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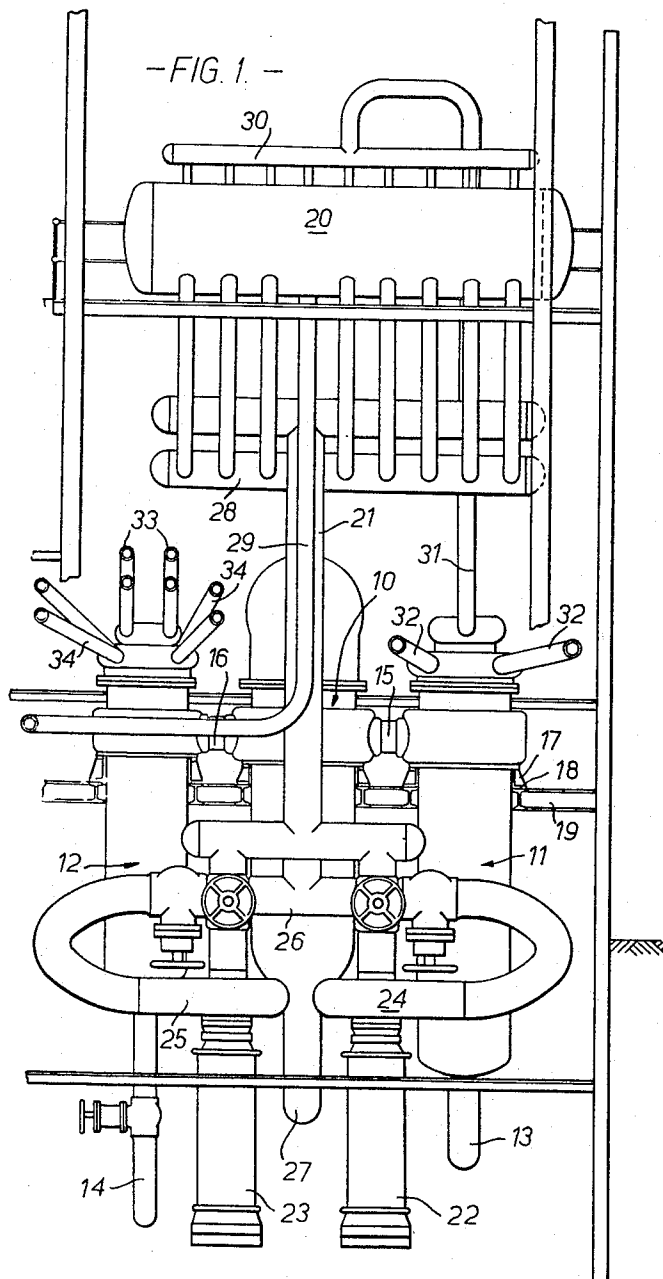
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3,354,869

HEAT EXCHANGERS

Filed Jan. 4, 1966

4 Sheets-Sheet 1



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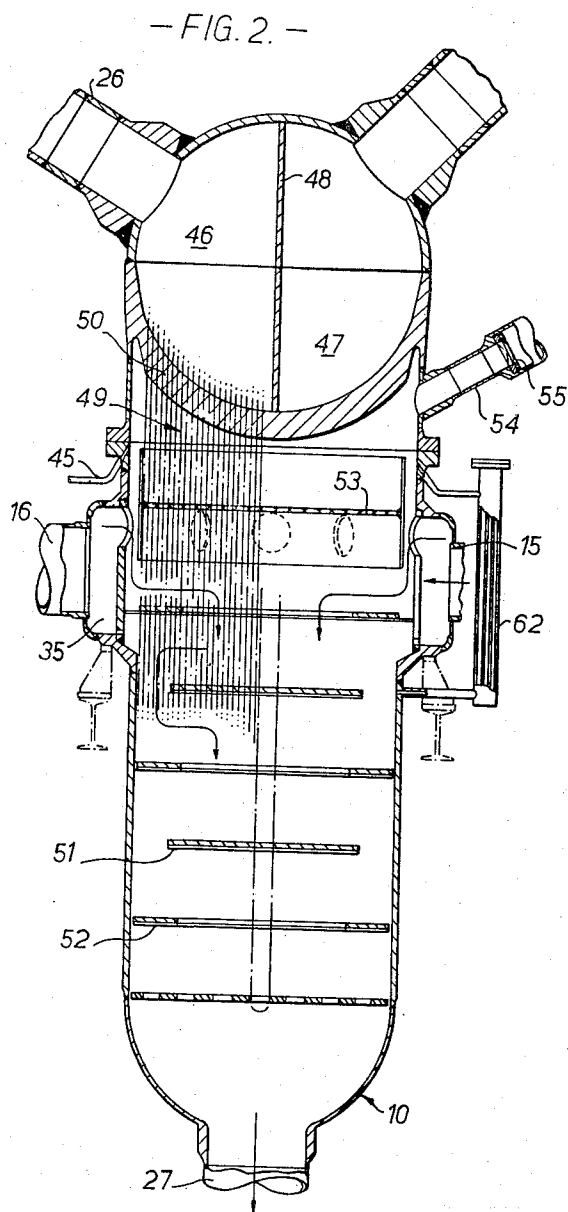
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3,354,869

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Filed Jan. 4, 1966

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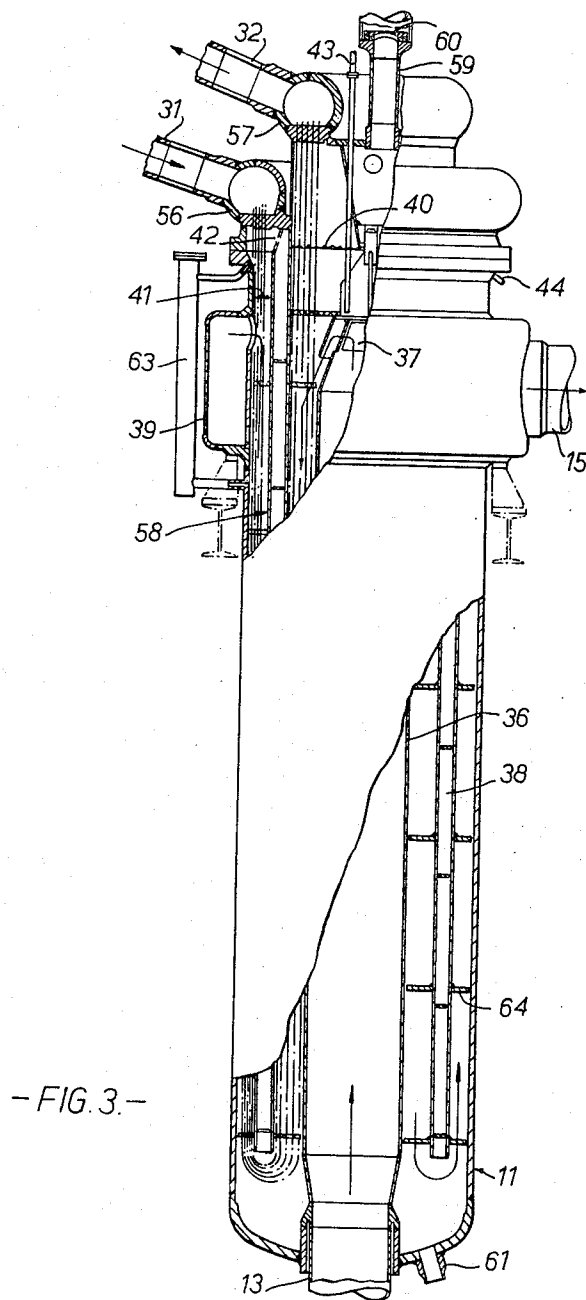
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3,354,869

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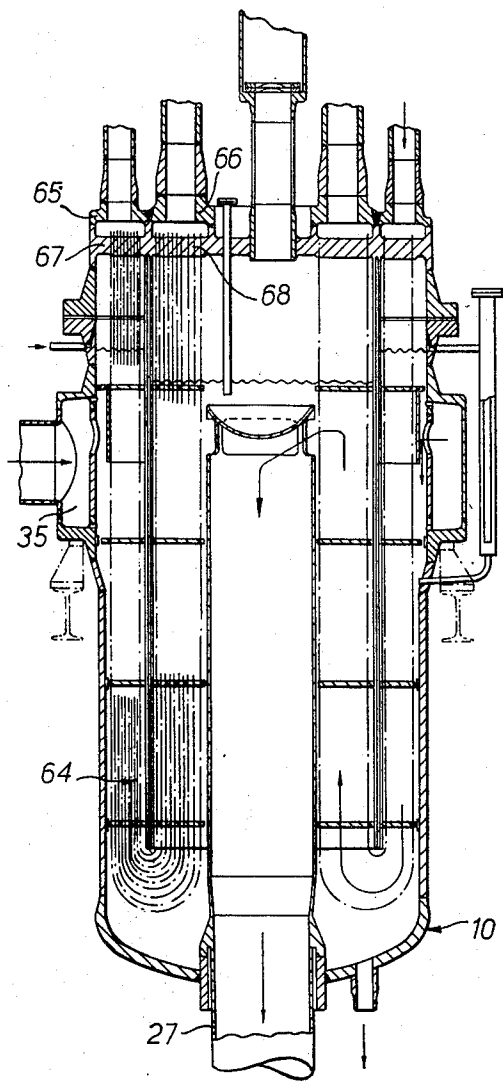
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- FIG. 4. -

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HEAT EXCHANGERS

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Filed Jan. 4, 1966, Ser. No. 518,693

Claims priority, application Great Britain, Jan. 4, 1965,
242/65

4 Claims. (Cl. 122—32)

The present invention relates in general to heat exchangers and in particular to liquid metal heated steam generators. The development of this kind of steam generator is being stimulated at the present time by the desire to exploit the excellent heat transfer properties of liquid metals like sodium.

Special considerations arise in the transfer of heat from hot sodium for the raising of steam; notably, the two fluids react with one another and in relation to the types of steel normally considered for boiler tubing the hot sodium has corrosive effects which are found to be significant when the importance of avoiding direct contact of the two fluids is so great.

Having regard to these considerations certain expedients aimed to lessen the risk of direct contact of the fluids are becoming common in this field of design; one such expedient is that all tube welds, for example tube to tube plate welds, are made where they will not be exposed directly to sodium, the tubes being elsewhere of continuously fabricated lengths. Taking the other approach that some possibility, however remote, of accidental direct contact of the fluids has to be accepted, it is believed to be an advantage to design in unit form so that the bulk of sodium available for reaction at any one place is limited; a disadvantage is that increasing subdivision into units tends to increase costs of construction.

In order to keep out of the liquid metal the tube to tube plate welds, or such other connections as may exist between the steam generating heat exchange elements and the headers therefor, it is already known to arrange that these connections are disposed in gas spaces. In a steam generator of this kind the invention provides that the flow path of the liquid metal over the heat exchange elements comprises a downward pass followed by an upward pass and that the gas spaces over these passes are adapted to be isolated from one another so that gas therein can be at different pressures during operation of the generator.

More particularly, according to the invention, a steam generator of the kind already referred to and of the shell and tube type is characterised in that the flow path within the shell of the liquid metal over the tubes comprises a downward pass followed by an upward pass and that the gas spaces over these passes are adapted to be isolated from one another so that the gas therein can be at different pressures during operation of the generator.

With light liquid metals like the low melting point alkali metals the gas spaces are small so that small increases of liquid metal level produce significant compression of the gas trapped in the gas spaces. In this way the level difference between the downward and upward passes can be kept small. Large pressure drops in the passes can be tolerated since the level difference can be suppressed and changes as a result of pressure drop variations will be low. This allowance on pressure drop means that the tube spacings can be lower and from this one gains two main advantages, namely, economy of size, and hence cost, and less liquid metal for reaction in the event of accident in any one place. A further advantage is that higher liquid metal velocities promote turbulence for good heat transfer and baffles for this purpose may no longer be necessary.

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By way of further description of the invention, reference will be made to the accompanying drawings showing a particular form of liquid metal heated steam generator in which are included various features of construction and combinations of parts characterising the invention. In the drawings:

FIGURE 1 is an elevation of the general arrangement of the generator,

FIGURE 2 is a vertical section through an evaporator, and
FIGURE 3 is a vertical section through a superheater,

and
FIGURE 4 is a vertical section through a modified form of the evaporator of FIGURE 2.

The illustrated generator is designed to receive hot sodium as its primary fluid from a fast nuclear reactor power plant; more specifically this hot sodium is that of an intermediate circuit into which heat is transferred from the reactor core coolant, also sodium. The invention is of course also applicable to other liquid metals, such as the sodium alloy commonly known as NaK, and to other circumstances, such as where the liquid metal is heated by fossil fuel firing.

The generator is based on a forced circulation sub-critical system and reheat is assumed to be called for by the steam cycle for which it is intended. Particularly in view of the cost penalty previously referred to, subdivision into units exists only to the extent of providing separate superheat, reheater and evaporator sections, the thermal capacity of the combination being limited to, say 200 mwt., so that for higher capacities multiple sets would be necessary in the complete generator plant.

In the general arrangement of FIGURE 1, the evaporator denoted 10 is in line with, and between, the superheater and reheater denoted respectively 11 and 12. The superheater and reheater receive hot sodium in parallel by bottom entry through respective inlet ducts 13 and 14. The sodium flows from the superheater and reheater and the evaporator through short connecting ducts 15 and 16 having a common axis passing through the centre of the evaporator, and the latter has a bottom outlet duct 27. In the region of these connecting ducts, each of the sections 10, 11 and 12 is attached rigidly at a common level to a respective ring beam, such as 17, and these ring beams are supported with freedom of movement, as by sliding on slip pads such as 18, on a box structure 19 carried by main stanchions of the building in which the generator is housed. This manner of support accommodates thermal expansion movements of the three sections.

A steam drum 20 above the sections 10, 11 and 12 has a recirculation downcomer 21 which branches into two centrifugal pumps 22 and 23 mounted with impeller casings 24 and 25 uppermost. These pumps deliver into the evaporator through an inlet riser 26 (running behind the branches of the recirculation downcomer as seen in FIGURE 1) and from the evaporator an outlet riser obscured by the recirculation downcomer in FIGURE 1 extends by way of a manifold 28 into the steam drum. The recirculation rate determined by the pumps is several times higher than the full load evaporation rate as an insurance against "steam blanketing" of the evaporator tubing; the main reason for avoiding this condition is the possibility that its occurrence would be intermittent and therefore lead to repeated changing of the temperature gradient across the tube walls with a consequent thermal stress fatigue effect. Feed water is fed directly into the steam drum through a pipe 29, the arrangement internally of the drum being such that this water is sprayed along its length into the reservoir of circulating water. Steam in the drum is dried by scrubbers (not shown) installed in the upper part of the drum and through a manifold 30

and a downcomer 31 is passed to the superheater 11. Main steam pipes from the superheater are indicated 32; sets of supply and return pipes to and from the reheater 12 are indicated 33 and 34 respectively.

With a shell and tube construction of the sections 10, 11 and 12, the expedient of keeping the tube to tube plate welds out of direct contact with sodium on the shell side is achieved by ensuring that the level of sodium is maintained below them, the interspace being filled with an inert gas, such as nitrogen. Were the bottom entry into the superheater and reheater to be utilised in conjunction with the bottom discharge from the evaporator to make a simple flow pattern for the sodium of single upward parallel passes in the superheater and the reheater followed by a single downward pass in the evaporator all the sodium surfaces in these sections could be blanketed by inert gas at the same pressure without any difference of level between these surfaces. Such an arrangement would allow a common gas blanket system comprising a common ring main and buffer volume interconnected by permanently open communications to the various gas spaces in the shells of the sections.

However, by reference to FIGURES 2 and 3, it will be readily apparent that, although the evaporator of FIGURE 2 does in fact employ a single downward pass of the sodium from a distribution annulus 35 (into which the connecting ducts 15 and 16 open) to the bottom outlet duct 27, the superheater of FIGURE 3 is not confined to a single upward pass as in the simple arrangement previously discussed, but in fact has three passes to enable full counterflow heat exchange, these passes being defined by a central single-wall extension 36 of the bottom entry duct 13 opening at its upper closed extremity through lateral ports 37 into the surrounding annulus and by an annular double wall partition or baffle 38 which extends downwardly in the annulus to a position somewhat above the bottom to separate a second downward pass from a third upward pass opening into a collector annulus 39. To achieve isolation of the gas spaces above the downward and upward passes the baffle 38 extends upwardly and is sealed to the top of the superheater shell so as to make a complete barrier to gas above the sodium surfaces indicated 40 and 41; in one of the walls adjacent the upper end of the baffle there are openings, as at 42, to allow between the walls a restricted flow of sodium which spills over through the openings. For charging the gas spaces, with nitrogen for example, there are blanket gas inlets 43 and 44 on the superheater (FIGURE 3); on the evaporator (FIGURE 2) the equivalent inlet is denoted 45. Each of these blanket gas inlets is to be understood to have an isolating valve (not shown). Although a common source of gas under pressure is conveniently employed for charging the various gas spaces, each space is isolated by the respective isolating valve, when the charging to the predetermined pressure has been accomplished, and the gas is then trapped.

Blanketing by trapped gas affords the possibility, by appropriate choice of the pressure, of bringing various surfaces of the sodium to levels best suited for compact design. In the illustrated design, the gas spaces are charged initially, when the sodium is static, to a common pressure and the different pressures are built up therein by the sodium finding its own levels during operation, the volume of the gas spaces being small enough to keep the level difference within the required limits.

To complete the description of the evaporator and superheater of FIGURES 2 and 3, it is deemed sufficient to point out briefly the other salient features. In the former, the inlet and outlet risers of the secondary water/steam circuit open respectively into inlet and outlet headers 46 and 47 formed in a spherical chamber by a division plate 48; tubes 49 welded into a tube plate 50 forming the lower half of the chamber describe a path of U configuration between the one header and the other to give two pass flow. To promote even heat transfer over

the large flow area involved there are baffles alternately of disc and annular form, such as 51 and 52, through which the tubes pass. At about the normal operating level of the sodium there is a vortex inhibitor 53 and the gas space above it communicates through a pipe 54 with a pressure relief device 55 taking the form of two bursting discs in series with a gas interspace; downstream of the pressure relief device the pipe 54 extends (not shown) to an effluent vent system.

With regard to the superheater, it should be pointed out that the construction of the reheater is so similar that separate description would be superfluous. The downcomer 31 opens into a toroidal inlet header 56 and the main steam pipes 32 lead away from a toroidal outlet header 57. Between these headers tubes 58 on an involute pitch to give uniform sodium flow cross section with equal pitch describe a path of U configuration to give two pass flow in full counterflow relationship with the second and third sodium passes previously referred to, the tubes being welded into the annular tube plates of the headers. In a pipe 59 at the top of the superheater there is provided a pressure relief device 60 in the same way as the evaporator. A sodium drain pipe which is normally closed is indicated at 61.

The tubes in all of the sections are in continuous lengths of seamless cold drawn stock between the tube to tube plate welds. There are spacer grids arranged at intervals along the tube bundles: in the evaporator these grids (not shown) lie on the baffles 51, 52 which are suspended by bars from the header structure of the water/steam secondary circuit; in the superheater (and reheater) these grids, as indicated at 64, are attached to the baffle 38. Sodium level detectors are also included: the attachments 62 (FIGURE 2) and 63 (FIGURE 3) are for this purpose and in this respect of the second sodium pass in the superheater another detector (not shown) is installed adjacent the blanket gas inlet 43.

In the modification of FIGURE 4, the evaporator is constructed for full counterflow heat exchange in a manner similar to the superheater and reheater. Since sodium enters at the distribution annulus 35 and leaves as before through the bottom-connected outlet duct 27, the downward pass is in the outer region of the tube bundle 64 and the upward pass in the inner region, this being the reverse of the arrangement in the superheater and reheater. It should also be noted that the replacement of the hemi-spherical headers 46 and 47 of FIGURE 2 by annular headers 65 and 66 considerably reduces the area of associated tube plates 67 and 68 and so allows a reduction of thickness and consequent simplification in the making of reliable tube welds. The annular shape of these headers is flatter than that of the headers 56 and 57 in FIGURE 3; this modification simplifies manufacture and could be adopted in the superheater and reheater design.

References herein to heat exchange elements and tubes are to be understood to include double wall constructions in which an interspace between the walls is filled with a barrier material intended to prevent contact of liquid metal and water in the event of a leak. The most important requirements for such a barrier material are that it should be chemically inert to both water and the liquid metal and should have good thermal conductivity; lead is suitable, possibly alloyed with a minor proportion of magnesium to lower the melting point.

What we claim is:

1. In a liquid metal heater steam generator of the shell and tube type, the combination comprising means forming a shell, a liquid metal inlet for admitting the liquid metal to the interior of the shell, a liquid metal outlet for the discharge of liquid metal from the interior of said shell, at least one baffle disposed substantially upright in the shell interior between said inlet and said outlet for defining in the liquid metal flowpath from said inlet to said outlet a downward flow pass followed by an upward flow pass, heat exchange elements disposed in the down-

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ward and upward passes and adapted for the generation of steam therein, headers to which the heat exchange elements are connected adjacent the top of the shell, separate gas spaces defined respectively over the downward and upward passes by a sealed relationship with the shell of an upper portion of the baffle, and means to charge the separate gas spaces with gas and thereafter maintain them isolated whereby during operation of the generator different pressures prevail in the gas spaces.

2. In a liquid metal heater steam generator of the kind wherein the steam is generated in heat exchange elements, the combination comprising a generator body, headers carried by the body, a plurality of hollow heat exchange elements within the body connected to said headers, means defining for the liquid metal a flow path over the heat exchange elements which comprises a downward flow pass followed by an upward flow pass, means forming over each pass a separate gas space, and means to charge the separate gas spaces with gas and thereafter maintain them isolated, whereby during operation of the generator different pressures prevail in the gas spaces.

3. A liquid metal heated steam generator comprising a shell vertically disposed so as to have an upper end, annular inlet and outlet headers having tube plates forming the wall of the shell at the upper end thereof, tubes with limbs describing a path of U configuration and connected respectively at one end to the tube plate of the inlet header and at the other end to the tube plate of the outlet header thereby to form an annular tube bundle supported dependently in the shell from the tube plates, connections to the headers respectively for the supply of water and

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the withdrawal of steam, an annular partition interposed between the tube limbs and sealed at its upper end to the shell intermediate the tube plates, first and second ducts opening into the shell interior to act as an inlet and an outlet for passing liquid metal in substantially counter-flow relationship with the direction of flow inside the tubes, the first duct opening laterally into the shell at an upper portion thereof and the second duct opening into the shell adjacent the bottom thereof and having an extension ascending within the space defined by the annular tube bundle to an open end approximately at the same level as the first duct, and means for charging gas beneath the tube plates and to maintain isolation of the gas inside the partition from that outside the partition whereby during operation of the generator a difference of gas pressure inside or outside the partition prevails.

4. A steam generator according to claim 3, wherein the partition is hollow and has openings adjacent opposite ends for allowing a restricted flow of the liquid metal therethrough.

References Cited

UNITED STATES PATENTS

2,336,832	12/1943	Badenhausen	122—34
3,187,807	6/1965	Ammon	122—32 X
3,126,949	3/1964	Boni et al.	122—32 X
3,227,142	1/1966	Bell et al.	122—34
3,245,464	4/1966	Ammon et al.	122—32 X

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