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(54) TUBE-IN-SHELL HEAT EXCHANGERS

(71) We, UNITED KINGDOM ATOMIC ENERGY AUTHORITY, London, a British Authority, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

This invention relates to tube-in-shell heat exchangers.

In general, tube-in-shell heat exchangers comprise a bundle of parallel tubes within a shell or container, one fluid being arranged to flow through the tubes in heat exchange with a second fluid flowing through the shell. The tubes are usually end supported by tube plates or sheets which separate the two fluids and in use the tube attachments to the tube plates and the tube plates can be subject to severe stress by thermal shock. Therefore, frequent inspection and servicing may be required. In some heat exchanger applications, for example, those wherein the heat exchangers are immersed in a nuclear reactor coolant such as liquid sodium, the inspection and servicing of tubes and tube plates is difficult to accomplish.

According to the invention in a tube-in-shell heat exchanger there is a longitudinally extending central tube member incorporating axially spaced cylindrical tube sheets to which the opposed ends of the tubes are attached and within the tube member there is a tubular baffle which slidably seals against the wall of the tube member between the cylindrical tube sheets to define two discrete co-axial flow ducts, the ducts being interconnected at a closed end region of the tube member by the heat exchange tubes and the tubular baffle comprises inner and outer spaced walls the interspace containing argon. In a heat exchanger according to the invention the baffle is readily removable and can be withdrawn to enable insertion of equipment for inspecting the wall of the tube member and tube attachments and to facilitate plugging of defective tubes.

Cylindrical tube sheets are believed to be superior to tube plates for carrying pressure loads and resisting the effects of thermal shock. Because the tensile stress created by pressure in the cylindrical tube sheet is spread over the full wall thickness, the wall may be relatively thin whereas in the flat tube plate normally associated with conventional heat exchangers the more complex stresses created by bending necessitate a relatively thick wall. Some protection against thermal shock for a heat exchanger according to the invention can be effected by arranging that the secondary heat exchange fluid (fluid of least temperature) is on the tube side and by providing a thermal baffle to prevent direct impingement of hot primary fluid onto the cylindrical tube sheets.

A construction of heat exchanger in accordance with the invention for use in a liquid sodium environment will now be described by way of example with reference to the fragmentary diagrammatic drawings Figs. 1 and 2 filed with the Provisional Specification which together present a sectional view.

In the tube-in-shell heat exchanger shown in the drawings a bundle of parallel heat exchange tubes is designated 1 and the shell 2. There is a central thimble shaped tube member 3 to which the ends 1*a* of the tubes are attached. The opposed ends 1*a* of the tubes are arranged in two discrete groups spaced along the longitudinal axis of the tube member 3 and the tubes are adapted for attachment thereto by cylindrical tube sheets 4 which are incorporated in the tube member; the tubes are bore welded into the tube sheets 4 by the tungsten inert gas process to form crevice free welds. In the tube member 3 there is a readily removable tubular baffle 5 which slidably seals against the wall of the tube member between the groups of the tube end attachments to define two discrete co-axial coolant flow ducts 6 and 7. The co-axial coolant flow ducts 6 and 7 are interconnected by the heat exchange tubes. The tubular baffle 5 is double walled to define an argon filled interspace for reducing heat transfer through the baffle and there is a flexible expansible region *5a* in the inner wall to prevent distortion of the baffle by differential thermal expansion of the two walls. A cylindrical baffle 8 is provided to prevent direct impingement of primary coolant fluid on the tube member 3 and tube sheets 4 and thereby attentuate thermal shock.

In use, primary coolant fluid flows vertically downwardly through the shell 2 over the tube bundle. The secondary fluid flows downwardly through the duct 6 of the baffle 5 thence upwardly through the heat exchange tubes 1 and the outer duct 7. By removing the baffle 5 access can be gained to the tube member for inspection of welds and if necessary for plugging any defective tubes.

In greater detail, the heat exchanger is arranged to depend from the roof (designated 9) of the vault of a nuclear reactor construction. The vault contains the reactor core submerged in liquid sodium at approximately 600°C and the heat exchanger is immersed in the sodium the level of the sodium being designated 'L' in the drawing. The exchanger has a housing 10 (shown in broken line) which has an inlet port 11 formed by a horizontal duct 12 for primary sodium and an outlet port 13 in the base region. An internal plenum 14 for distributing primary fluid flow uniformly around the heat exchanger is bounded by the baffle 8 and a perforated baffle 15. A perforated horizontal grid plate 16 effects a uniform flow profile to the tube bundle. After flowing downwardly through the tube bundle the primary fluid enters a discharge plenum 17 which is arranged to pass some flow into the upper regions of the pool of sodium and the remainder to mix in the lower pool regions. A further grid assembly 18 is provided above the inlet port level to reduce flow turbulence with the plenum 14; such flow turbulence causes surface disturbance which induces gas entrainment in the sodium. A cylindrical sleeve 19 vertically slidable in the shell is actuated from above the roof of the vault to provide cut-off and coarse flow control by variably obturating the inlet port 11. Heat exchange coils 20 are for use when the reactor has become inoperative to remove decay heat to outside the vault. Inlet and outlet ports 21, 22 for the secondary sodium are located above the roof 9 of the vault. A drain tube 23 extends from the base within the tube member 3 to a drain facility situated between two spaced annular seals 24, 25 which close the upper end of the duct 7. Sodium can be discharged from the tube member 3 by way of the drain tube 23 and drain facility by pressurising the upper regions with argon gas. The tube member 3 has a removable top cover 26 to enable the tubular baffle 5 to be withdrawn into a steel containment flask and thus expose the internal wall of the cylindrical tube sheets 4 and the tube ends for inspection and repair by suitable equipment. Advantages derived from the invention in such a nuclear reactor application comprise:

(a) the inside surface of the tubular member 3 can be visually inspected by television camera or endoscope,

(b) crack development can be detected by stress wave emission,

(c) tube wall thickness can be inspected by eddy current techniques,

(d) tubes can be examined for leakages by temporarily plugging tube ends and checking for depressurisation, and

(e) defective tubes can be closed by plug welding both ends.

Such techniques are carried out in an argon/sodium vapour environment at approximately 200°C.

In an alternative construction the heat exchange tubes are of helical form. Exchangers having helically wound tubes have the advantage that a smaller number of tubes are required to achieve the desired heat transfer rate but they have the disadvantage that the secondary fluid flow is subject to high pressure drop.

WHAT WE CLAIM IS:—

1. A tube-in-shell heat exchanger wherein there is a longitudinally extending central tube member incorporating axially spaced cylindrical tube sheets to which the opposed ends of the tubes are attached, there being within the tube member a tubular baffle which slidably seals against the wall of the tube member between the cylindrical tube sheets to define two discrete co-axial flow ducts, the ducts being interconnected at a closed end region of the tube member by the heat exchange tubes and wherein the tubular baffle comprises inner and outer spaced walls, the interspace containing argon.

2. A heat exchanger according to claim 1 wherein the inner wall of the tubular baffle has a flexible expansible region.

3. A nuclear reactor construction having a core submerged in a pool of liquid metal within a closed vault and a tube-in-shell heat exchanger according to anyone

of the preceding claims, the heat exchanger being contained in a housing depending from the roof of the vault, the heat exchange tubes being disposed vertically and submerged in the liquid metal.

4. A nuclear reactor construction according to claim 3 wherein the heat exchanger shell has a radial inlet port for liquid metal, and wherein there is a cylindrical sleeve slidable along the longitudinal axis of the shell for variably obturating the inlet port.

5. A nuclear reactor construction according to claim 4 wherein there is a cylindrical baffle encircling the tube member and disposed to prevent direct impingement of liquid flowing through the inlet port on to the cylindrical tube sheets.

6. A nuclear reactor construction according to any one of claims 3, 4 and 5 wherein there is a drain tube extending from the closed lower end region of the tube member to a drain facility situated between two spaced annular seals which close the upper end of the outer duct of the co-axial fluid flow ducts.

7. A tube-in-shell heat exchanger substantially as hereinbefore described with reference to the drawings accompanying the Provisional Specification.

8. A nuclear reactor construction substantially as hereinbefore described with reference to the drawings accompanying the Provisional Specification.

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1 447 051 PROVISIONAL SPECIFICATION

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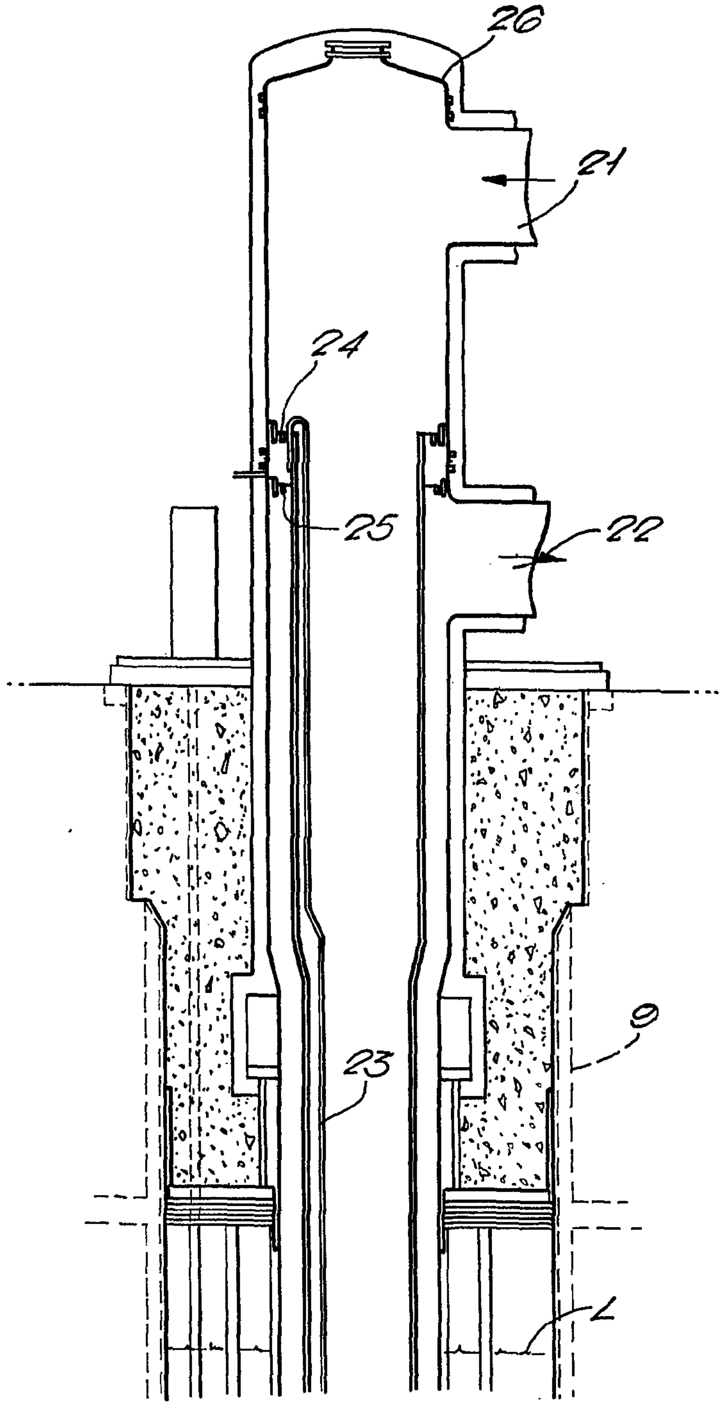
SHEET 1

FIG. 1.



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SHEET 2

FIG. 2.