United States Patent

[11] 3,545,536

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[54] **HEAT EXCHANGERS**
4 Claims, 6 Drawing Figs.

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[51] **Int. Cl.** F28f 13/00
[50] **Field of Search** 165/134, 159, 160; 122/32, 34

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ABSTRACT: A tubulous heat exchanger arranged to transfer heat from a heating fluid flowing over the tubes to a heat-absorbing fluid flowing within tubes and including shielding means over a portion of the tubes to reduce the rate of heat transfer therethrough. The main embodiment includes an inert gas space communicating with the shielding means to provide a blanket of gas between the tube and shielding means and an inlet compartment to confine the crossflow path of the heating fluid to the shielded portion of the tubes. An alternate embodiment uses the shielding means in combination with a flow diverting plate.

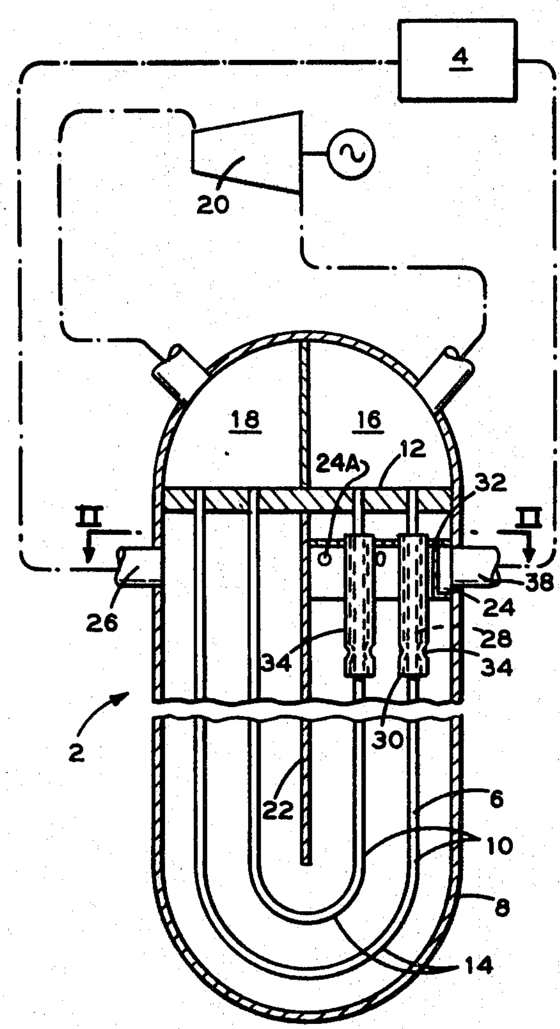


FIG. 1

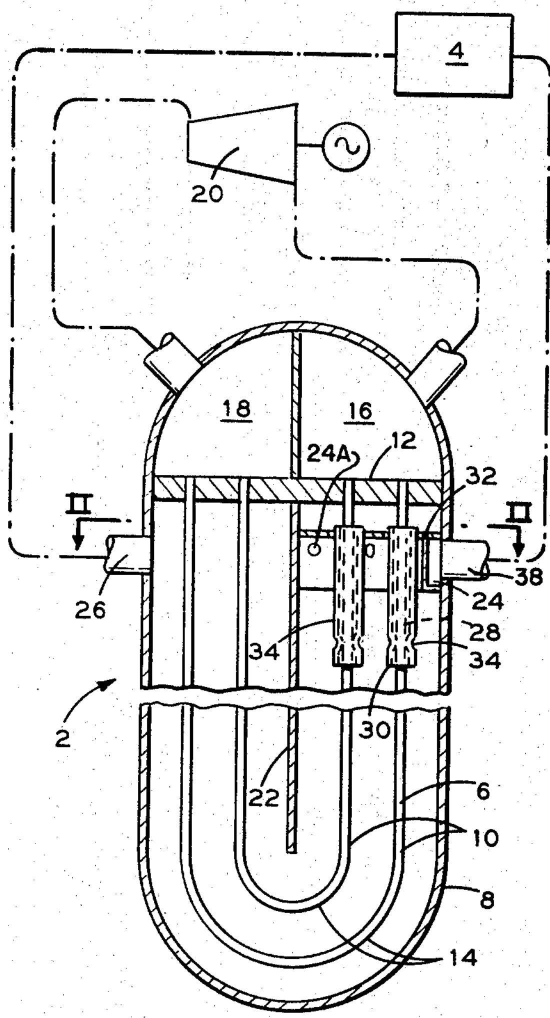


FIG. 5

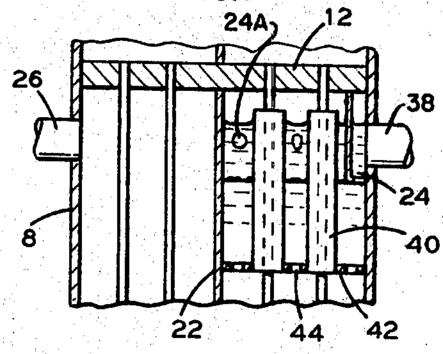


FIG. 3

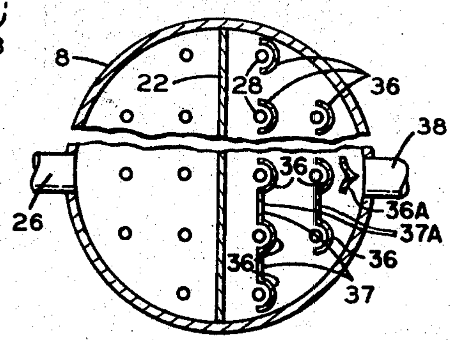


FIG. 3A

FIG. 4

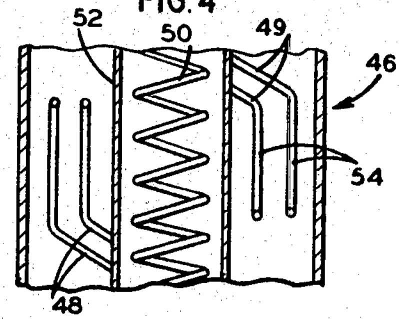
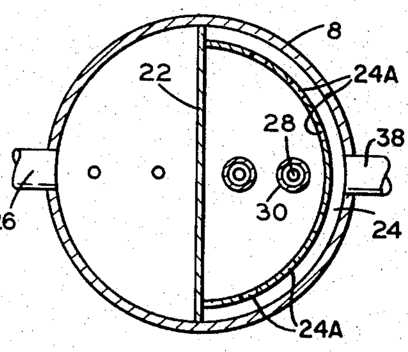


FIG. 2



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HEAT EXCHANGERS

This invention relates to heat exchangers and, more particularly, to tubulous heat exchangers in which heat is transferred from liquid metal serving as an intermediate heat carrier to a secondary liquid, such as water, flowing within the tubes to vaporise the liquid, the intermediate heat carrier initially being heated by liquid metal serving as primary coolant of a nuclear reactor.

In the liquid state metals generally have a relatively high coefficient of heat conductivity and the heat input to the tubes containing the secondary liquid is liable to exceed the rate at which a localised departure from nucleate boiling occurs accompanied by a localised temperature fluctuation within the tubes and an instability in the fluid flow within the tubes results, causing localised, fluctuating overheating of the tube wall which in extreme cases might lead to eventual tube failure arising from the varying thermal stress in the tube wall. Again, at least in an arrangement having forced flow of the secondary liquid within the tubes, it is desirable to restrict the heat input to the tube portions in which boiling occurs, namely the transition zone, in order to maintain substantially stable conditions in the zone, particularly with regard to the tube wall temperature which is otherwise liable locally to fluctuate over a wide range at high heat fluxes and boiling conditions and thereby produce varying thermal stresses which might lead to eventual tube failure. The rate of heat transfer between the liquid metal and the tube wall depends on a number of factors, one of which is the direction of relative flow of the two liquids. Thus the rate of heat transfer may be up to five times higher if the liquid metal is flowing in a cross flow relationship, that is perpendicularly, to the direction of flow of liquid within the tubes than it is when the liquid metal is flowing in a direction parallel to the liquid within the tubes. Furthermore, the heat transfer rate under crossflow conditions may be approximately four times as great at the front of the tube, that is the portion of the tube first presented to the flow of liquid metal, than at the rear of the tube. Another factor which influences the heat transfer coefficient is the heat content of the liquid metal and if this exceeds a value, determined by the heat transfer conditions, at which localised fluctuating, overheating of the tube wall is liable to occur it is necessary that the heat content be reduced initially by heat transfer at a restricted rate to a value appropriate to the downstream, in the liquid metal flow, heat transfer conditions.

The thermal stress in a tube wall depends, amongst other things, upon the wall thickness and while an increase in wall thickness will restrict the heat transfer through the wall it will also increase the thermal stress across the wall and also increase the deleterious effect of repeated variations in the value of the stress arising from localised, fluctuating, overheating.

A tubulous heat exchanger arranged to transfer heat from liquid metal flowing over a bank of tubes to liquid flowing within the tubes according to the present invention includes imperforate baffle means adapted to restrict the rate of heat transfer from the liquid metal to the liquid flowing within the tubes at regions of the tubes liable otherwise to tube failure due to localised, fluctuating, overheating to a rate less than that at which such localised, fluctuating, overheating is liable to occur while maintaining a full rate of heat transfer over the remainder of the tubes.

The invention will now be described, by way of example, with reference to the accompanying, partly diagrammatic drawings, in which:

FIG. 1 is a sectional elevation of a heat exchanger, showing, for the sake of clarity, only a portion of a tube bank to an enlarged scale, and indicating, in block form, connections to an associated nuclear reactor through an intermediate heat exchanger and to an associated turbine and generator;

FIG. 2 is a sectional plan view taken on the line II–II of FIG. 1;

FIGS. 3 and 3A are sectional plan views of alternative arrangements of a tube bank and corresponds with FIG. 2;

FIG. 4 is a sectional elevation of a portion of a further alternative arrangement of a tube bank; and

FIG. 5 is a sectional elevation of a portion of another alternative arrangement of a tube bank.

Referring to FIGS. 1 and 2 of the drawings, the heat exchanger **2** is positioned in the intermediate coolant flow circuit of a sodium cooled nuclear reactor **4** and includes a tube bank **6** two tubes only of which are shown, positioned within an upright, elongated, tubular vessel **8**. The tube bank consists of a plurality of straight tube lengths **10** extending from a tube sheet **12** positioned at an upper end of the vessel **8** downwardly to return bends **14** respectively connecting pairs of tube lengths. The upper compartment or portion of the vessel above the tube sheet is partitioned to provide a water inlet chamber **16** and a steam outlet chamber **18** connected to a turbine unit **20** and the portion of the vessel below the tube sheet is provided with a baffle **22** to direct the lower compartment or flow of liquid sodium downwardly from an inlet compartment **24** of semiannular cross section having apertures **24A** spaced around the inner wall thereof and through the first passageway on one side of the vessel below the tube sheet to the base of the vessel and then upwardly through the second passageway to an outlet **26** positioned on the opposite side of the vessel to the liquid sodium outlet and at the same level as the inlet. At the level of the liquid sodium inlet and outlet, the liquid sodium flow is in a direction substantially perpendicular to the axes of the tube lengths while below this level the liquid sodium flow is in a direction substantially parallel to the tube length axes. The regions **28** of the tube lengths **10** immediately subjacent the inlet chamber are provided with individual sleeves or collars **30** attached to a grid plate **32** and closely spaced from the respective regions **28** of the tube lengths by means of indentations **34** to form stagnant flow spaces around the regions. The space intermediate the tube plate **12** and the grid plate **32** is occupied by argon gas at pressure. The sleeves or collars **30** are extended downwardly to a level at which the liquid sodium flow is in a direction substantially parallel to the tube length axes and by virtue of the stagnant flow spaces defined thereby limit the heat flux at the said regions **28** without increasing the thermal stress within the walls of the tube lengths. Thus the heat flux at the regions of the tubes at which the liquid sodium flows in a crossflow relationship is reduced to a value approximately equal to the value of the heat flux in the immediately subsequent parallel flow regions of the tubes and to a value less than that at which a departure from nucleate boiling is liable to occur so that any danger of tube "burn-out" and consequent tube failure is avoided.

In alternative arrangement (not shown), the heat flux at the said regions **28** of the tube lengths **10** is limited to a value less than that at which a departure from nucleate boiling occurs by positioning bodies of refractory insulating material around the respective regions.

As shown in the alternative arrangement of FIG. 3, a sufficient reduction in the heat flux is achieved by positioning a flow diverting plate **36A** spaced opposite the discharge end of fluid inlet **38** and arranging shields **36** around the regions **28** of the tube lengths adjacent the liquid sodium inlet **38** to provide stagnant flow spaces adjacent the frontal portions of the individual regions of the tube lengths since the heat transfer coefficient at such frontal portions in crossflow relationship is approximately four times as great as the heat transfer coefficient at the rear portions of such tubes. The provision of the shields **36** is sufficient to limit the heat flux at the said regions of the tubes as to ensure that the heat flux is less than that at which a departure from nucleate boiling occurs. In an alternative embodiment of this arrangement shown in FIG. 3A the shields are connected together by plates **37** having apertures **37A**. The plates **37** form inlet baffles adapted to direct the flow of liquid sodium from the inlet **38** in a downward direction. It will be appreciated that the shields and connecting plates may be formed of a single plate which will have a corrugated cross-sectional profile.

In the further alternative arrangement shown in FIG. 5 sleeves or collars **40** are supported on and extend through an apertured grid plate **42** positioned below the level of the liquid sodium inlet **38** with the upper ends of the sleeves or collars **40** in communication with a gas space formed subjacent the tube sheet. The pressure loss due to flow of the liquid sodium through the apertures **44** in the apertured plate is sufficient to permit the gas space within the sleeves or collars to extend downwardly to approximately the level of the apertured plate, thereby limiting the heat flux in the said regions **28** of the tube lengths.

It will be appreciated that, if the tube bank **6** is utilized as an evaporator, discharging saturated steam or a mixture of steam and water to the outlet chamber **18** the heat flux at the regions of the tube lengths immediately subjacent the outlet chamber where the liquid sodium flows in crossflow relationship to the tube lengths is liable to exceed a value at which a departure from nucleate boiling occurs and that it may therefore also be necessary to provide such sleeves or collars, shields, baffles or thermal insulating bodies at the aforesaid regions immediately subjacent the outlet chamber.

It will be appreciated that, in such a heat exchanger operating with forced flow of fluid and full evaporation within the tubes, the regions of the tubes in which evaporation is effected, namely the transition zone, may be made regions of relatively low heat input by providing sleeves defining stagnant flow spaces either around the individual tube regions or around groups of the individual tube regions. Alternatively, thermally insulating material may be provided around the individual tube regions or shields may be provided to restrict the heat transfer rate to the tube regions.

It will also be appreciated that the invention is applicable to heat exchangers having banks of tubes of helical or sinuous form with the tubes extending substantially perpendicular to the liquid metal flow, the initial portions of the tube being protected against overheating as hereinbefore described while serving to extract heat from the liquid metal to a heat content at which the resultant heat flux is less than that liable to cause localised, fluctuating, overheating in the immediately subjacent tube regions. In tube banks of this form arranged to operate with forced flow of fluid and full evaporation of the fluid within the tubes, the regions of the tubes at which transition of the fluid occurs may be protected from overheating as hereinbefore described or it may suffice to vary the nature of the flow of the liquid metal over the tube from a crossflow to a parallel-flow relationship, as is indicated in FIG. 4 or alternatively a combination of the change of flow with the other aforesaid means for restricting the heat flux at the regions may be utilized to restrict the rate of heat transfer at the regions. Referring to FIG. **4**, there is shown a portion of a helical tube, forced flow, full evaporation, heat exchanger **46** in which an outer array **48** of helical tube lengths extends downwardly from a water inlet chamber (not shown) and a liquid sodium inlet (not shown) and surrounds an inner array **50** of helical tube lengths connected to the tube lengths of the outer array at the lower ends thereof and discharging to a superheated steam outlet chamber (not shown). A cylindrical baffle **52** is positioned between the inner and outer arrays of tube lengths and liquid sodium flows downwardly over the outer array **48** and upwardly over the inner array **50** to a liquid sodium outlet (not shown). It will be appreciated that the liquid sodium flows in a substantially crossflow relationship to the helical tube lengths and the fluid flowing therein, and that it is necessary to protect the initial inlet regions of the tube lengths from over heating as hereinbefore described. In addition, it is also necessary to protect the regions of the tubes at which transition of the water to steam occurs. Accordingly, straight tube lengths **54** are interposed in the helical tube lengths of the outer array at the region where transition occurs, so that a parallel flow relationship exists between the liquid sodium and the water at the region at which transition occurs, thereby reducing the heat flux in the tube walls at that region. Further reduction of the heat flux, if necessary, may be effected by providing sleeves defining stagnant flow spaces either around the individual tube regions or around groups of the individual tube regions. Alternatively, thermally insulating material may be provided around the individual tube regions to restrict the rate of heat transfer to the regions.

I claim:

1. A forced flow heat exchanger comprising:
   - an elongated cylindrical pressure vessel;
   - a tube sheet transversely arranged within and dividing said vessel into an upper and a lower compartment;
   - partition means for dividing the upper compartment into an inlet and an outlet chamber;
   - a plurality of U-tubes disposed within the lower compartment with the ends of said tubes connected to the tube sheet and each of the tubes having one end communicating with the inlet chamber and the other end with the outlet chamber in said upper compartment, each tube having an inlet and an outlet leg section joined by a U-bend portion;
   - baffle means extending diametrically across the lower compartment and between said inlet and outlet legs to form a first and second passageway;
   - a perforated semicircular plate positioned in the plane of the vessel wall near the upper end of said first passageway and forming a closed inlet compartment discharging normal to the longitudinal extent of said tubes;
   - a grid plate transversely arranged within and dividing said first passageway into an upper and a lower space;
   - sleeve means supported from the grid plate and covering an upper portion of the inlet legs of said tubes to provide a heat shield extending from a level above the plane of discharge from said inlet compartment to a level substantially below said plane of discharge, each of said sleeve means being spaced from the respective tube to provide flow communication between said upper and lower space;
   - means for supplying a heat absorbing fluid to the inlet chamber and for removing said fluid from the outlet chamber after its passage through the U-tubes; and
   - means for delivering a heating fluid to said inlet compartment to be discharged therefrom along a plane substantially normal to the longitudinal axis of the U-tubes, said sleeve means extending along the tubes sufficiently to insure deflection of the heating fluid to a flow path substantially parallel to the longitudinal axis of said tubes.

2. A forced flow heat exchanger according to claim 1 wherein the grid plate is mounted above said inlet compartment.

3. A forced flow heat exchanger according to claim 1 wherein the grid plate is mounted below the inlet compartment and has apertures accommodating the flow of heating fluid therethrough.

4. A forced flow heat exchanger according to claim 1 wherein the upper space in said first passageway is occupied by a gas substantially inert to the heating fluid.