PATENT SPECIFICATION

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(54) NUCLEAR REACTOR INSTRUMENTATION

(71) We UNITED KINGDOM ATOMIC ENERGY AUTHORITY, London, a British Authority do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to liquid metal cooled nuclear reactors.

In a liquid metal cooled nuclear reactor core comprising a multiplicity of parallel, closely spaced fuel pins, the pins are usually arranged in discrete groups to facilitate handling and replacement. Each group can comprise a cluster of pins enclosed within a peripheral wrapper and such an assembly is hereinafter referred to as a fuel element sub-assembly. In order to ensure the safe operation of a liquid metal cooled fast reactor, it is necessary to maintain constant surveillance of some parameters of the coolant flowing through at least some of the sub-assemblies. Such parameters may be, for example, temperature and rate of flow of coolant because an increase in temperature accompanied by a fall in the rate of flow may indicate the formation of a restriction to coolant flow through the sub-assembly. However, in a liquid metal cooled nuclear reactor having a large quantity, say 500, of monitored sub-assemblies, a multiplicity of sensors is required if each sub-assembly is to be monitored for a plurality of parameters and if a conventional redundancy technique whereby each instrument is installed three-fold is to be employed. For example, in a reactor core having 500 monitored sub-assemblies in each of which coolant temperature and rate of coolant flow is to be sensed or measured, a total of 3000 sensors would be required.

According to the invention, a liquid metal cooled nuclear reactor comprises a multiplicity of fuel element sub-assemblies through which fluid coolant can flow upwardly, at least some of the fuel element sub-assemblies being arranged to be monitored by instrument units, some of the monitored fuel element sub-assemblies each being arranged to feed a fraction of coolant flow to three instrument units and some of the instrument units each being arranged to sense the temperature and the rate of flow of a sample of coolant derived from three fuel element sub-assemblies, each instrument unit comprising a sleeve which defines a coolant flow duct and houses a sensing insrtument, the sleeve having a plurality of inlet ducts each arranged for receiving coolant flow from a fuel element sub-assembly and a single outlet. In such an arrangement of liquid metal cooled nuclear reactor each of the two parameters, temperature and rate of flow, can be sensed in relation to a sub-assembly by three instrument units.

The invention also resides in an instrument unit for sensing the temperature, and rate of liquid metal flow of a sample of coolant derived from a plurality of sub-assemblies of a liquid metal cooled nuclear reactor. A preferred instrument unit according to the invention comprises a sleeve housing a sensing instrument and having at least three inlet ducts and a single outlet, the sensing instrument having three thermocouple hot junctions connected in series, the hot junctions and inlet ducts being arranged in associated pairs, the hot junction of each pair being disposed for exposure to flow through the associated inlet duct, and electromagnetic windings about an inductive core arranged to sense variation in flow of liquid metal by flux distortion. The sensing instrument may also include a thermocouple disposed to sense the mean temperature of the sample flow of coolant derived from a plurality of sources whereby the temperature of coolant flow through a sub-assembly can be deduced from the three temperature readings associated with that sub-assembly.

The invention will be more clearly understood from the following description of nuclear reactor instrumentation given by way of example with reference to the diagrammatic drawings accompanying the Provisional Specification wherein:

Fig 1 is a fragmentary plan view of a nuclear reactor core,

Fig 2 is a fragmentary side view,

Fig 3 is a sectional view of a flow and temperature sensing instrument

Fig 4 is an end view of the instrument shown in Fig 3, and

Fig 5 is a detail of the sensing instrument drawn to a larger scale.

Figure 1 illustrates a fragment of a fast nuclear reactor core which is cooled by liquid sodium. The core comprises a multiplicity of fuel element sub-assemblies of hexagonal cross-section arranged side by side. The sub-assemblies comprise wrappers or shrouds containing clusters of fuel pins and the coolant flows upwardly over the fuel pins. To ensure the safety of the reactor a constant watch is maintained on the coolant flow so that any variables in the parameters (being pre-cursors of pending fault conditions) are detected sufficiently early to enable corrective action to be taken. The reactor core illustrated has a total of 500 fuel element sub-assemblies some of which are required to be monitored. Flow and temperature instrument units for monitoring fuel element sub-assemblies are provided and, referring now to Figure 2 each unit comprises a sensing instrument 1 housed in a sleeve 2 having inlet ducts 3 for receiving coolant flow from the central regions of three adjoining sub-assembly outlets. Typically, each sensing instrument is capable of sensing variations in the parameters of flow and temperature of a sample of coolant flow derived from the three adjoining sub-assemblies.

In Figure 1 the sub-assemblies are identified in rows, for example, 3.2, 4.2, 5.2, which are sub-assemblies 3, 4, and 5 in the horizontally shown row 2. The sensing stations are identified by characters Q, R and S in horizontally shown rows, for example Q2, R3, and the inlet ducts of the sleeves 2 are designated A, B and C. The instrument unit in station Q2 receives flow from each of sub-assemblies 3.2, 4.2, and 3.3 by way of inlet ducts Q2A, Q2B and Q2C respectively. From another aspect, the total sample flow from sub-assembly 3.3, for example, is shared between instrument units in stations Q2, R3 and Q3. A change of output temperature, say, from sub-assembly 3.3 is thereby sensed by the instrument units at stations Q2, R3, and Q3. It is still sensed if the instrument units in one or two out of three sensing stations fail. As shown in Fig 2 the sensing instrument 1 is suspended within the sleeve 2 and the proportional sample of coolant is forced through the annulus bounded by the sensing instrument 1 and the sleeve 2 to exhaust through an orifice 4 into a dome 5. The dome 5 has an outlet for conducting a sub-sample to fission product sensing means whilst the remainder of the sample derived from three sub-assemblies is discharged from the base of the dome 5.

The sensing instrument shown in Figures 3 and 4 comprises a flowmeter and a composite thermoelectric transient detector. A thermoelectric cable 6 (shown diagrammatically in Figure 5) has a conductor with ceramic insulation *6a* and stainless steel sheathing *6b* and the conductor comprises, in series, chromel and alumel sections *6c* and *6d* presenting three thermocouple hot junctions. The hot junctions are disposed at the nose of the unit in such a manner that they are each exposed to coolant flow through separate inlet ducts 3. The resultant electromagnetic force is the aggregate of the electromagnetic forces derived from the three thermocouples and is representative of the aggregate of the temperatures of the streams of coolant flowing through the three inlet ducts of the sleeve; a transient temperature of any one stream is indicated by the change of voltage at the terminals of the sensing instrument. The nose of the sensing instrument has three ribs *1a* for protecting the thermocouple hot junctions against damage and for engagement with a socket *1b* in the sleeve 2 to locate the hot junctions in the appropriate coolant streams. For measuring the mean velocity of the sodium flow through the annulus in the conventional manner the unit has electromagnetic windings 8 on a ferromagnetic core 9; the resultant flux distortion signal is proportional to the rate of flow through the annulus. At the rear of the sensing instrument one or more thermocouple hot junctions are mounted at 10 to provide an additional protective feature. The thermocouple 10 measures the mean temperature of the coolant sample passing along the annulus which reading (provided that the mean sample is made from three equal component samples) can be utilised in conjunction with mean temperature readings derived from adjoining sensing instruments for extraction of a common value, say, Ta. The value Ta is the steady-state value of a sub-assembly outlet temperature and is useful for process purposes and as a safety measurement to allow any slow blockage of the sub-assembly to be reliably detected.

The exhaust coolant flow from each

sleeve 2 contains a mean value of the fission products from three sub-assemblies and the representative sub-sample is passed to the counting system. The arrangement gives redundancy of fission product sampling points without loss of bulk detection sensitivity although it does, however, reduce the location sensitivity by a factor of 3.

WHAT WE CLAIM IS:

1. A liquid metal cooled nuclear reactor comprising a multiplicity of fuel element sub-assemblies through which coolant can flow upwardly, at least some of the fuel element sub-assemblies being arranged to be monitored by instrument units, some of the monitored fuel element sub-assemblies each being arranged to feed a fraction of coolant flow to three instrument units and some of the instrument units each being arranged to sense the temperature and the rate of flow of a sample of coolant derived from three fuel element sub-assemblies, each instrument unit comprising a sleeve which defines a coolant flow duct and houses a sensing instrument, the sleeve having a plurality of inlet ducts each arranged for receiving coolant flow from a fuel element sub-assembly and a single outlet.

2. A liquid metal cooled nuclear reactor according to claim 1 wherein coolant flow from the single outlet is directed into a dome member having an upper outlet for directing a sub-sample of coolant flow to fission product sensing means.

3. An instrument unit for a liquid metal cooled nuclear reactor according to either of claims 1 and 2, the instrument unit comprising a sleeve housing a sensing instrument and having three inlet ducts and a single outlet, the sensing instrument having three thermocouple hot junctions connected in series, the hot junctions and inlet ducts being arranged in associated pairs, the hot junction of each pair being disposed for exposure to flow through the associated inlet duct and electro-magnetic windings about an inductive core arranged to sense variation in flow of liquid metal by flux distortion.

4. An instrument unit according to claim 3 wherein the sensing instrument has a fourth thermocouple disposed for exposure to combined flows of coolant through the inlet ducts thereby to sense the mean temperature of the coolant flow through the sleeve.

5. A liquid metal cooled nuclear reactor substantially as hereinbefore described with reference to the drawings accompanying the Provisional Specification.

6. An instrument unit substantially as hereinbefore described with reference to the drawings accompanying the Provisional Specification.

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Agent for the Applicants.

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1 434 939 PROVISIONAL SPECIFICATION
2 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEET 1

FIG. 1.

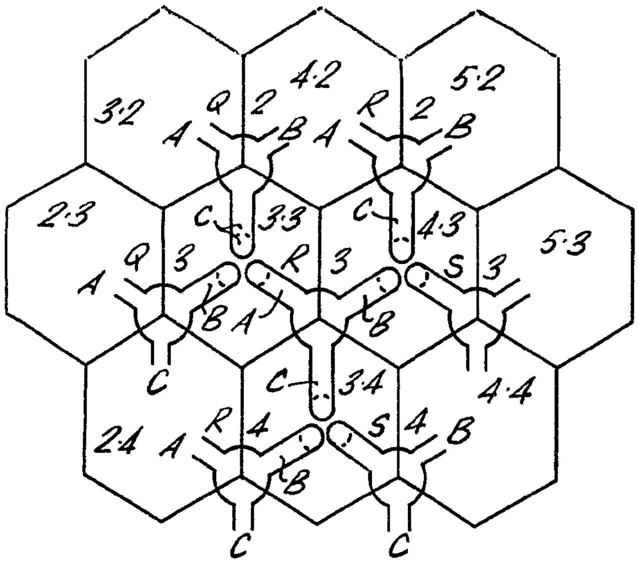
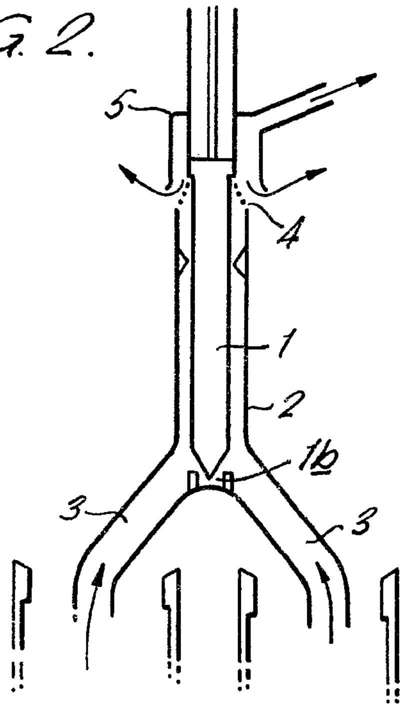


FIG. 2.



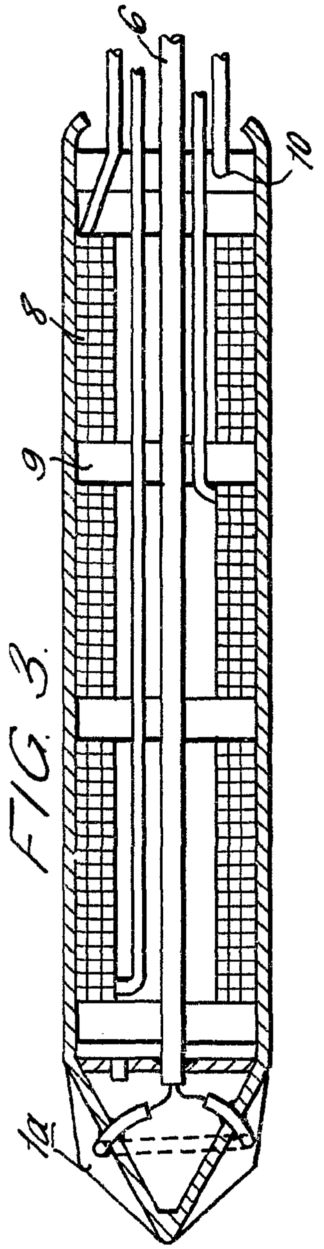


FIG. 3.

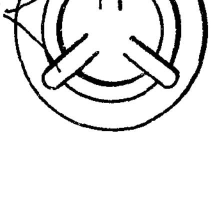


FIG. 4.

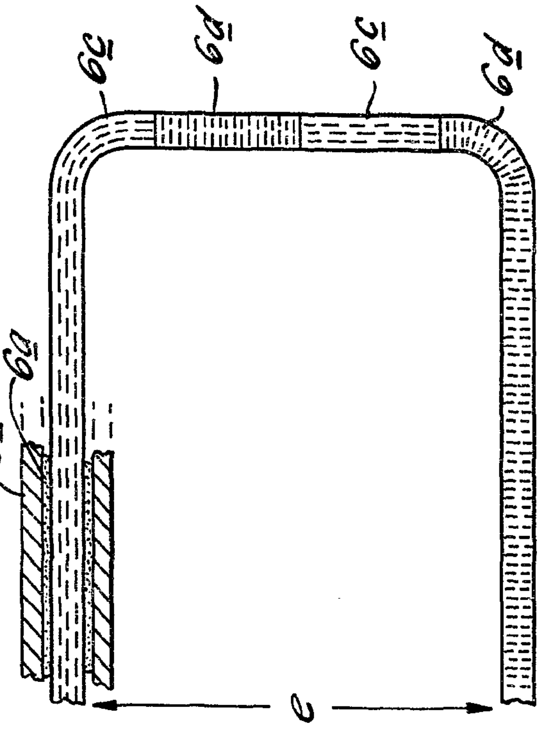


FIG. 5.