Aug. 9, 1966 S. ROSENBLATT 3,265,125

RADIATOR SEALING SCHEME

Filed Feb. 5, 1964

FIG. 1

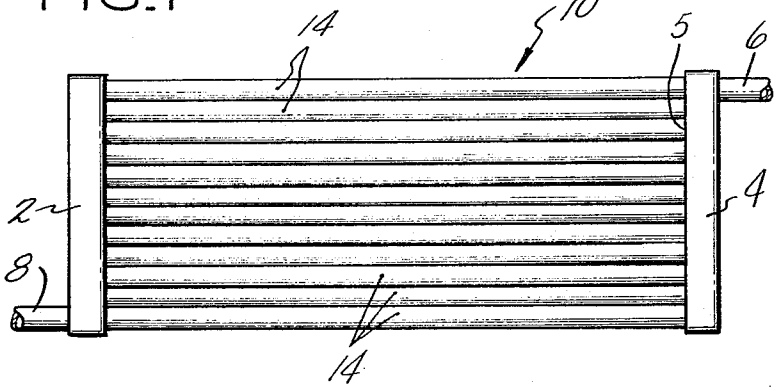


FIG. 2

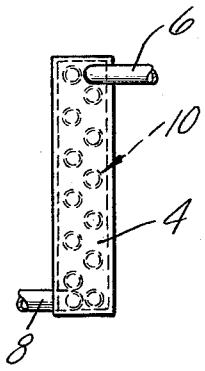
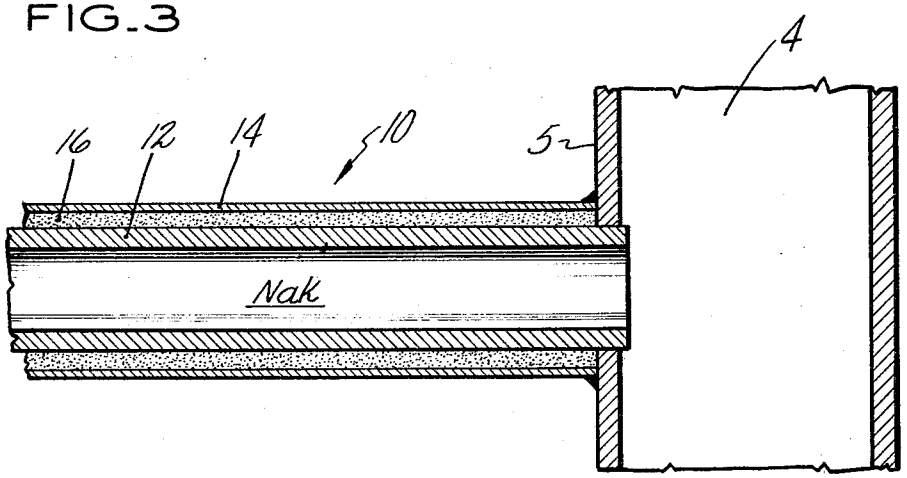


FIG. 3



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RADIATOR SEALING SCHEME

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This invention relates to self-sealing means for radiators and is particularly concerned with sealing means for liquid metal containing radiators for use in space vehicles which may encounter small meteoroids in flight and as a result suffer pin-hole size punctures of the liquid containing radiator tubes.

It is an object of this invention to provide an arrangement by which such a radiator may have a puncture of the liquid metal containing tubes thereof automatically sealed as a result of the leakage of liquid metal therefrom.

A further object of this invention is the provision of another material adjacent the liquid metal containing tubes of the radiator which reacts with any liquid metal which may escape from the radiator tubes to seal the escape passage.

More specifically, it is proposed to surround the radiator tubes by another material which, upon contact with escaping liquid metal from a tube, will react to produce molten metal at sufficient high temperature to weld and seal the leak passageway. This is accomplished by surrounding the radiator tubes with a jacket containing the fusible material so that upon contact of the liquid metal with the fusible material sufficient heat will be generated by chemical reaction to melt an adequate amount of the fusible material in the immediate vicinity of the leak passage and cause it to fuse with the material from which the radiator tube is made at the point of the leak.

A further object of the invention is generally to improve the construction and performance of space vehicle radiators.

These and other objects and advantages of the invention will be pointed out or will become obvious as a result of the following detailed description of a preferred embodiment of the invention illustrated in the accompanying drawing.

In this drawing, FIG. 1 is a side elevation, partly in section of a space radiator unit shown somewhat diagrammatically; FIG. 2 is an end view of FIG. 1; and FIG. 3 is a sectional detail of a short length of a radiator tube of the radiator of FIG. 1 adjacent one of the headers.

In the arrangement shown in the drawings the radiator unit has opposed headers **2** and **4**, one of which has an inlet **6**, the other of which has an outlet **8**. The arrangement shown is used particularly in the cooling cycle in a satellite-borne radiator which is frequently used in cooling the liquid metal in nuclear power-generating systems. It will be understood that a number of units may be employed which may be either fixed or deployable. The headers are connected by a plurality of tubes **10** which extend in parallel relation to each other and provide for a flow of the fluid from the inlet to the outlet header. The headers, as shown herein, are elongated transverse members and the tubes lie slightly staggered but generally in the same planes as the headers so as to present the maximum radiating surface for the projected area of the radiator, while allowing the necessary spacing for the tubes where they enter the tube sheets **5** of the headers. Obviously, numerous other arrangements of the tubes are possible which will provide the required exposure of the tubes for radiation of heat.

Each tube consists of an inner tube **12** and an outer tube or jacket **14**. The inner tubes extend through the

tube sheets **5** in the headers and communicate with the interior of the headers. The outer tubes merely abut the confronting surfaces of the tube sheets. Both tubes are connected to the header tube sheets in a fluid-tight manner by brazing or welding. With this arrangement the liquid metal in the inlet header **4** flows through tubes **12** to the outlet header **2**. The annular space **16** surrounding tubes **12** is filled with a material which, in the event of a puncture of tubes **14** and **12** by a meteoroid, will react with the liquid metal issuing from the leak passage to produce molten metal to seal the leak passage.

The material in annular spaces **16** may be, for example, the fluoride salt of any metal which is not corroded by the cooling fluid in the radiator at the radiator temperature. With NaK as a radiator cooling fluid at 1400° F., columbium fluoride or manganese fluoride or fluorides of any of the refractory metals will produce the desired sealing results. These same metal salts are also satisfactory with lithium as the radiator cooling fluid.

It may be desirable to use a mixture of metal salts and viscosity modifiers to produce a very high viscosity of the material in space **16** at operating temperature. It will be understood that at 1400° F. the metal salt will be molten and, since the space is filled with the metal salt in powder form at room temperature, the molten salt is under some pressure at 1400° F. It is also desirable that the salt have a high viscosity since the surface tension of the molten salt has an important bearing on the positive feeding of salt to the puncture. Suitable modifiers to increase viscosity are glass powders, lithium fluoride, powdered columbium, nickel, or a ceramic material such as thorium oxide.

The metal fluorides and the metal or ceramic modifier are packed into space **16** in finely powdered form, fused, and sealed therein under compression by the brazing or welding of the ends of the tube to the header tube sheets surrounding the inner tubes **12** which extend through the tube sheets and are also welded thereto. The metal salts in space **16** will react with the NaK in tubes **12** to seal a puncture passage through tubes **12** and **14**. The result of bringing metal salts into contact with NaK to produce a brazing alloy may be represented by the following general reaction: $M_1F+M_2F+NaK \rightarrow M_1+M_2+(NaK)F+heat$.

Tests indicate that the amount of heat generated by this reaction is sufficient to melt and alloy M_1+M_2, and that upon the dissipation of this heat of reaction into the radiator, the alloy will solidify in the leak passages and form a seal against further leakage.

These tests were carried out in a specially constructed test rig which duplicates very closely the space environment. This rig includes a closed vessel installed in a furnace which is partially filled with NaK or Li radiator cooling fluid. The space above the NaK is provided with an inert gas atmosphere such as argon. Also in this space is suspended a double-walled crucible closed at its top except for a vacuum connection. Holes of varying diameter are drilled through the inner and outer walls of the crucible to simulate meteoroid punctures. The salt mixture is packed within the annular space between the crucible walls. When the NaK and the crucible have been heated by the furnace to 1400° F. temperature, the evacuated crucible is lowered into the NaK, thus simulating the conditions which will prevail if a radiator tube is punctured in space. The liquid metal enters the crucible through the pre-drilled holes. The reaction between the metal salts surrounding the holes and the NaK generates heat which decreases the viscosity of the metal salts allowing them to feed more readily to the puncture and seal the latter with a continuing supply of metal.

Tests were carried out using a mixture of manganese fluoride and nickel fluoride and a radiator coolant of

NaK in an inert atmosphere. The reaction was instantaneous and smooth with evolution of heat and an arc-like glow of light. Metallographic examination of the melted metal conclusively proved that a true intermetallic composition was formed. Lithium substituted for NaK reacted identically. A mixture of the two metal salts in the proportion of NiF 70 w./o.+MnF 30 w./o. has been found satisfactory. CbF and NiF is another good substance which will not corrode the radiator material in the presence of Li or NaK at operating temperatures for these cooling fluids.

It will be evident from the above description of a preferred embodiment of the invention that as a result of this invention self-sealing means has been provided for radiators. It will be further evident that the sealing means provided is especially adapted for space radiators which may be subjected to meteoroid bombardment.

While several means for carrying out the invention have been disclosed, it will be understood that numerous other variations are possible within the scope of the invention as defined by the following claims. For example, the radiator tubes may be made in the form of thin flat envelopes if desired to which surface extending fins are attached.

I claim:

1. A space radiator having at least one tube through which to circulate a fluid,

a tubular jacket surrounding said tube and radially spaced therefrom to form an annulus therearound, and

a sealant in said annulus, said sealant consisting essentially of a metallic salt which is chemically reactive exothermically with said fluid and which forms a brazing material therewith, the brazing material being formed in the event of a tube leak and operating to seal the leakage passage.

2. The radiator of claim **1** in which the fluid is a sodium-potassium alloy and the sealant consists essentially of at least one fluoride selected from the group consisting of the fluorides of columbium, manganese, nickel and other refractory metals which are compatible with the sodium-potassium alloy at the radiator operating temperature.

3. The radiator of claim **1** in which the fluid is a sodium-potassium alloy and the sealant consists essentially of at least one fluoride selected from the group consisting of the fluorides of columbium, manganese, nickel, molybdenum, tantalum, and zirconium.

4. The radiator of claim **3** in which the sealant consists essentially of a mixture of manganese fluoride and nickel fluoride.

5. The radiator of claim **3** in which the sealant consists essentially of a mixture of columbium fluoride and nickel fluoride.

6. The radiator of claim **1** in which the fluid is molten lithium and the sealant consists essentially of at least one fluoride selected from the group consisting of the fluorides of columbium, manganese, nickel and the other refractory metals which are compatible with molten lithium at the radiator operating temperature.

7. The radiator of claim **1** in which the fluid is molten lithium and the sealant consists essentially of at least one fluoride selected from the group consisting of the fluorides of columbium, manganese, nickel, molybdenum, titanium, and zirconium.

8. The radiator of claim **7** in which the sealant consists essentially of a mixture of manganese fluoride and nickel fluoride.

9. The radiator of claim **7** in which the sealant consists essentially of a mixture of columbium fluoride and nickel fluoride.

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