the tubular spine designated 1 and a typical grid 2. With reference now to Figures 1 and 2 the grid comprises an inner strap 3 and a coaxial outer strap 4 co-joined by six equally angularly spaced radially extending spider arms or spokes 5. Extending between adjacent spider arms there are arcuate strap members 6 which are arranged to form spaced coaxial intermediate support straps for the heat exchange tubes 7 disposed in substantially coaxial banks. The arcuate strap members 6 carry corrugated strip 8 (as shown in Figure 3) on each side, the corrugations each serving to cradle a tube 7 and the strips have end fittings for the arcuate strap members welded to them. The arcuate strap members 6 are attached to the spider arms by co-operating end fittings 9 which are fastened together with bolts 10 penetrating the spider arms as shown in Figures 4, 5 and 6. The inner and outer banks of tubes 7 are supported from the inner and outer straps 3 and 4

by corrugated strips 8 welded thereto. The corrugated strips are angularly displaced relative to each other, the displacement being in opposite directions for successive grids so as to brace the tubes at points along their lengths thereby to reduce the tendency to vibrate due to fluid flow through the shell. The grids are resiliently supported from the tubular spine 1 each by means of an annular spring 11 co-axially disposed with the spine and engaging with two circular series of six radially extending forked brackets 12, 13 associated with the spine 1 and grid 2 respectively. The spring 11 comprises a stack of relatively slidable annular laminations or leaves designated 11a in Figure 1.

The six forked brackets 12 of a series each have a pair of radially outwardly extending arms and as shown in Figures 1 and 7 are welded to an annular stepped collar 14 which is itself welded to the tubular spine. Upper and lower flanges 15 and 16 carried by the collar 14 support sections of an inner wall 17 of an annular shroud 18 for the bundle of tubes. The six forked brackets 13 of a complementary series have radially inwardly extending forked arms which extend through slots in the inner strap 3 and as shown in Figures 1 and 2 are welded to recessed inner ends of the spider arms 5. Each forked bracket 13 is interposed between two neighbouring brackets 12. Each outer strip 4 is stepped to receive lower and upper ends of outer walls 19 of the tubular shroud 18 the lower end of each wall being welded to an outer strip 4 whilst the upper end for each wall is slidably fitted to an outer strap. The outer strap at the upper and lower grid plates of the series has an annular spring adapted to bear sealingly on the wall of the shell designated 20.

The described construction provides flexibility in the mountings of the tube bundle on the central spine so that groups of heat exchange tubes 7 can be longitudinally displaced relative to the spine and to adjoining groups of tubes to accommodate differential linear thermal expansion.

Figure 8 illustrates a nuclear reactor of the liquid metal cooled fast breeder type having a fuel assembly 21 submerged in a pool 22 of liquid sodium coolant in a primary vessel 23. The primary vessel is suspended from the roof of a containment vault 24 and there is provided a plurality of coolant pumps 25 and heat exchangers 26 of the kind hereinbefore described, only one of each of the pumps and heat exchangers being shown. The fuel assembly 21 is mounted on a diagrid 27 and housed with the heat exchangers in a core tank 28 whilst the pumps, which deliver coolant to the diagrid, are disposed outside of the core tank. The core or fuel assembly 21 comprises a plurality of sub-assemblies which upstand from the diagrid in closely spaced side-by-side array and is surrounded by a neutron shield 29. Control rods 30 and instrumentation 31 are shown penetrating the roof of the vault and passing down towards the fuel assembly through a core cover plate structure 32. The core cover plate structure depends from a rotatable inner plug 33 which is

mounted eccentrically in an outer plug 34 rotatable in an aperture in the roof of the vault. The plug 33 carries a fuelling machine 35 which, by rotation of the plugs 33, 34, can be arranged to command any fuelling position of the fuel assembly.

In operation of the nuclear reactor relatively cold coolant drawn from the region of the pool which is outside of the core tank 28 is flowed upwardly through the fuel assembly 21 by the pumps 25 by way of the diagrid 27. The coolant flow impinging on the core cover plate is deflected radially to flow into the intermediate heat exchangers 26 through which it passes in heat exchange with a secondary liquid metal coolant associated with steam generating plant disposed externally of the vault.

CLAIMS

1. A tube-in-shell heat exchanger comprising a bundle of heat exchange tubes having a central spine extending longitudinally through a shell and a series of longitudinally spaced transverse grids resiliently mounted on the central spine within the shell and disposed to provide transverse support for bracing the tubes apart.

2. A tube-in-shell heat exchanger according to claim 1 wherein resilient mountings for the grids on the central spine each comprise

an annular series of brackets rigidly secured to the spine, the brackets each having a pair of radially outwardly extending forked arms, a complementary annular series of forked brackets having radially inwardly extending arms rigidly secured to a grid, each bracket of one series being interposed between two neighbouring brackets of the complementary series, and a resilient annular member disposed transversely to the spine in engagement with the forked arms of both complementary series of brackets.

3. A tube-in-shell heat exchanger according to either of claims 1 and 2 wherein the resilient annular member comprises a stack of relatively slidable annular laminations.

4. A tube-in-shell heat exchanger according to any one of the preceding claims wherein successive grids of the series brace the tubes from their nominal in-line positions in opposed directions.

5. In a liquid metal cooled fast breeder nuclear reactor construction of the kind comprising a nuclear fuel assembly submerged in a pool of coolant in a primary vessel, a tube-in-shell intermediate heat exchanger comprising a bundle of heat exchange tubes having a central spine extending longitudinally through the shell and a series of longitudinally spaced transverse grids resiliently mounted on the central spine within the shell and disposed to provide transverse support for bracing the tubes apart, successive grids displacing the tubes from their nominal in-line positions in opposed directions, resilient mountings for the grids on the central spine each comprising an annular series of brackets rigidly secured to the spine, the brackets each having a

- pair of radially outwardly extending forked arms,
a complementary annular series of forked
brackets having radially inwardly extending arms
rigidly secured to a grid, each bracket of one series
5 being interposed between two neighbouring
brackets of the complementary series, and a
resilient annular member disposed transversely to
the spine in engagement with the forked arms of
- 10 both complementary series of brackets.
6. A tube-in-shell heat exchanger substantially
as hereinbefore described with reference to
Figures 1—7 of the accompanying drawings.
7. A liquid metal cooled fast breeder nuclear
reactor construction substantially as hereinbefore
15 described with reference to the accompanying
drawings.