(12) UK Patent Application (19) GB (11) 2 137 107 A

(43) Application published 3 Oct 1984

(21) Application No 8332006

(22) Date of filing 30 Nov 1 1983

(30) Priority data

(31) 480961 (32) 31 Mar 1983 (33) US

(71) Applicant
Westinghouse Electric Corporation, (USA—Pennsylvania),
Gateway Center, Pittsburgh, Pennsylvania 15235,
United States of America

(72) Inventor
Richard Paul Colburn

(74) Agent and/or address for service
Ronald Van Berlyn, 23 Centre Heights, London, NW3 6JG

(51) INT CL[3]
B01D 29/20 G21C 17/04

(52) Domestic classification
B1D 1509 1821 1906 2305 NA
G6C 39Y 405 DB DC

(56) Documents cited
GB A 2008963 GB 1242487
GB 1487368 US 3905905

(58) Field of search
B1D
G6C

(54) **Fission Gas Detection System**

(57) A device for collecting fission gas released by failed fuel rods which device uses a filter 2 adapted to pass coolant 1 but to block passage of fission gas bubbles 15 due to the surface tension of the bubbles. The coolant may be liquid metal.

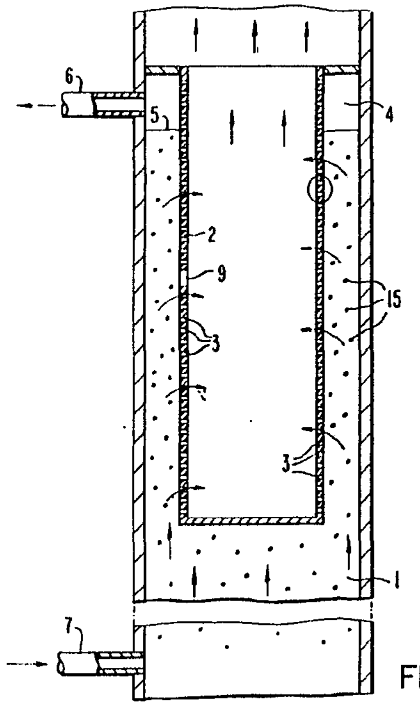

FIG. I

GB 2 137 107 A

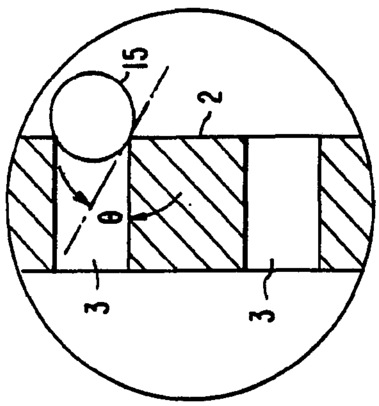

FIG. 2

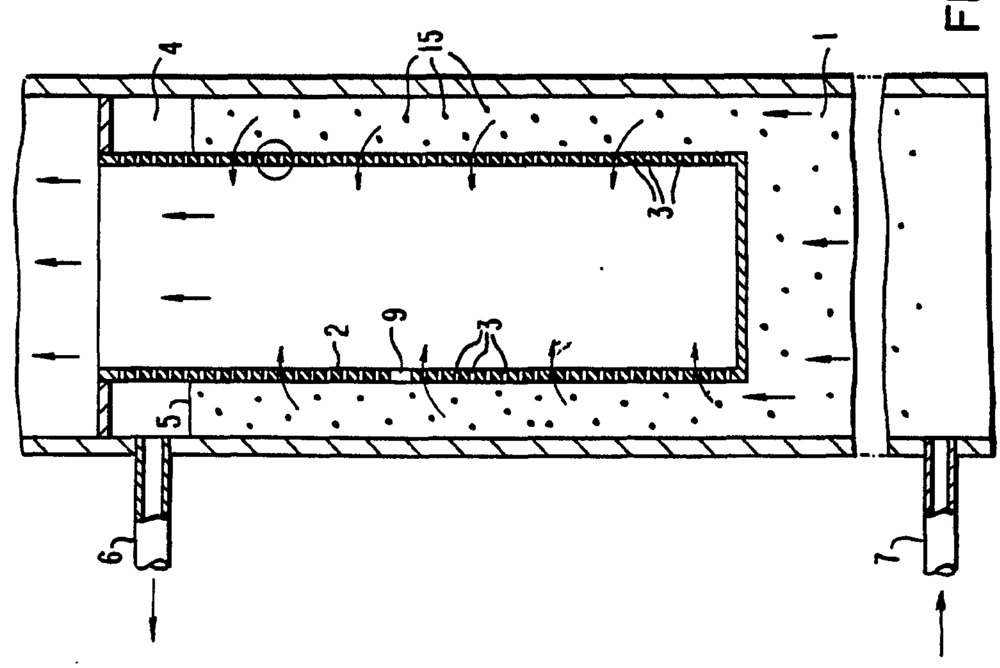

FIG. 1

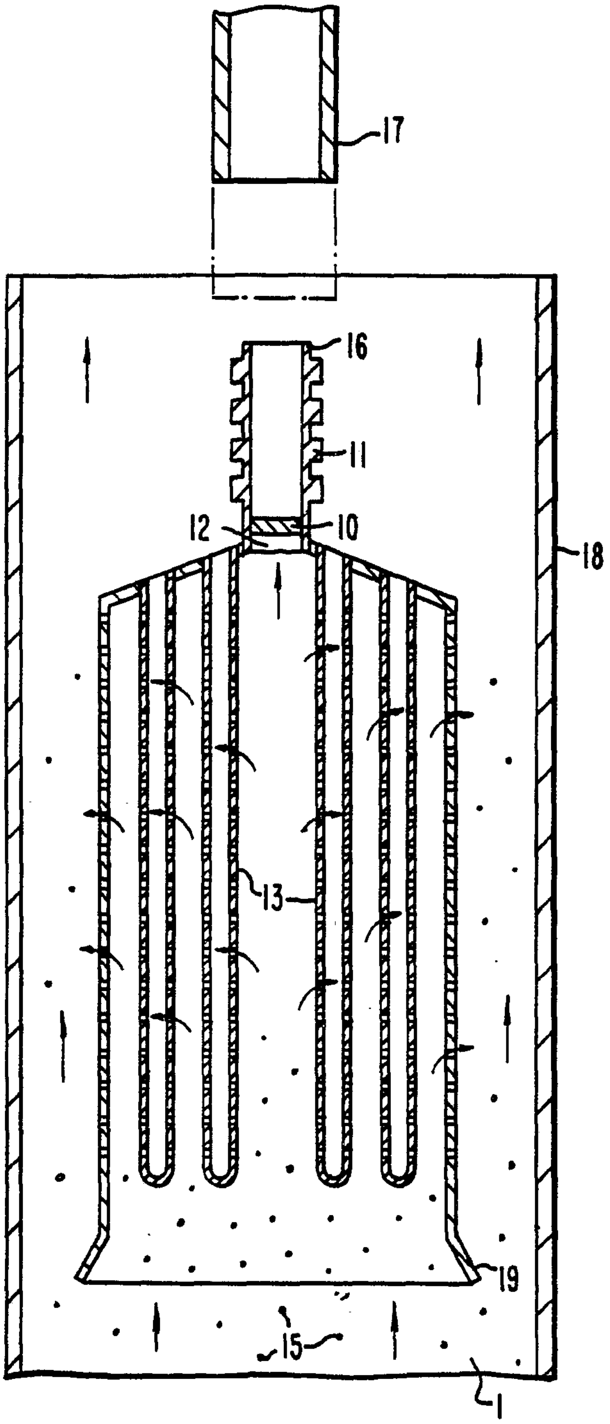

FIG. 3

SPECIFICATION
Fission Gas Detection System

This invention relates to systems used to detect and locate failures of the cladding of fuel rods in nuclear fuel assemblies used in nuclear reactors, especially sodium cooled nuclear reactors.

Nuclear reactors contain a fuel core which is a grouping of fuel assemblies each of which has a plurality of fuel rods. A fuel rod is a cylindrical, metal tube which contains nuclear fuel pellets. The metal of the tube separates the fuel pellets from reactor coolant which flows over the surface of the tube or cladding.

A penetration of the cladding, termed a fuel failure, may allow fission fragments, particularly gases, to escape from the fuel rod into the reactor coolant. These gases may mingle with the gas contained in a cover gas region which is usually a feature of liquid metal cooled reactors.

Nuclear reactors may experience fuel failure in spite of rigorous quality control and conservative operating procedures. Most of the failures result from pin-hole cracks in the cladding and/or end plug welds. Such failures are now detected by analysis of fission-gas outside the core (e.g., in the reactor cover gas) and by observation of delayed neutron precursors in the reactor coolant.

One of the problems faced by reactor instrumentation is to detect and monitor failed fuel in such a manner that safe operation of the reactor is not impaired. This problem can be solved by having the ability to quickly obtain and analyze samples of fission gas released by failed fuel. There is a need to locate the leaking fuel assembly rapidly in order to expedite its removal and minimize reactor down time.

Consequently, it is the principal object of the present invention to provide a method for obtaining a sample of fission gas from reactor coolant and quickly identify the leaking assembly.

With this object in view, the present invention resides in a device for collecting gas bubbles entrained in a liquid contained in a flow path (1) having a filter (2) disposed therein so as to force said liquid to flow through said filter (2), characterized in that said filter (2) has holes (3) of a diameter appropriate to prevent passage of entrained gas bubbles through said filter due to the surface tension forces on said bubbles which oppose passage through said holes; that a plenum (4) is provided within said flow path (1) to gather the gas bubbles prevented from passage through said filter (2), and that means (6) are provided for retrieving said gas bubbles accumulated in said plenum (4).

The invention will become more readily apparent from the following description of a preferred embodiment thereof shown, by way of example only, in the accompanying drawings, wherein:

Fig. 1 is a schematic of a first embodiment;
Fig. 2 is a detail from Fig. 1; and
Fig. 3 is a schematic of a second embodiment.

The invention acts on a stream of reactor coolant immediately after passage through the fuel core of the reactor.

A first embodiment is illustrated schematically in Fig. 1. A stream of coolant 1 from the core, containing entrained gas bubbles 15 enters from the bottom. A cylindrical filter element 2, with a pore 3 size of $<100\ \mu$ meters, would be wetted by the coolant as it passes through filter 2. When an entrained fission gas bubble 15 contacts filter 2 in the vicinity of a pore 3, (it must displace the liquid in the pore to pass) then a balance of forces is set up between the liquid, solid filter and gas interfaces as illustrated schematically in the expanded view of Fig. 2. As the gas attempts to pass through pore 3 it exerts a pressure ΔP over the pore opening forming a miniscus with contact angle θ. The balance of forces may be expressed:

$$\Delta P \pi r^2 = 2\pi r \sigma \cos\theta;$$

σ=surface tension (dynes/cm) (1)

For the bubble to pass through pore 3, ΔP must be large enough to that $\theta \to 0$ ($\cos\theta \to 1$). For pressure drops below this value the gas will accumulate in annulus 4 near the upper end of the filter. As the gas accumulation continues it will tend to expand and displace the fluid-gas interface 5 downward. This would tend to decrease the useful surface area of the filter which would increase the pressure drop and decrease the total liquid flow through the filter. To prevent gas blanketing of an excessive area of the filter, the gas could be bled-off through outlet 6. Alternatively the system may be designed to allow the gas blanket accumulation to increase the pressure drop across the filter to the critical pressure and start to force some of the accumulate gas through the filter. Any subsequent gas bubbles arriving with the coolant would continue to mix with the gas blanket but a bleed of the gas blanket would pass through the filter.

In general it is preferred to periodically draw off the accumulated gas to check for fission gas.

The actual volume of fission gas released from a breached rod is relatively small ($<<1$l) and the system could be operated in a continuous "feed and bleed" mode in which a stream of inert gas would be added to the coolant stream upstream from the filter at inlet 7 and continuously bled-off at outlet 6 to provide a continuous gas sample stream. This sample would be enriched in fission gas when rod failure occurred. The "feed and bleed" mode would also provide a sparging action to disengage any dissolved fission gas. After the gas was drawn off it would be routed past a scintillation detector and mass spectrometer for conventional analysis.

The system could be designed to accommodate the desired coolant flow rate with a pressure drop across the filter below the critical pressure drop which would force gas through pores 3. This would be accomplished by proper selection of the pore size and filter surface area.

Sample calculation

The critical ΔP may be calculated from equation (1) for a given value of r and σ

$$\Delta P_c = \frac{2\sigma \cos\theta}{r} \rightarrow \frac{2\sigma}{r}$$

for cos $\theta \rightarrow 1$

For liquid sodium at 500°C, σ=210 dynes/cm. For a 10 μm pore diameter $r=5\times10^{-4}$ cm. (r=radius of pore)

$\Delta Pc=8.2\times10^5$ dynes/cm$^2\cong$11 psi.

A second embodiment is illustrated schematically in Fig. 3. The device locates a filter 10, of relatively small area, in a tube 11 at a high point in a fission gas disengagement device. Typically this would be in or near the upper end of each fuel assembly in the reactor. During initial operation all filters would be wetted by the coolant and coolant would flow through tube 11. The flow rate through tube 11 would be comparable to that through an equal area of filter on the main gas disengagement filter 13. If a fuel element should rupture and leak fission gas, the gas disengagement device on the assembly will intercept some representative fraction (say 10 to 20%) of the assembly effluent and will strip the entrained gas bubbles from it. The buoyant forces on the entrapped gas will tend to concentrate it at the upper end 12 of the disengagement device where the small tube filter 10 is located. The accumulation of gas will lead to gas blanketing of the small filter 10 and ultimately complete blockage of coolant flow through small tube 11. A device (not shown) such as an eddy current sensor would monitor the accumulation of fission gas intercepted by the larger filter. A wide range of gas detection methods or associated sodium displacement measurements may be applied. If the device is located within the upper end of the fuel assembly, the sipping devices (17) could be mated to the outlet nozzle (16) to sample for accumulated gas.

If the device were located above the fuel assembly it could contain sensors such as eddy current devices to detect the accumulation of gas below the small filter. This would permit continuous remote monitoring of each fuel assembly.

The sipping operation could be performed immediately after detection of gas by the sensor or it might be delayed to some more convenient time such as a scheduled shutdown. Then each of the assemblies containing leaking rods could be identified, verified and removed. The presence of several leakers or even the simultaneous occurrence of several leakers would not interfere with identification. Since the inventory of released gas would be retained by the filter until sampling was performed, there would be no need to immediately identify the leaker when it occurs (as in the case of gas tagging). Similarly, if the gas sampling and analysis system was down when one or more of the leaks occur, there is no irreversible loss of identification capability. Since the device accumulates the fission gas over the entire period the assembly operates in the breached condition, it does not depend on inducing fission gas release from the breached rods at the time of sampling

For the sipping operation the sipping device 17 would be mated to the filter tube outlet 16 or the sipping system could be permanently attached to the outlet nozzle as part of a stationary sipping system with a common manifold system or rotary selector valve. By rapidly drawing on this tube the critical pressure drop across the small filter would be exceeded and the accumulated gas would be drawn through the filter up into the gas sampling stage where it could be analyzed to confirm the presence of fission gas and determine the amount.

The gas accumulation monitoring in the tubes provides a simple and rapid method for fuel failure detection and location. The sipping procedure allows the verification of leaker identity. The filter device is a simple passive unit with no moving parts.

EXAMPLE

In a typical installation, (see Fig. 3) the main gas disengagement filter for a full size fuel assembly could be a cylinder 18 7.5 cm. in diameter by 15 cm. long surrounding 12 tubular filters 13 1.3 cm. diameter by 15 cm. long. This would provide approximately 0.09 m^2 of filter surface. A deflector cone 19 would be designed to create approximately 5 psi pressure drop across the filter when the full assembly flow was at its rated 500 gpm. A 10 μm scintered stainless steel filter will allow about 20 gpm/ft^2/psi pressure drop. Then the 0.35 kg/cm^2 across 0.09 m^2 would accommodate 360 l/min flow or about 20% of the total fuel assembly flow. With good mixing in the assembly it can be assumed about 20% of the released gas would be intercepted by the main filters. Even if only 10 ml of gas were released by the breached rod, the 2 ml captured by the gas disengagement filter would be enough to gas blanket the small filter. During the sipping operation application of >0.7 kg/cm^2 pressure drop across the filter would draw the gas through the filter.

This invention was conceived during performance of a U.S. Government Contract designated DE-AC06-76FF02170.

CLAIMS

1. A device for collecting gas bubbles entrained in a liquid contained in a flow path (1) having a filter (2) disposed therein so as to force said liquid to flow through said filter (2), characterized in that said filter (2) has holes (3) of a diameter

appropriate to prevent passage of entrained gas bubbles through said filter due to the surface tension forces on said bubbles which oppose passage through said holes, that a plenum (4) is provided within said flow path (1) to gather the gas bubbles prevented from passage through said filter (2), and that means (6) are provided for retrieving said gas bubbles accumulated in said plenum (4).

2. A device as claimed in claim 1, characterized in that said liquid is a liquid metal coolant of a nuclear reactor.

3. A device as claimed in claim 1 or 2 characterized in that said filter (2) has a 1 mm. diameter hole (9) for the limitation of gas blanketing of said filter.

4. A device as claimed in claim 1, 2 or 3 characterized in that said filter holes (3) are 100 μm in diameter.

5. A device as claimed in any one of claims 1 to 4, characterized in that said path has means (7) for the injection of an inert gas upstream of said filter (2).

6. A device as claimed in any of claims 1 to 5, wherein said device is installed in a nucelar fuel assembly for monitoring rod cladding failure and subsequent fission gas release characterized in that a second filter (10) is disposed in said path, such that a portion of the coolant passes through said second filter (10), said second filter (10) being oriented essentially horizontally and transverse to the first filter (2) such that said second filter (10) becomes gas blanketed by fission gas bubbles which gather in said plenum when cladding failure occurs, and means are provided for monitoring coolant flow through said second filter to indicate failure.

Printed in the United Kingdom for Her Majesty's Stationery Office, Demand No. 8818935, 10/1984. Contractor's Code No. 6378.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.