PATENT SPECIFICATION

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(54) HEAT EXCHANGER

(71) We, CLARKE CHAPMAN LIMITED, (formerly Clarke Chapman-John Thompson Limited), a British Company of Victoria Works, Gateshead, County Durham, NE8 3HS, 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:—

The invention relates to methods of heat exchange and to heat exchangers.

The invention particularly relates to a method of heat exchange, and to an intermediate heat exchanger for use in nuclear power plant of the fast reactor type in which heat is extracted from the reactor core by primary liquid metal coolant and heat is transferred to secondary metal coolant by means of the intermediate heat exchanger.

One of the main requirements of such a heat exchanger if used in a pool-type fast reactor is that pressure drop on the primary (reactor coolant) side has to be kept to a minimum consistent with the maintenance of a limited dynamic head in the reactor pool vessel.

The heat exchanger also needs to be compact enough to be accommodated in the reactor vessel. The tubes of the heat exchanger must be capable of inspection and access must be available for detection of leaking tubes and for plugging leaking tubes.

Where the heat exchanger is situated outside the reactor vessel, as in the case of a loop system reactor, a higher pressure drop on the primary (reactor coolant) side is possible and space restriction on the heat exchanger is less severe.

An object of the invention is to provide a method of heat exchange and a heat exchanger suitable inter alia for use in such reactors.

A further object is to provide a method of heat exchange and a heat exchanger which ensures that excessive temperature variations or so-called temperature transients are not imposed on welded tube joints by sudden changes in the primary (reactor coolant) flowpath.

An intermediate heat exchanger, according to the invention comprises an outer upright cylindrical wall, spaced from and surrounding an intermediate upright cylindrical wall defining between them a first duct part, and an inner upright cylindrical wall spaced from and surrounded by the intermediate wall and defining with the intermediate wall a second duct part, first like ends of the duct parts being in communication and second like ends being closed by planar tubeplates spaced apart in the lengthwise direction of the ducts, the intermediate wall being in part formed by a flexible part which extends upwardly from the upper surface of the lower tubeplate and which is adapted to allow relative movement of the tubeplates, the heat exchanger also comprising tubes secured to and extending between the tubeplates within the duct parts.

Such a heat exchanger is suitable for carrying out the method according to the invention.

Preferably, both tubeplates are annular.

A method of heat exchange according to the invention comprises passing primary liquid metal through a duct which is partly bounded by planar tubeplates and passing secondary liquid metal through tubes within the duct and joined to the tubeplates and maintaining a liquid metal level in the duct out of contact with joints between the tubes and the tubeplates.

The tubes are preferably each of U-shape with straight limbs accommodated one in each duct part.

Preferably, the U-tubes are arranged in nested sets and preferably the ends of the limbs in each set lie on a line of involute shape.

In the alternative form of construction the tubes may be helical.

The tubes may take forms other than U or helical.

One form of heat exchanger and a method of heat exchange using it will now be described by way of example with reference to the drawings accompanying the Provisional Specification.

Figure 1 is a diagrammatic vertical section through the heat exchanger and part of the containment structure of a pool-type nuclear generating plant and is sub-divided into parts marked (a), (b) and (c) and also a further enlarged detail part (d); and

Fig. 2 is an enlarged section on the line II—II in Figure 1.

The heat exchanger shown has an outer upright cylindrical wall 10 spaced from and surrounding an intermediate upright cylindrical wall 12 and an inner upright cylindrical wall 14 spaced from and surrounded by the intermediate wall 12.

The intermediate wall 12 is of double-layer construction and has an expansion joint at 16 to allow differential expansion of the layers.

A first annular duct part 18 is defined by the outer and intermediate walls, 10, 12 and a second annular duct part 20 is defined by the intermediate and inner walls 12, 14.

The lower ends of the duct parts 18, 20 are in communication, a concave annular deflector 22 is connected to the lower end of the outer wall 10 and extends inwardly almost to the intermediate wall 12.

The inner wall 14 extends at 23 below the deflector 22 and an annular part spherical cap 24 extends downwardly from the lower end of a cylindrical sheath assembly 26 and is joined at its inner edge to the extension 23 of the inner wall 14.

The inner wall 14 and extension 23 together define a third duct part 28. The duct parts 18, 20 and 28 make up a single duct.

The upper end of the first duct part 18 is closed by an annular flat tubeplate 30 and the upper end of the second duct part 20 is closed by an annular flat tubeplate 32 spaced below the tubeplate 30.

The lower inner edge of the tubeplate 30 is joined to the upper outer edge of the tubeplate 32 by a flexible cylindrical extension wall-piece 34 forming part of the intermediate wall 12.

The upper inner edge of the tubeplate 32 supports a hemispherical dome 36 closing the upper end of the third duct part 28.

The lower inner edge of the tubeplate 32 carries an annular bearing ring 38 slidingly engaging the upper inner surface of the intermediate wall 12.

The inner surface of the wall-piece 34 is sealingly engaged by the lower end of a waisted duct cylinder 40 of double layer construction, which leads from an inlet 41. The outer wall 10 is effectively continued above the tubeplate 30 by a waisted cylindrical section 42, which leads to an outlet 44.

Both tubeplates 30 and 32 are planar that is they are not integral with nor rigidly secured to any component constructed or proportioned such as to impose constraint upon or induce distortion of, the tubeplates as temperatures fluctuate.

The tubeplates are planar also in the sense of presenting plain flat unobstructed upper faces for tube leak detection and tube plugging as mentioned below.

The use of the hemispherical dome 36 permits a high degree of flexibility in conjunction with the annular tubeplate 32.

The tubeplate 30 is also annular and is not rigidly connected to the duct cylinder 40.

Both tubeplates 30, 32 are connected to light ductwork components only so that restraints on and distortion of the tubeplates are wholly eliminated or rendered negligible.

U-shaped tubes have their ends welded respectively to the tubeplates 30 and 32. Figure 2 shows the pattern of the limbs of the U tubes. The tubes are arranged in nested sets so that an innermost tube in a set has the ends of its limbs 45, 46 welded to the respective tubeplates for example, and the outermost tube has the ends of its limbs 47, 48 welded to the respective tubeplates.

Each nested set of U-tubes lies in a notional envelope of involute curved shape. Thus, the ends of U-tubes in each set lie along an involute line, as shown in Figure 2. The innermost tube in a set has one limb extending from its end 45, say, downwardly in the duct part 20 adjacent the wall 12, the curved tube part of the U passing beneath the wall 12 and the other limb extending upwardly adjacent the other side of the wall 14 in the duct part 18 to its end 46. The next tube in the set embraces the innermost tube (having ends 45 and 46) and its limbs extend parallel to the limbs of the innermost tube. Each successive tube embraces the preceding tube. The outermost tube embraces all the other tubes and its limbs (having ends 47 and 48) extend adjaent the walls 14 and 10, respectively. In Figure 1 two innermost tubes and two outermost tubes are diagrammatically indicated at 49, 51, 53 and 55, respectively, by lines representing the central axes of the tubes.

Each set of tubes lies within a notional envelope of involute shape as viewed from one end so that the ends of the limbs of the tubes in the set lie on a line of involute shape, as do the end of the limbs of the tubes in the other sets, as shown in Figure 2. The parts of the tubes intermediate the limbs are also of involute shape.

The heat exchanger is enclosed within a concrete shield 50, which also contains a pool of primary liquid metal 52 which circulates through a nuclear core (not shown) to extract heat from the core. The pool has a dynamic level 54 (during operation of the plant) when the metal is at 600°C, a static level 56 and a dynamic level 58 when the temperature of the metal is 400°C.

The pool has an outlet 60 leading to the duct part 18. Liquid metal passing through the outlet 60 passes through openings 61 in the wall 10 and first encounters a decay heat coil 62 and is circulated during operation of the heat exchanger by a pump (not shown) downwardly through the duct part 18, upwardly through the duct part 20, through opening 64 in the inner wall 14 and downwardly through the duct part 28 and so out of the heat exchanger. The primary liquid metal is re-circulated back through the nuclear core and back to the pool 52.

Secondary liquid metal is circulated by a pump (not shown) and enters through the inlet 41; it passes downwardly through the cylinder 40; through the tubeplates 32, downwardly within the inner limits of the U-tubes within the duct part 20 counter-currently to the primary liquid metal; around the curves of the U-tubes; upwardly within the outer limits of the U-tubes within the duct part 18 also counter-currently to the primary liquid metal through the tubeplates 30; between the cylinder 40 and the section 42; and out of the outlet 44.

The primary liquid metal has working levels 70, 72 and 74 in the duct parts 18, 20 and 28 which are well below the welded joints between the U-tubes and the tube-plates 30, 32. Inert blanketing gas is provided beneath the tubeplates 30, 32 and above the liquid levels 70, 72 and 74. The wall 12 is open at its upper end to the blanket gas to ensure gas insulation between its two walls, which are at different temperatures as dictated by the different temperatures of the liquid metal in the duct parts 18 and 20.

This means that after a period during which the heat exchanger is inoperative, when very hot primary liquid metal begins to flow, it does not strike the relatively cold tubeplates 30, 32 and so severe thermal shock to the welded tube joints and to the tubeplates is avoided.

The heat exchange described above has the advantage that detection of leaking tubes and plugging of leaks can readily be carried out. The duct cylinder 40 is removable to facilitate those operations and the flat upper faces of the planar tube-plates 30, 32 makes leak detection and the tube plugging a greatly simplified procedure.

In a modification the wall 12 could be open at its lower end, so allowing primary metal liquid to enter between its layers. The stagnant metal would provide some insulation. To limit convection, annular baffles would be included between the layers of the wall 12.

In an alternative form of construction the tubes may be nested helices. One end of a tube could be joined to a tubeplate and the tubes could coil downwardly within one duct and then a "tail" could extend from the lower end of the helix to another duct part.

Alternatively a tube could be made up of two helices, one in one duct part and the other in another duct part, with a short joining section of tube extending between the helices beneath the intermediate wall.

WHAT WE CLAIM:—

1. A method of heat exchange comprising primary liquid metal through a duct which is partly bounded by planar tube-plates and passing secondary liquid metal through tubes within the duct and joined to the tubeplates and maintaining a liquid metal level in the duct out of contact with joints between tubes and the tubeplates.

2. An intermediate heat exchanger for use in performing the method claimed in claim 1, comprising an outer cylindrical wall, spaced from and surrounding an in-cent the walls 14 and 10, respectively. In between them a first duct part and an inner upright cylindrical wall spaced from and surrounded by the intermediate wall and defining with the intermediate wall a second duct part, first like ends of the duct parts being in communication and second like ends being closed by planar tubeplates spaced apart in the lengthwise direction of the ducts, the intermediate wall being in part formed by a flexible part which extends upwardly from the upper surface of the lower tubeplate and which is adapted to allow relative movement of the tubeplates, the heat exchanger also comprising tubes secured to and extending between the tubes within the duct parts.

3. A heat exchanger according to claim 2, in which the tubes are generally U-shaped.

4. A heat exchanger according to claim 3, in which the tubes have straight limbs accommodated one in each duct part.

5. A heat exchanger according to claim 3 or 4, in which the tubes comprise tubes nested within other tubes.

6. A heat exchanger according to claim 3, 4 or 5, in which the tubes are arranged in sets and each set lies within a notional envelope of involute shape, the parts of the tubes intermediate the limbs being of involute shape and lying on a line of involute shape.

7. A heat exchanger according to claim 2 or 3, in which the tubes are helical.

8. A method of heat exchange substantially as hereinbefore described with reference to the drawings accompanying the Provisional Specification.

9. An intermediate heat exchanger sub-

stantially as hereinbefore described with reference to the drawings accompanying the Provisional Specification.

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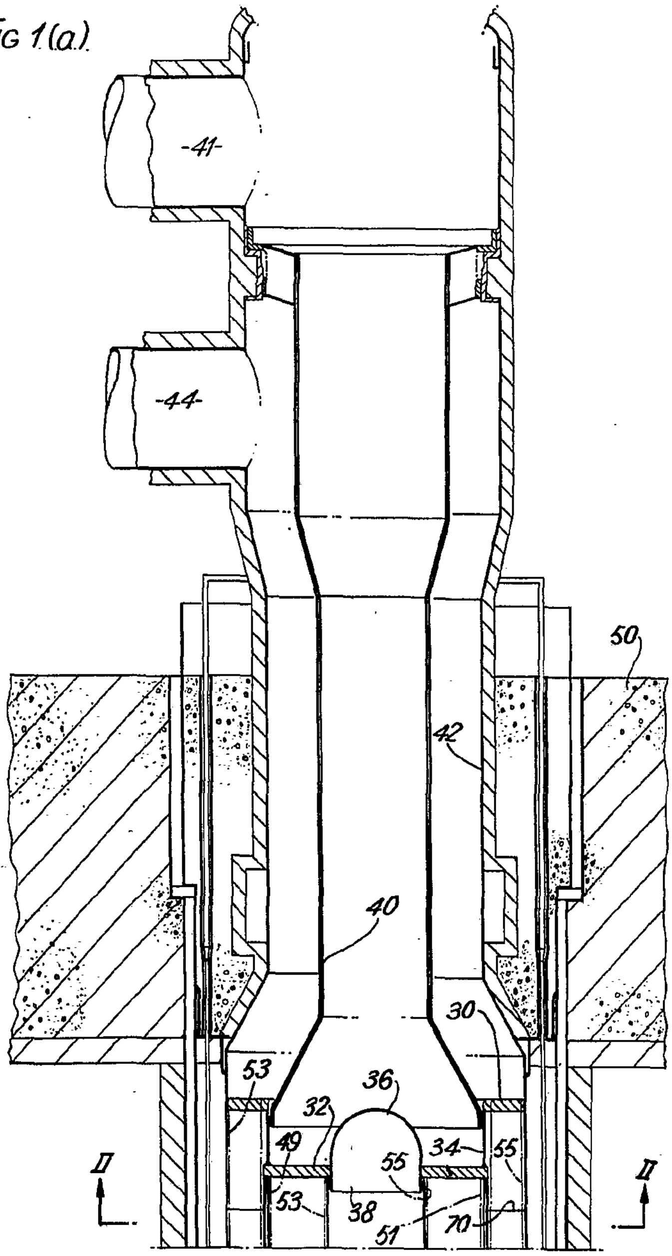
4 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheet 1

FIG 1(a).



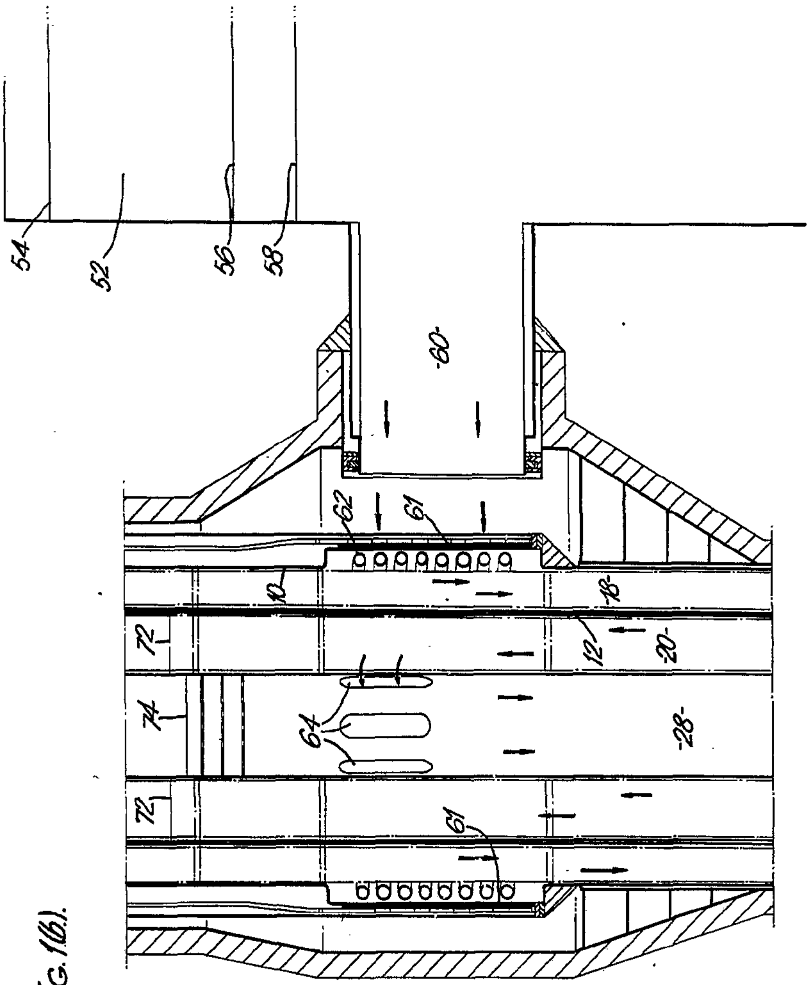


FIG. 1(b).

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Sheet 3

FIG. 1(C).

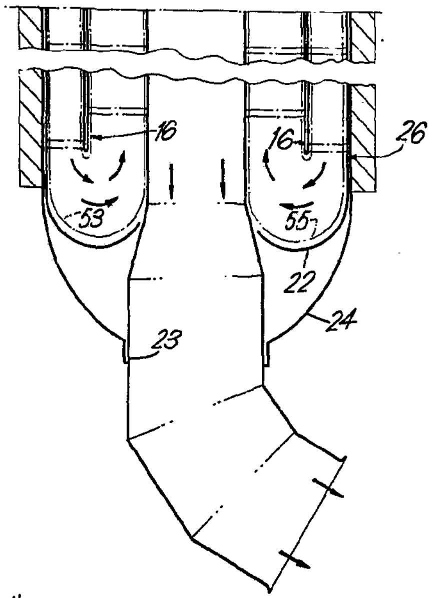

FIG. 1(d).

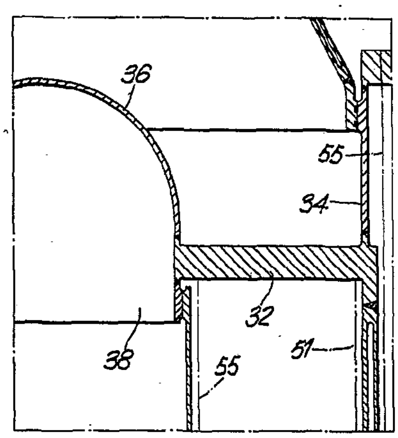

FIG. 2.