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[54] LIQUID METAL STEAM GENERATOR


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[51] Int. Cl. ................................................ F22b 1/06
[58] Field of Search ............. 122/32, 33, 34; 165/70


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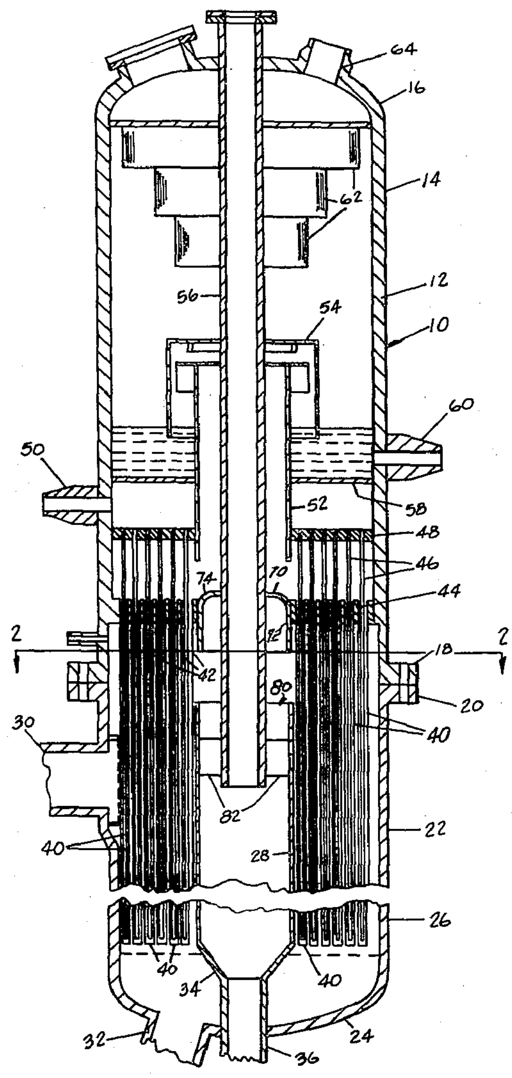
[57] ABSTRACT


A liquid metal heated steam generator which in the event of a tube failure quickly exhaust out of the steam generator the products of the reaction between the water and the liquid metal. The steam is generated in a plurality of bayonet tubes which are heated by liquid metal flowing over them between an inner cylinder and an outer cylinder, the inner cylinder extending above the level of liquid metal but below the main tube sheet, and a central pipe extends down into the inner cylinder with a centrifugal separator between it and the inner cylinder at its lower end and an involute deflector plate above the separator so that the products of a reaction between the liquid metal and the water will be deflected downwardly by the deflector plate and through the separator so that the liquid metal will flow outwardly and away from the central pipe through which the steam and gaseous reaction products are exhausted.


7 Claims, 2 Drawing Figures



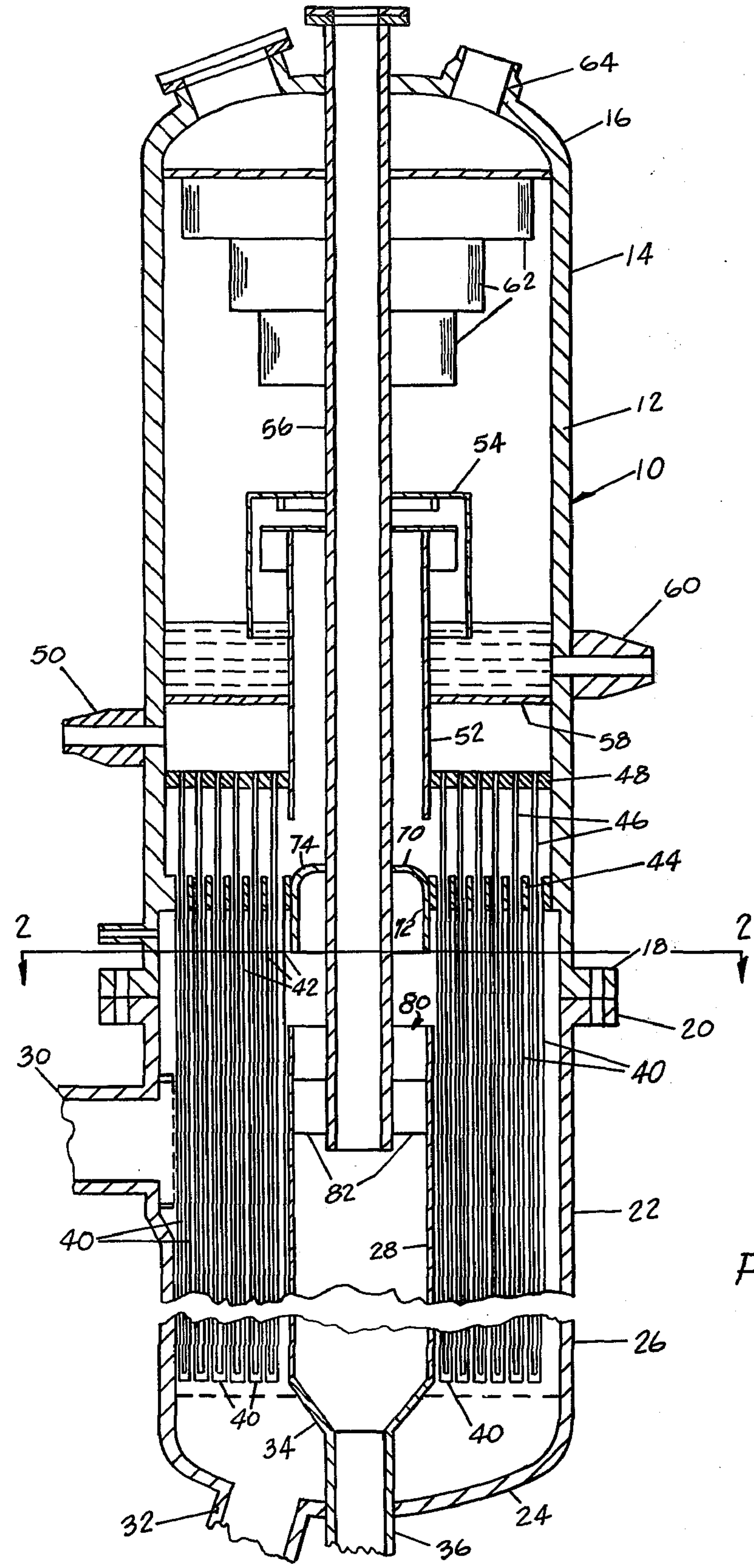

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FIG. 1

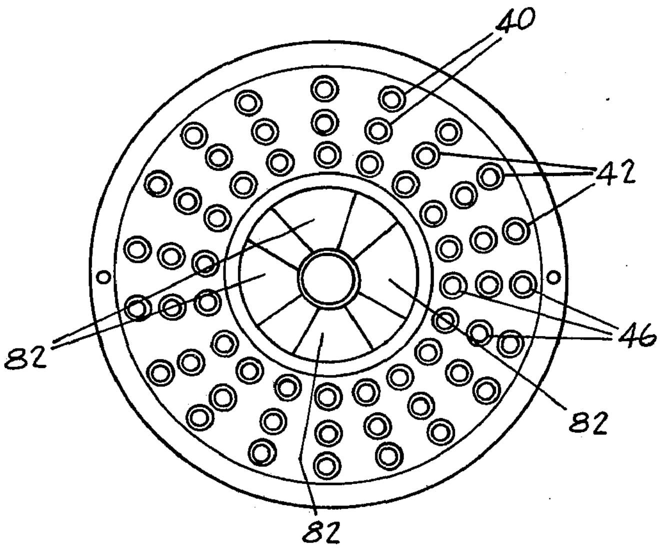


FIG. 2

# LIQUID METAL STEAM GENERATOR

## BACKGROUND OF THE INVENTION

One of the most familiar types of nuclear power plants uses a liquid metal such as sodium to cool the reactor and to transfer heat to water to generate steam. Without proper precautions, such a system would be inherently unsafe because a failure in the surface which was used to indirectly exchange heat between the sodium and water would result in a violent reaction. The possibility of a sodium-water reaction is ever present because of potential failures of boundaries between sodium and water. Such failures could be attributed to corrosion, erosion, fatigue, etc.

It is important that a liquid metal steam generator be designed so that in the event of a violent reaction between liquid metal and water, the products of that reaction can be quickly exhausted out of the steam generator to a reservoir to prevent the build-up of a pressure sufficient to cause an explosion.

## SUMMARY OF THE INVENTION

It is an object of the present invention to overcome the drawbacks found in the prior art such as those discussed above. Accordingly, a liquid metal heated steam generator is provided with a vertically extending elongated body in which a series of bayonet tube assemblies are positioned to extend downward into a body of flowing liquid metal to thereby bring water into indirect heat exchange with the liquid metal to make steam. The bayonet tubes are arranged in the annular space between an inner cylinder and an outer cylinder, the inner cylinder extending to a level below the top of the bayonet tubes but above the level of the body of liquid sodium. A central relief pipe extends down into the inner cylinder, with a centrifugal separator placed between the pipe and the inner cylinder so that in the event of a reaction between the liquid sodium and the water, the products will flow upwardly over the top of the inner cylinder and then down through the centrifugal separator so that the liquid sodium is thrown outwardly and away from the bottom of the central pipe so that steam and other gases of the reaction can pass upwardly through the pipe and out of the steam generator to thereby prevent the generation of a pressure which would result in an explosion.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a front view partly in section of a liquid metal heated steam generator made in accordance with the present invention; and

FIG. 2 is a view partly in section taken substantially along the line 2—2 of FIG. 1.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

There is shown in FIG. 1 a sodium heated steam generator indicated generally as **10**. The generator **10** has an outer shell **12** which is made up of an upper cylindrical section **14** which is closed at **16** at its top and has at its bottom an outwardly extending annular flange **18**. The flange **18** mates with a flange **20** which is positioned at the top of a lower cylindrical section **22** which is closed at its bottom **24** so that the sections **14** and **22** can be bolted together to form substantially a cylindrical vessel with closed ends.

The lower cylindrical section **22** has a cylindrical side wall **26** which forms the outer cylinder of an annular space defined by it and a coaxial inner cylinder **28**. The liquid metal such as sodium which supplies heat to generate the steam flows through this annular space entering through the sodium inlet **30** which is placed in one side of the outer cylinder **22** at a location adjacent to the top thereof and leaves the generator **10** through a sodium outlet **32** in the bottom **24** of the lower cylindrical section **22**. The sodium flows around the space between the inner cylinder **28** and the outer cylinder **26** but does not flow up into the inner cylinder **28** because it is provided with a flared transition section **34** which at its lower end merges with a downwardly extending drain pipe **36** which extends through the bottom **24** of the lower section **22**, the transition section **24** and drain pipe **36** serving to seal off the bottom of the inner cylinder **28** from sodium flowing down between it and the outer cylinder **26**.

Steam is generated in bayonet tube assemblies **40** which extend down into the annular space between the inner cylinder **28** and the outer cylinder **26**.

The bayonet tubes **40** each have an outer tube **42** which projects downwardly from a main tube sheet **44** which is placed in the lower portion of the upper cylindrical section **14**. The upper tube sheet **44** is annular in configuration.

The bayonet tubes **40** each have an inner tube **46** which are coaxial with respect to the outer tubes **42** and which extend to a level above that of the main tube sheet **44** and to the upper tube sheet **48**.

Water enters the steam generator **10** through a water inlet **50** in the side of the upper cylindrical section **14** above the upper tube sheet **48** and flows downwardly through the upper tube sheet **48** and the inner tubes **46**. The bottoms of the outer tubes **42** are closed so that once the water passes through the inner tubes **46**, it must reverse its direction and flow upwardly through the annular spaces between the inner tubes **46** and the outer tubes **42**. It is during this upward flow that the water is converted into steam because of the heat furnished to the outer tubes **42** by the liquid sodium flowing downwardly from the liquid sodium inlet **30**.

If desired, means can be positioned in the annular spaces between the outer tubes **42** and the inner tubes **46** to eliminate departure from nucleate boiling. Spiral vanes, for example, will induce sufficient tubulance to prevent layers of steam from forming on the inner walls of the outer tubes **42** and thereby assure that nucleate boiling is present during operation.

The generated steam is collected between the upper tube sheet **48** and the main tube sheet **44**. It flows upwardly through a vapor duct **52** which projects through the center of the upper tube sheet **48** and leads into a vapor-water separator **54** at its upper end.

The vapor duct **52** and the vapor-water separator **54** are both coaxial with respect to a relief pipe **56** which extends through the center of both of them and which has a purpose which will be explained later. The water which is separated out by the vapor-water separator **54** falls down in the space between the vapor duct **52** and the outer sheel **12** which is above an annular plate **58** encircling the vapor duct **52** and which at its outer periphery engages tightly against the outer shell **12**. The annular plate **58** is above the water inlet **50** and below a water outlet **60** in the side of the upper cylindrical section **14** of the generator **10**. Thus, the water which is separated out of the vapor by the vapor-water separator **54** drops downwardly to form a pool of water which is annular and above the annular plate **58** and between the vapor duct **52** and the outer shell **12** of the generator **10.** This water flows outwardly through a water outlet **60** to be reintroduced eventually into the generator **10** through the water inlet **50.**

Steam leaving the vapor-water separator **54** flows upwardly through a series of driers **62** which separate out any vapor which pass through the separator **54** so that the vapor will form in droplets and fall down into the pool of water above the annular plate **58.** The steam then passes through the steam outlet **64** in the top **16** of the upper cylindrical section **14** to leave the steam generator **10.**

The relief pipe **56** extends through the top **16** of the upper cylindrical section **14** and downward to a level below the top of the inner cylinder **28.** It also extends through a deflector **70** which has a cylindrical side wall **72** which extends through and engages against the main tube sheet **44,** and an inward curving top **74.** The deflector **70** is above the inner cylinder **28** and prevents any communication through the main tube sheet **44** except through the bayonet tubes **40.**

In the space between the central relief pipe **56** and inner cylinder **28,** a cylindrical separator **80** is positioned. It is close to the bottom of the relief pipe **56** and close to the top of the inner cylinder **28.** Essentially it consists of a series of spiral vanes **82** which are shown in plan in FIG. **2.**

In the event of a failure of one of the bayonet tubes **40,** the products of the reaction will follow the path of least resistance and move upwardly between the inner cylinder **28** and the outer cylinder **26.** They will then move inwardly over the top of the inner cylinder **28** and down through the centrifugal separator **80.** Because the vanes **82** are spiral in configuration, the products of reaction will move in a helical path through the separator **80.** The heavier products of the reaction, that is, the liquid sodium will move outwardly so that it will cling against the side of the inner cylinder **28,** the transition section **34** and drain pipe **36** to leave the steam generator **10** while the gaseous products of the reaction can move unobstructed upward through the relief pipe **56.**

With this arrangement, there is no gas under pressure forming pockets within liquid sodium to propel the same to thereby cause considerable damage. Similarly, exiting gas will not have plugs of the heavy liquid sodium which could cause considerable damage when moving at fairly high velocity with the gas.

The foregoing describes but one preferred embodiment of the present invention. Other embodiments being possible without exceeding the scope of the present invention as defined in the following claims.

What is claimed is:

**1.** A liquid metal heated heat exchanger wherein said liquid metal is the primary fluid and the secondary liquid is water which will react violently with the liquid metal if it should contact the metal, comprising:

an inner cylinder;

an outer cylinder coaxial with and encircling said inner cylinder, the top of said outer cylinder being higher than the top of said inner cylinder;

a primary fluid inlet for admitting fluid in the upper portion of the space between the inner cylinder and said outer cylinder;



a primary fluid outlet for allowing said primary fluid to pass out of the annular space between said inner cylinder and said outer cylinder;

heat exchange tubes for carrying secondary fluid to be heated by said primary fluid, said heat exchange tubes extending parallel to said inner cylinder and said outer cylinder in the annular space between said inner cylinder and said outer cylinder;

a relief pipe extending down into said inner cylinder, the bottom of said pipe being below the top of said cylinder;

a centrifugal separator positioned in the annular space between said relief pipe and said inner cylinder;

whereby in the event of a failure of one of said heat exchange tubes resulting in a reaction between said primary fluid and said secondary fluid, the products of said reaction will flow upwardly over the top of said inner cylinder and then downwardly through said cylindrical separator so that the heavier products of said reaction will be thrown outwardly and against said inner cylinder and the gaseous products of said reaction will be in the central portion of said inner cylinder to be free to move upwardly through said relief pipe.

**2.** The heat exchanger defined in claim **1** further comprising a drain pipe connected to the bottom of said inner cylinder for allowing the heavy products of a reaction between said primary fluid and said secondary fluid to move out of said heat exchanger.

**3.** The heat exchanger defined in claim **2** further comprising; an annular main tube sheet wherein said tubes pass through said annular main tube sheet, said annular main tube sheet being positioned above said centrifugal separator, an outer shell, said outer shell encircling said tubes, said main tube sheet being sealed at its outer periphery to said shell, said relief pipe extending down through said main tube sheet, and a deflector plate bridging the annular space between said relief pipe and said main tube sheet to deflect the products of a reaction between said primary fluid and said secondary fluid caused by a failure of one or more of said tubes downwardly and into said centrifugal separator.

**4.** The heat exchanger defined in claim **3** further comprising a vapor duct encircling said relief pipe above said deflector, an annular plate encircling said relief pipe above said main tube sheet, a water steam separator above said plate and communicating with the top of said vapor duct so that water coming out of said separator will form a pool on said plate.

**5.** The heat exchanger defined in claim **4** wherein said separator is annular in configuration and encircles said relief pipe.

**6.** The heat exchanger in claim **5** further comprising a vapor drier, said drier encircling said relief pipe above said separator.

**7.** The heat exchanger defined in claim **4** wherein said tubes are components of bayonet tube assemblies and include outer tubes extending downwardly from said main tube sheet and which are closed at the lower ends thereof, and inner tubes, said heat exchanger further comprising an upper tube sheet positioned between said annular plate and said main tube sheet, a water inlet for bringing in water above said upper tube sheet to be fed down through said inner tubes, said vapor duct having a bottom positioned below said upper tube sheet and above said main tube sheet to collect the vapor coming up from the annular space between said inner tubes and said outer tubes.

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