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(54) APPARATUS FOR PRODUCING AND MEASURING A UNIFORM TEMPERATURE IN A FLOWING MEDIUM

(71) We, INTERATOM, Internationale Atomreaktorbau GmbH, a German company, of 433 Mülheim (Ruhr), Wiesenstrasse 35, Germany (fed rep), 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 an apparatus for producing and measuring a uniform temperature in a flowing medium. It may be used, for example, for measuring the temperature of the coolant issuing from the fuel element of a nuclear reactor.

Where a uniform temperature exists over the entire cross-section of flow of a flowing medium, the measurement of a representative temperature generally presents no difficulty. If, however, zones of differing temperature exist in a flowing medium within the cross-section of flow, for example warmer or colder flow zones at the edge than at the centre, it is generally necessary either to use a plurality of temperature sensors and to provide for compensation of the measured results, or thoroughly to mix the flowing medium, for example by way of partial exchange of flow zones of the edge with those of the centre, before encountering one single temperature sensor, so as to obtain a representative temperature value as a measured result. A combination of the two measures is also conceivable.

Under special circumstances, however, namely where there is a non-uniform distribution of relatively warm zones and relatively cold zones and, moreover, possibly changing flow zones, over the cross-section of flow, measures of the aforesaid type are either not sufficient, not suitable and/or not applicable. An example of such a case is the measurement of a representative temperature of the coolant issuing from a fuel element of a nuclear reactor.

In the coolant which flows through between the rods, including the fuel or breeder rods, of the core elements of a nuclear reactor, and which subsequently issues from the core element, bands of different temperature occur where the output distribution in the core element is non-uniform and varies in dependence on the respective operating condition. This phenomenon may have very different causes. Thus, for example, the local disposition of the various core elements, such as fuel, breeder or absorber (control) elements in relation to one another which, moreover, changes, or the deformation of the rods, or some of the rods, or of the element casing in itself. In order to obtain a measurement of a representative temperature of the coolant under such circumstances by arranging a plurality of temperature sensors and compensating their measured results, it would virtually be necessary to abut temperature sensor with temperature sensor. For constructional and economic reasons this is impossible. Another possibility, therefore, is to provide one temperature sensor per core element, this then being disposed, together with a throughput sensor, on a guide tube for example, the guide tube and thus the temperature sensor also being able to deviate laterally relative to the axis of the core element. The temperature sensor thus comes into contact with different bands of flow so that the measured result cannot be termed representative and cannot adequately be used for monitoring purposes.

According to one aspect of the present invention there is provided an apparatus for producing and measuring a uniform temperature in a flowing medium, which apparatus comprises:

a tube having a single inlet and a single outlet for the flowing medium;

a swirl producing device positioned in the tube in the flow path of the flowing medium;

a swirl reducing device positioned in the tube in the flow path of the flowing medium and located so as to be downstream of the swirl producing device; and

a temperature sensor for measuring the temperature of the flowing medium downstream of the swirl reducing device.

Preferably, the swirl reducing stage is arranged directly behind the swirl producing stage.

The swirl producing stage may comprise essentially a swirl member formed of several spatially curved, preferably helical and substantially circularly symmetrically arranged guide plates.

In this way, pressure energy impinging on the front of the swirl member is converted into kinetic energy and this is converted back into pressure energy again in the swirl reducing device, distributed substantially over its length. In this way, with a slight overall energy loss and with relatively simple, and, moreover, stationary means, a thorough mixing of the flowing medium or coolant of all temperature bands is obtained with a very considerable degree of intermixing over the entire cross-section of flow. This means that both radial and axial shifts of the temperature sensor relative to the fuel element or the like have no effect on the temperature measurement and that the measured result actually shows the representative temperature prevailing in the flowing medium. The apparatus thus proves to be advantageously applicable and suitable for monitoring the operation of a nuclear reactor even where the requirements are very high.

To promote the swirl formation the blades are expediently disposed on a hub which may be streamlined so as to minimise turbulence.

The swirl reducing device may be formed from several inclined ribs, spines, rods or narrow blades extending perpendicular to the direction of flow.

According to an embodiment of the invention, the swirl reducing device includes ribs which extend substantially from the axis of the flow cross-section or tube in a radial direction, preferably until close to or abutting the wall of the tube, the ribs, or a section of the ribs, being arranged on a rearward, relative to the direction of flow, extension of the streamlined hub, preferably an extension with a cross-section smaller than that of the hub, and the ribs being arranged radially of the axis and axially spaced successively in sets in the direction of flow, the ribs having a substantially planar cross-section in width and are aligned at an angle of incidence inclined to the direction of flow and are designed to be adjusted where necessary, the ribs also having narrow faces, one or both of which, lie substantially in planes perpendicular to the axis. The ribs and the pitch of the guide plates of the swirl producing stage are constructed with like or/and differing angles of incidence with the pitch of the blades preferably opposed to one another. The ribs of the swirl reducing stage are constructed alike as regards the angle of incidence and the pitch direction or/and different in sections, but are preferably constructed to be the same or similar in each set. Particular importance for the mixing effect is attached to the two latter of the aforementioned measures.

According to a further development of the invention the swirl reducing stage may have a greater length than the swirl producing stage.

Consequently the conversion of the swirl energy into pressure energy is distributed over a relatively large axial section in relation to the swirl producing stage, and this is thus effected gradually. It is important here, together with the already mentioned measures, to obtain a high degree of mixing efficiency and yet, at the same time, to avoid disadvantageous effects, such as the occurrence of cavitation.

Finally it is also proposed that the swirl producing stage and the swirl reducing stage may be accommodated in a tube which is matched in its lower section in a funnel-like manner to the cross-section of the housing of the core element of a nuclear reactor, in or near the element head, and that in addition a compensating section or stage in the form of a flow duct free of fitted components, is provided between the swirl reducing stage and the temperature sensor within the core element head.

For a better understanding of the present invention and to show more clearly how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:—

Figure 1 shows an apparatus according to the present invention for producing and measuring a uniform temperature in a flowing medium; and

Figure 2 shows an apparatus, similar to that shown in Figure 1 but on a smaller scale, for measuring the temperature of the coolant issuing from the core element of a nuclear reactor.

Figure 1 shows an apparatus for use in the measurement of a representative temperature in a flowing medium, which device comprises a swirl producing stage A with a swirl member 1 and a swirl reducing stage B with a correcting device 2. The stages A and B are provided in the flow cross-section of a flowing medium or, in the case of a nuclear reactor, of a flowing coolant and are arranged one behind the other, the stage B being downstream of the stage A. The stages A and B are bounded by a wall of a tube 3^1 or by a sleeve 3 (Figure 2). The swirl reducing stage B is here disposed directly after the swirl producing stage.

In Figure 2, the same reference numerals are used to indicate similar parts to those shown in Figure 1. According to Figure 2, the apparatus is accommodated in a sleeve 3 and the sleeve is accommodated in the top section 41 of a core element 4 above the core element rod bundles 42—also containing other element rods—the lower section of the sleeve 3 being matched in funnel like manner to the hexagonal shape of a fuel element encasing housing 43. A compensating section or stage

C which is free from fitted components is disposed downstream of the swirl reducing stage B. Substantially at the end of the stage C there is located a temperature sensor 5, specifically for the purpose of measuring the representative temperature of the flowing medium, issuing from the core element 4 or from the rod bundles 42. The temperature sensor 5 is disposed on the lowest end of a guide tube 6 which is also provded with a throughput sensor 7. The arrows in Figure 2 illustrate the relative changes in position which can occur, during operation, between the core element 4 and the temperature sensor. In order to obtain a representative temperature as a measured result it is a prerequisite that these changes in position remain without any effect on the measured result.

The swirl producing stage A essentially comprises several spatially curved, in other words helical and circularly symmetrically arranged blades 11, which are disposed on a streamlined hub 12 and these together represent the swirl member 1.

The swirl reducing stage B or correcting device 2 is formed of several ribs 21 which extend from the axis of the flow cross-section or duct, in a radial direction, up to the wall of the tube 3^1 or the sleeve 3 and are arranged in sets behind one another in the direction of flow, in planes radial to the axis, and are attached to a rearward extension 22 of the hub 12—if applicable adapted to be wholly or partly rotatable or adjustable about its longitudinal axis, this not being illustrated further. The ribs 21 have a substantially flat cross-section in width, their narrow edges 211 lie in planes perpendicular to the axis. Of particular importance for the swirl reducing effect changing kinetic into pressure energy, is the angle of incidence, inclined to the flow or stream direction, which is opposed to the pitch of the blades 11 of the swirl producing stage.

The swirl reducing stage B has—in the direction of flow—a greater length than the swirl producing stage A, so that the swirl or kinetic energy is very gradually changed back into pressure energy again. With this procedure of firstly converting the pressure energy relatively quickly into swirl energy and then converting this back into pressure energy again relatively slowly, the efficientlcy of mixing depends to a great extent on obtaining a very good mixing effect both in the radial and in the axial directions of the tube.

By varying the determinant parameters, such as the angle of emergence of the blades of the swirl member, shape(s), arrangements, number, position and angle of incidence of the ribs, and cross-sections of the ribs in the correcting or pressure reducing stage, the pressure loss and a maximum variation of the temperature at the temperature sensor from an actual mean temperature can be determined or kept so low that in practice they have no disadvantageous effect.

WHAT WE CLAIM IS:—

1. An apparatus for producing and measuring a uniform temperature in a flowing medium, which apparatus comprises:

a tube having a single inlet and a single outlet for the flowing medium;

a swirl producing device positioned in the tube in the flowpath of the flowing medium;

a swirl reducing device positioned in the tube in the flowpath of the flowing medium and located so as to be downstream of the swirl producing device; and

a temperature sensor for measuring the temperature of the flowing medium downstream of the swirl reducing device.

2. An apparatus as claimed in claim 1, wherein the swirl reducing device is located immediately downstream of the swirl producing device.

3. An apparatus as claimed in claim 1 or 2, wherein the swirl producing device comprises a swirl member formed of a plurality of spatially curved guide plates.

4. An apparatus as claimed in claim 3, wherein the guide plates are helical and are arranged symmetrically about the axis of the tube.

5. An apparatus as claimed in claim 3 or 4, wherein the guide plates are mounted on a hub.

6. An apparatus as claimed in claim 5, wherein the hub is shaped so as to minimise turbulence in the medium flowing past the hub.

7. An apparatus as claimed in any preceding claim, wherein the swirl reducing device comprises a plurality of radially extending ribs which are inclined to the direction of flow of the flowing medium.

8. An apparatus as claimed in claim 7, wherein the ribs extend from the axis of the tube and abut against the wall thereof.

9. An apparatus as claimed in claim 7 or 8, when appendant to claim 5 or 6, wherein the ribs are arranged on the hub.

10. An apparatus as claimed in claim 9, wherein that portion of the hub on which the ribs are arranged has a smaller diameter than that portion on which the guide plates are arranged.

11. An apparatus as claimed in any one of claims 7 to 10, wherein the ribs are arranged in successive sets in the direction of flow.

12. An apparatus as claimed in any one of claims 7 to 11, wherein the ribs have a substantially plane cross-section in width and are aligned at an angle of incidence inclined to the direction of flow.

13. An apparatus as claimed in any one of claims 7 to 12, wherein the ribs are constructed to be adjustable.

14. An apparatus as claimed in claim 12

or 13, wherein the ribs have radially different angles of incidence.

15. An apparatus as claimed in claim 12, 13 or 14, wherein one or both narrow edges of the ribs lie in planes normal to the axis of the tube.

16. An apparatus as claimed in any one of claims 7 to 15, when appendant to claim 3, 4, 5 or 6, wherein the guide plates of the swirl producing device are inclined relative to the ribs of the swirl reducing device.

17. An apparatus as claimed in any preceding claim, wherein the swirl reducing device extends in the direction of flow for a greater distance than the swirl producing device.

18. An apparatus as claimed in any preceding claim, wherein the tube includes a compensating section free from fitted components, the compensating section being located downstream of the swirl reducing stage and upstream of the temperature sensor.

19. An apparatus substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

20. In combination with a nuclear reactor, an apparatus as claimed in any preceding claim, wherein the tube is located so as to be adjacent to the head of a fuel element.

21. A combination as claimed in claim 19, wherein a portion of the tube is funnel shaped so as to match the cross-section of a housing for the fuel element.

22. A combination substantially as hereinbefore described with reference to the accompanying drawings.

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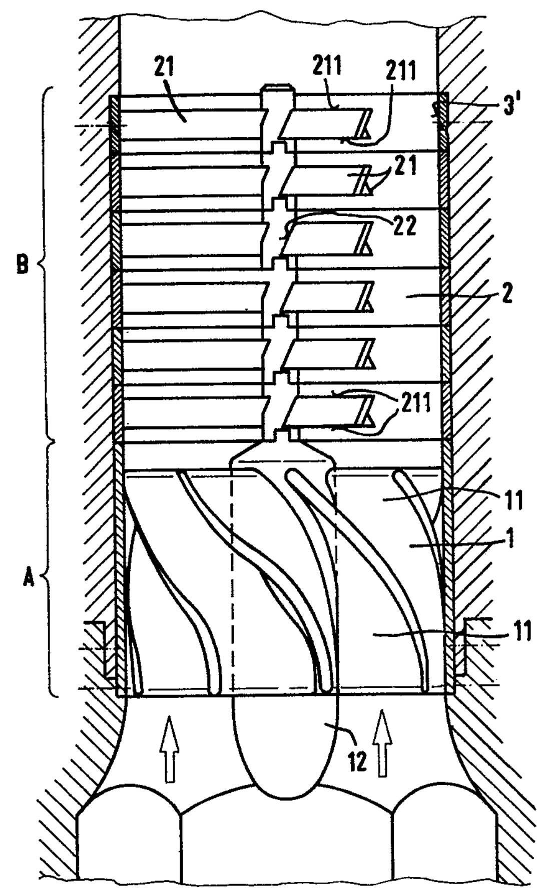

Fig. 1

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2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

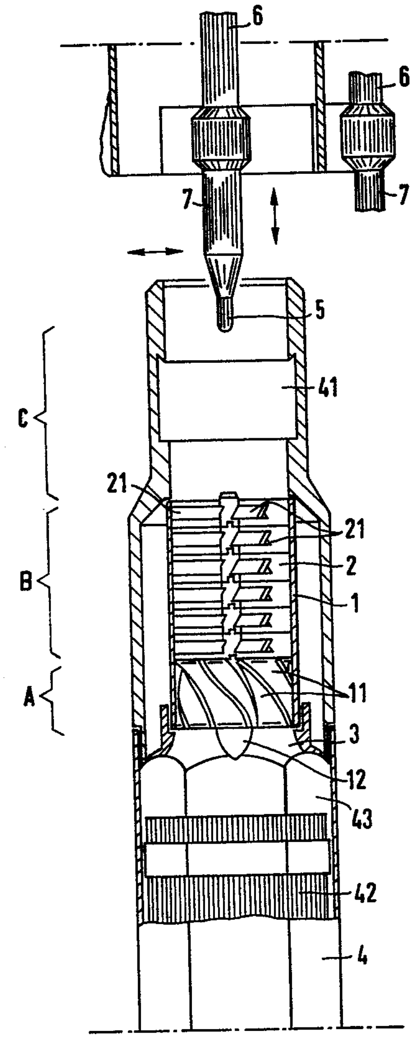

Fig. 2