Oct. 24, 1972 J. H. GERMER 3,700,551

DEVICE TO PREVENT SODIUM FREEZING AROUND SHAFT PENETRATION

Filed Feb. 18, 1971 2 Sheets-Sheet 1

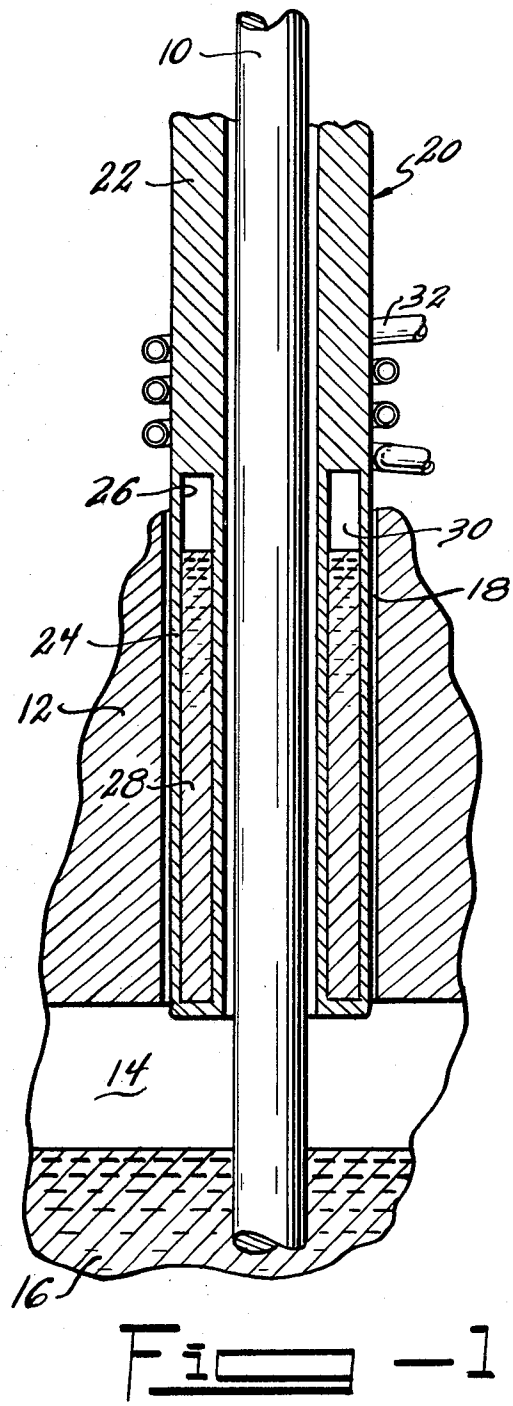
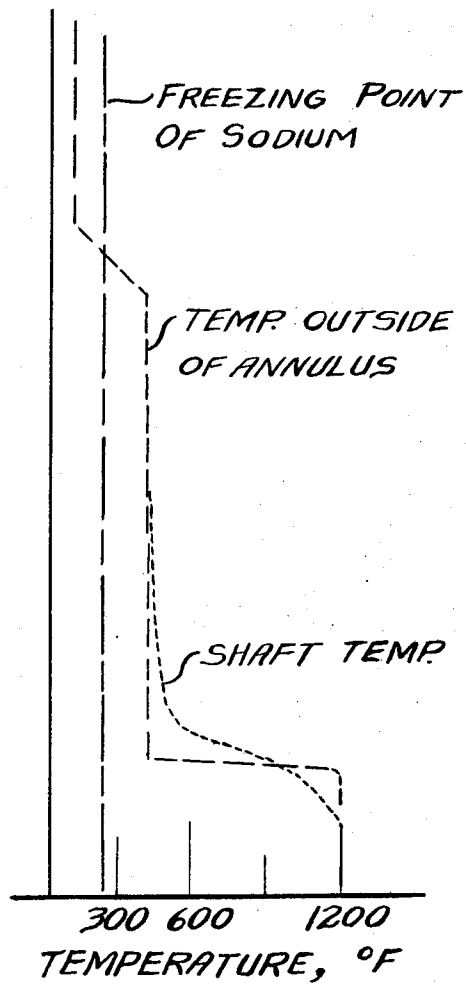


Fig. 1

Fig. 2



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Fig — 3

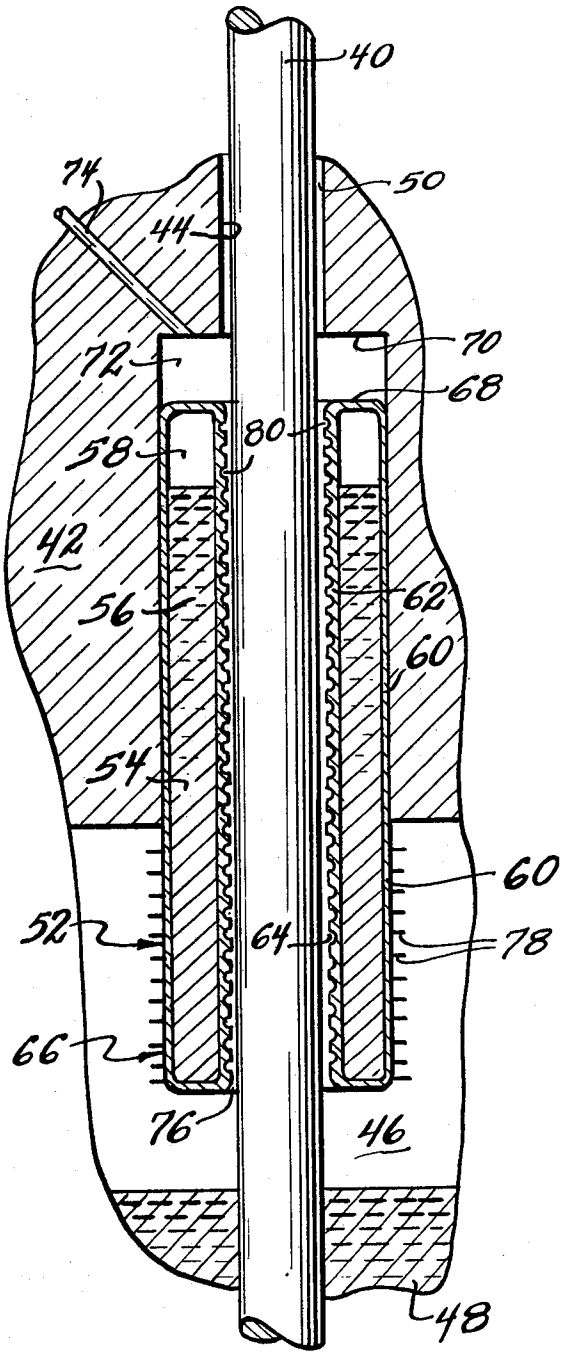
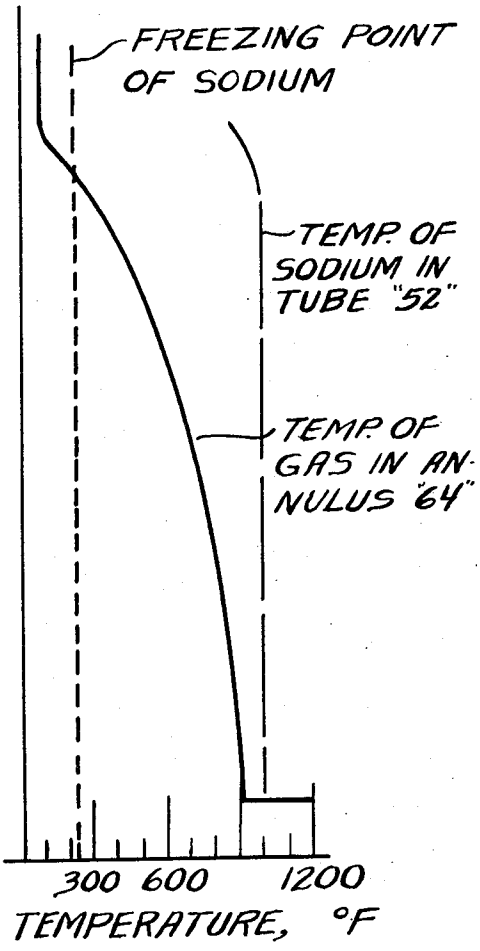


Fig — 4



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DEVICE TO PREVENT SODIUM FREEZING AROUND SHAFT PENETRATION

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ABSTRACT OF THE DISCLOSURE

A device for preventing sodium vapor from freezing around a movable shaft extending into a pool of hot sodium through a cover gas provided thereabove. The device consists of a sealed hollow-wall tube containing sodium positioned around the shaft in the region of possible freezing with its lower end in heat exchange contact with the cover gas. Means may be provided for passing inert gas through the annulus between the shaft and the hollow-wall tube countercurrent to sodium vapor rising from the pool of hot sodium.

CONTRACTUAL ORIGIN OF THE INVENTION

The invention described herein was made in the course of, or under, a contract with the United States Atomic Energy Commission.

BACKGROUND OF THE INVENTION

This invention relates to means for preventing vapors of a liquid metal from freezing around a movable shaft which extends into the liquid metal. In more detail, the invention relates to means for preventing sodium from freezing around a control rod shaft for a sodium-cooled fast breeder nuclear reactor.

A sodium-cooled reactor is ordinarily provided with an inert gas (such as argon) over the sodium in the region above the reactor. It is generally referred to as a cover gas. The cover gas is at essentially the same temperature as the reactor outlet sodium, about 1200° F. At this temperature, a considerable amount of sodium vapor will be present in the cover gas.

Various penetrations, in particular control rod drive shafts, extend through the reactor's upper shield, through this cover gas space, and down into the sodium.

It is desirable to operate the upper ends of these shafts at a considerably lower temperature than the cover gas since the control drive is located at the upper end of the shaft. The resulting temperature difference in the annular spaces surrounding these shafts is such that a considerable amount of naturally convecting hot, vapor-laden gas will tend to circulate in the annulus. This presents a serious problem when sodium vapors condense and freeze in the annulus.

The present invention consists of a device which prevents sodium from freezing in this annulus. The device assures that the surfaces of the shaft with a temperature below the freezing point of sodium are located in regions that are not easily accessible to sodium vapor diffusion. The invention will, of course, also apply to systems employing other liquid metals in a similar way.

BRIEF DESCRIPTION OF THE DRAWINGS

The device may be better understood by reference to the drawings in which:

FIG. 1 is a partial sectional view showing a control drive shaft penetrating the shield, cover gas and liquid sodium of a sodium-cooled nuclear reactor and disclosing one embodiment of the present invention.

FIG. 2 is a graph showing the temperature along the control drive shaft according to this embodiment of the invention.

FIG. 3 is a partial sectional view disclosing an alternative embodiment of the invention and

FIG. 4 is a graph showing temperatures according to this embodiment of the invention.

As shown in FIG. 1 a control rod drive shaft **10** penetrates upper shielding **12** of a sodium-cooled fast breeder reactor and extends through a cover gas **14**—such as argon—into a pool **16** of liquid sodium submerging the core of the reactor. Annulus **18** between shaft **10** and shielding **12** is wide enough to accommodate a metallic tube **20** having a solid upper portion **22** and a lower portion **24** having a cavity **26** therein. Lower portion **24** is nearly full of sodium **28** leaving an expansion space **30** above the sodium. Also a cooling coil **32** surrounds the solid portion **22** of the tube **20** keeping the temperature at this point below the freezing point of sodium.

As is well known, the heat transfer properties of liquid sodium are such that heat addition to the lower end of a sodium-filled vessel is readily transferred to the upper end. For this reason, a very large heat flow would be required to cause the lower end of the sodium in cavity **26** to rise in temperature much above the temperature of the upper end and the sodium can be considered essentially isothermal. Since the thermal resistance of the walls of tube **20** which serve to conduct heat from the sodium **28** contained in cavity **26** to the cooling coils **32** is lower than the thermal resistance at the lower end of tube **20** between sodium **28** and the hot cover gas **14**, the temperature of the sodium **28** is substantially less than the average of the temperatures of the hot cover gas **14** and the cooling coils **32** which would be the temperature of the sodium if these thermal resistances were equal. The difference in the thermal resistances is due to the relatively poor heat transfer characteristics of argon gas compared to those of the metal—such as stainless steel—of which tube **20** is formed.

FIG. 2 indicates the temperature profile that results. Two features of importance will be noted.

(A) The temperature in the annulus **18** is above the freezing point of sodium except near the upper end at a remote distance from the hot cover gas **14**.

(B) The portion of the annulus below that which is below the freezing point of sodium is all at a low temperature relative to the hot cover gas. For this reason, sodium vapor in the hot cover gas entering the lower end of the annulus will have ample opportunity to condense and run downward, thus very little of this sodium vapor will ever reach the region where freezing will occur.

One feature of this arrangement is that the major portion of the length of the device cannot cool to a temperature below the freezing point of sodium by removing heat at the upper end, for instance by cooling coil **32**. If the upper end of tube **20** were to cool to below the freezing point of sodium, it would freeze and increase in thermal resistance due to suppression of natural convection, thus causing heat from the lower end to raise the temperature. For this reason the device acts as a thermostat to prevent the possibility of reaching the freezing point in a region of high sodium vapor content in the gas.

A second embodiment of the invention is shown in FIG. 3. As shown in FIG. 3, a control rod drive shaft **40** penetrates the upper shielding **42** of a sodium-cooled fast-breeder reactor through an aperture **44** and extends through the hot cover gas **46** into the liquid sodium **48** within which the core of the reactor is submerged. The diameter of the aperture **44** is such that there is a narrow, annular space **50** between the shaft **40** and shielding **42**, except at the lower end of the shield **42**. In this

region the diameter is increased to receive a sodium-filled hollow-wall tube **52**.

Tube **52** has a totally enclosed, hermetically sealed cavity **54** containing sodium **56** and a void space **58** for sodium expansion. The outer surface **60** of tubular member **52** is in close fitting contact with the shield **42** while the inner surface **62** defines an annular space **64** about the shaft **40** similar to the space **50** above. The lower end **66** of tube **52** extends into the hot cover gas **46** below the bottom of shield **42** while the upper end **68** is spaced from a shoulder **70** connecting the two diameters of aperture **44**, thus forming an open area **72** into which a cool inert gas is fed through inlet **74**.

This cool gas passes downward through the annular space **64** where it picks up heat from the surface **62** of tube **52** and discharges at exit **76** to mix with the hot cover gas **46**. The outer surface **60** of tube **52**, located within the area of the hot inert gas **46**, is provided with fins **78** to improve the heat transfer from the hot gas **46** to the sodium **56**, while helical grooves **80** located in the inner surface **62** of tube **52** tend to improve the heat transfer from the sodium **56** to the gas in annulus **64**.

As has been stated heat addition to the lower end of a sodium-filled vessel is readily transferred to the top. Thus, looking at the graph of FIG. 4, it can be seen that, with the liquid sodium **48** and cover gas **46** being at about 1200° F., the temperature of the sodium in tube **52** is constant except where the cool gas enters. As shown in the left-hand curve, the cooling gas is admitted through inlet **74** at a temperature below the freezing point of sodium. In annular space **64**, this gas heats up almost instantly, above the freezing temperature of sodium, and its temperature gradually increases until, at exit **76** of the annulus **64**, it is close to the temperature of the sodium **56** in tube **52**.

Thus it is seen that the cool argon entering through inlet **74** will prevent hot gas from entering annulus **44**. This is desirable since the control drive operates in the region of the upper end of annulus **44**. Because of the presence of tube **52** the temperature of the argon passing downwardly through annulus **64** is above the freezing point of sodium except for a small region near the upper end of annulus **64**. Thus, in order for sodium to freeze it would have to diffuse against the stream of argon over most of the length of the annulus.

It will be observed that satisfactory results could not be attained merely by the introduction of a gas through inlet **74** at any temperature. If a hot gas in introduced it will prevent sodium from freezing but it would be difficult to maintain the upper end of annulus **44** at a low temperature due to natural convection currents. If a cold gas is introduced most of annulus **64** would be at the temperature of the inlet stream of argon and severe condensation and freezing of sodium would occur near the lower end of annulus **64** as a result of back diffusion from the hot argon gas **46**.

It will be understood that the invention is not to be limited to the details given herein but that it may be modified within the scope of the appended claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A device for preventing liquid metal vapor from freezing around a movable shaft extending into a pool of liquid sodium through a cover or shield provided thereabove, there being a cover gas present in the space between the pool of liquid sodium and the cover, said device comprising a sealed hollow-wall tube containing liquid sodium having an expansion space at the top of the hollow positioned around said shaft and spaced therefrom in at least the lower portion of said cover with its lower end in heat exchange contact with the cover gas.

2. A device according to claim **1** and including means for passing an inert gas downwardly through the annulus between said shaft and said hollow-wall tube into the cover gas.

3. A device according to claim **1** wherein said hollow-wall tube includes a solid portion at the top thereof and means for cooling said solid portion.

4. In a fast breeder nuclear reactor including a core submerged in a pool of liquid sodium wherein a plurality of movable shafts penetrate to the pool of sodium through a shield disposed above the reactor core and wherein a cover gas fills the space between the pool of sodium and the shield, the improvement comprising a sealed hollow-wall tube containing sodium surrounding each movable shaft and spaced therefrom as it passes through at least the lower portion of the shield, the lower end of said hollow-wall tube being in heat exchange contact with the cover gas.

5. The improvement of claim **4** wherein said hollow-wall tube forms the lower portion of a metal tube which surrounds the shaft in the region of the shield and including means for cooling the solid portion of said metal tube.

6. The improvement of claim **5** wherein the thermal resistance of the walls of the expansion space for the sodium in said hollow-wall tube is lower than the thermal resistance of the wall between the sodium in the hollow-wall tube and the cover gas at the lower end of the hollow-wall tube.

7. The improvement of claim **4** and including means for passing an inert gas downwardly through the annulus between the shaft and the hollow-wall tube.

8. The improvement of claim **7** wherein the hollow-wall tube extends below the bottom of the shield into the cover gas.

9. The improvement of claim **8** wherein the extension of the hollow-wall tube contains a plurality of circumferential metal fins.

10. The improvement of claim **9** wherein the inner wall of the hollow-wall tube has a helical groove therein facing the movable shaft.

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REUBEN EPSTEIN, Primary Examiner

U.S. Cl. X.R.

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