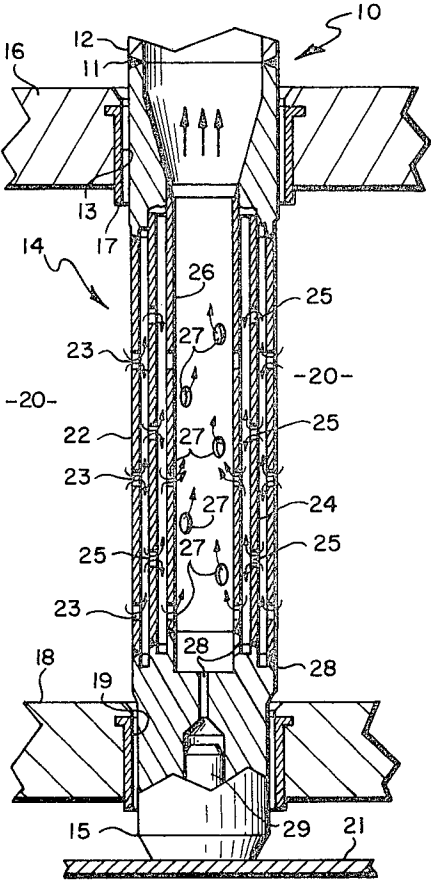


[54]	FLOW-THROTTLING ORIFICE NOZZLE	3,373,082	3/1968	Dahlgren	176/44
[75]	Inventor: Harold L. Sletten, Northridge, Calif.	3,383,287	5/1968	Jackson	176/78
[73]	Assignee: Rockwell International Corporation, El Segundo, Calif.	Primary Examiner—Leland A. Sebastian			
		Assistant Examiner—Roger S. Gaither			
		Attorney, Agent, or Firm—L. Lee Humphries; Henry Kolin			
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[51]	Int. Cl.	G21c 15/22, G21c 15/24			
[58]	Field of Search	176/40, 44, 54, 60, 61, 176/78, 64, 57, 65			

[56]	References Cited				
	UNITED STATES PATENTS				
3,235,465	2/1966	McDaniel et al.	176/64		
3,281,326	10/1966	Hargo	176/78		
3,368,946	2/1968	Jenssen	176/78		

[57] **ABSTRACT**
A series-parallel-flow type throttling apparatus to restrict coolant flow to certain fuel assemblies of a nuclear reactor is comprised of an axial extension nozzle of the fuel assembly, the nozzle having a series of concentric tubes with parallel-flow orifice holes in each tube. Flow passes from a high pressure plenum chamber outside the nozzle through the holes in each tube in series to the inside of the innermost tube where the coolant, having dissipated most of its pressure, flows axially to the fuel element.

6 Claims, 4 Drawing Figures



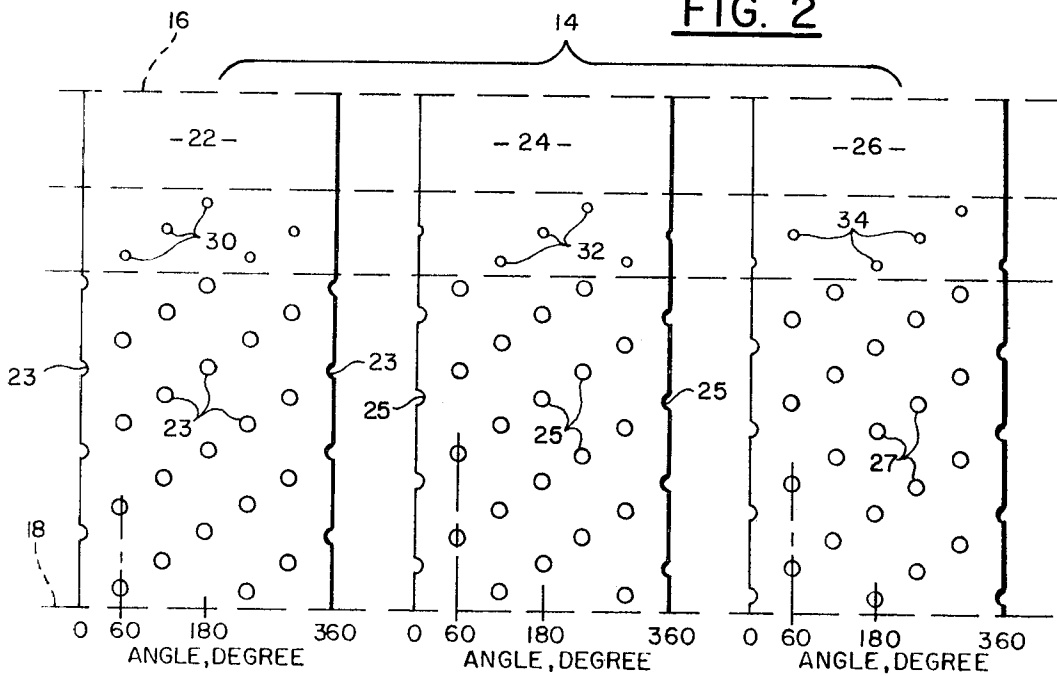
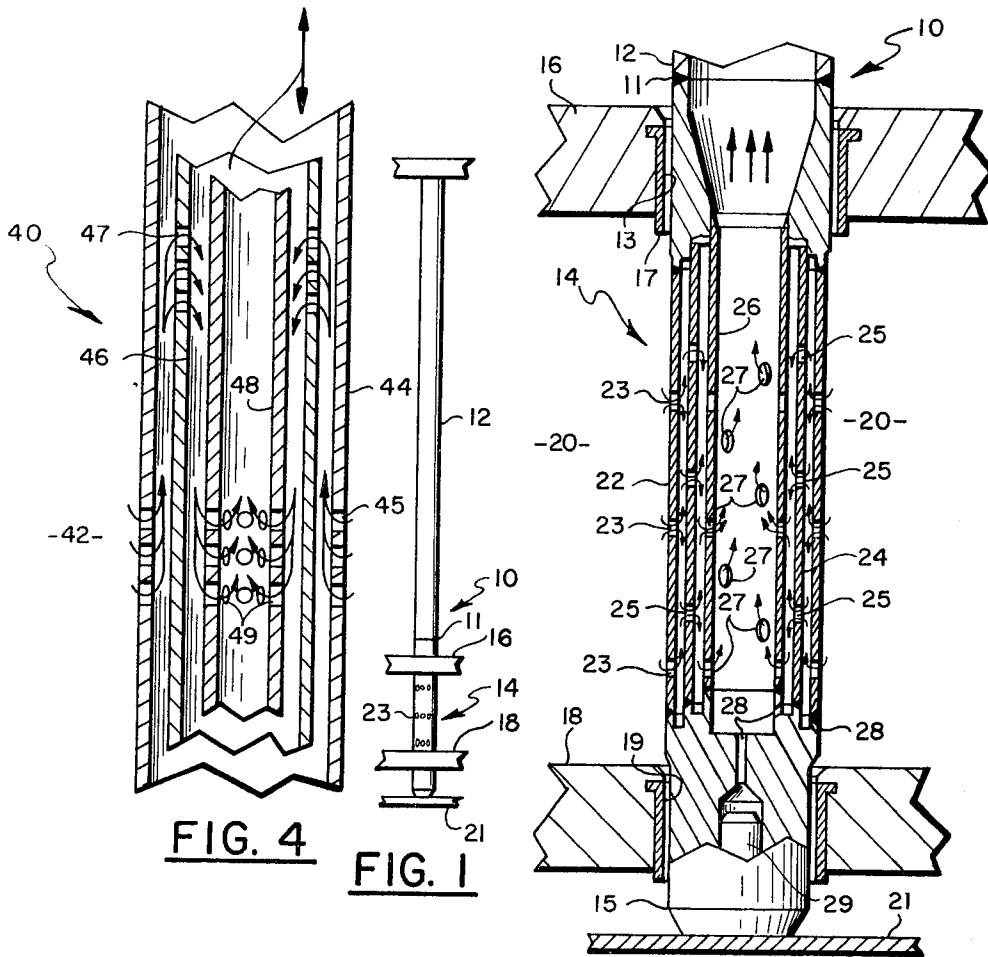


FIG. 3

FLOW-THROTTLING ORIFICE NOZZLE**BACKGROUND OF THE INVENTION****1. FIELD OF THE INVENTION**

In nuclear reactors, particularly the fast breeder type, coolant is supplied to the fuel assemblies generally from a high pressure plenum. A throttling device must be utilized to satisfy the requirement of low flow in some fuel assemblies operating at low power and low pressure loss. It is necessary to reduce the high pressure of the coolant in the high pressure plenum prior to entering the fuel element region of the fuel assembly. The throttling device must dissipate most of the high pressure energy in order to limit flow rate to the low power fuel assemblies and at the same time provide sufficient flow area and parallel flow paths to minimize the chance of plugging the entrance to the fuel assemblies.

2. DESCRIPTION OF THE PRIOR ART

There are many flow control or throttling devices in the prior art. An example of a flow control throttling device is found in U.S. Pat. No. 3,545,492. This device provides a series of orifice plates in a conduit, each of the orifice plates being positioned radially transverse to the axis of the conduit. The series of orifice plates are spaced apart, one from the other, the upstream orifice plate having a single orifice therein, the opening being fairly large. The second downstream orifice plate has two orifices therein, each orifice being smaller in diameter than the single orifice in the first orifice plate. The third, fourth, and fifth orifice plates each have more and more apertures therein as they progress sequentially down the conduit. This device is primarily a means to prevent the cavitation of liquids within a conduit. The axes of the orifice are displaced radially and circumferentially about the plate centers so as to be in misalignment with the axes of the orifices in adjacent plates. The object of the device is primarily to minimize the pressure drop while preventing cavitation. The instant invention maximizes pressure drop to maintain low flow through a fuel assembly.

Another example, U.S. Pat. No. 3,368,946, provides a means to cool a fuel assembly in a nuclear reactor. Flow enters the region of the fuel elements in a path parallel to the length of the fuel elements. Flow enters a central opening axially aligned with the fuel elements and impacts a parabolically shaped inner body, the narrow crown being positioned adjacent the inlet so that the fuel impacts the parabolic object and is diverted along the axial length of the body, thus directing or diverting the coolant flow substantially radially towards the surrounding fuel elements. A perforated cylinder outwardly of the concentrically aligned fuel elements provides an outlet path for the coolant flow passing through the fuel element rods. Thus, the coolant flow flows through the inner space of the fuel body in a partly longitudinal and partly transverse direction. It is important to note that there is a little pressure drop in the foregoing device. The system would not dissipate high pressure or act to throttle the incoming flow, as does the present invention.

Yet another example within the prior art of a cooling device is found in U.S. Pat. No. 3,114,798. This patent discloses a means to cool a remote television camera that is monitoring a nuclear reactor. The components of the television camera are housed within a cylindrical body which has, surrounding the body, a series of concentric perforated tubes. The whole assembly is en-

cased in a cylindrical body. Coolant enters the outer casing through an annulus formed by the outer casing and the first perforated cylinder. The inner cylinder has along one side a series of equidistantly spaced holes aligned axially opposite the opening in the outer casing. The entering coolant subsequently enters through the perforations in the first inner cylinder into an annular space formed by the first inner cylinder and an adjacent perforated cylinder inwardly positioned. The second perforated cylinder has a series of aligned apertures therethrough, the apertures being axially positioned opposite to the perforations in the first inner cylinder so that the coolant flow must again traverse the entire annulus formed by the first inner cylinder and the second inner cylinder. Thus, the coolant cools the entire periphery of the second inner cylinder, and so on. The entire assembly protects the inner cylinder housing the television camera from the high temperatures surrounding the camera. The cooling system does not throttle or lessen the incoming fluid pressure as does the apparatus of the instant invention. The system is used primarily to shield a television camera from a thermal and radiation environment.

SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide a method and apparatus to restrict coolant flow to the low power fuel assemblies in a nuclear reactor.

More specifically, it is an object of this invention to provide a series of concentric tubes with parallel flow orifice holes in each tube that are not aligned, thus providing a tortuous path for the coolant flow between concentric tubes which provides a pressure drop from tube to tube.

A particular type of flow throttling device herein described has specific design characteristics that satisfy the requirements that are peculiar to certain types of fuel assemblies such as the "radial blanket" type of fuel assemblies associated with the fast breeder reactor. These fuel assemblies have low power relative to the primary fuel assemblies of the reactor and obtain their supply of coolant from a common source, which is the high pressure plenum chamber. The present invention provides a throttling device that dissipates most of this high pressure energy inherent in the high pressure plenum in order to limit the flow rate to these fuel assemblies and at the same time provide sufficient flow area and parallel flow paths to minimize the chance of plugging the entrance to the fuel assembly.

A series-parallel combination of flow paths in an inlet nozzle extension of the assembly is provided by this throttling device which consists of a number of concentric tubes with orifice holes therein. The tube diameters are chosen to provide an annular space or chamber for flow between adjacent tubes. This space is closed at the ends and all flow must pass in series through one tube to the next from outside the nozzle to inside of the innermost tube where it flows axially to cool the nuclear fuel elements in the interior of the fuel assembly. The apertures in each of the concentric tubes adjacent one another are not aligned, requiring that the fluid make at least two turns and travel a maximum distance axially and circumferentially in the annular space or chamber between tubes. The net result of the non-aligned holes in each of the concentric tubes is that the flow is turned first upwardly between the outer tube and the middle tube, then downwardly between the

middle tube and the inner tube, which would add hydraulic resistance to satisfy specific pressure drop and flow rate requirements. The essential feature of the invention is that it utilizes concentric cylindrical shells as an integral part of an inlet nozzle for a nuclear fuel assembly to provide series and parallel flow throttling.

An advantage over the prior art is the ability to dissipate high pressure energy through the throttling device while maintaining the pressure high in the chamber surrounding the device.

Another advantage over the prior art is realized in that there is a larger flow area and number of parallel inlet ports provided which greatly reduce the chances of plugging the entrance to the assembly should there be debris in the coolant system.

Yet another advantage is realized in that the design conforms very well to the inlet coolant system of a nuclear reactor of which there are many fuel assemblies in parallel supplied by the device of the present invention, the fuel assemblies being in close proximity in the limited space of a high pressure inlet plenum chamber.

Still another advantage over the prior art is realized in that the multiple concentric tube concept will add stiffness in handling to an extension nozzle of a fuel assembly and therefore will give the assembly more lateral support.

The above noted objects and advantages of the present invention will be more fully understood upon a study of the following description in conjunction with the detailed drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an overall view of a fuel assembly with a nozzle extension attached thereto;

FIG. 2 is a cross sectional view of the nozzle extension, the extension being immersed in a high pressure plenum chamber between a pair of grid plates;

FIG. 3 is a developed view of a typical throttling device with three tube sections representing each of three concentric tubes, each developed tube section having apertures therein that are non-aligned when compared to an adjacent tube section; and

FIG. 4 is a cross sectional view of an alternative embodiment illustrating another array of orifices in each concentric tube.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning now to FIG. 1, the fuel assembly generally designated as 10 is comprised of a fuel assembly housing 12, which generally encases fuel elements consisting of a bundle of fuel rods. The fuel assembly 10 is further comprised of an extension nozzle generally designated as 14, which is metallurgically bonded or otherwise fixed to the fuel assembly housing at joint 11. For example, the extension nozzle 14, positioned between the grid plates 16 and 18, makes up approximately one-sixth of the total fuel assembly length. However, the relative nozzle length need not be limited to the foregoing example. The fuel assemblies, less the extension nozzle herein described, are well known in the art.

FIG. 2 illustrates the elongated housing or extension nozzle 14 which extends through an upper grid plate 16, through bearing sleeve 13. The bottom 15 of extension nozzle 14 extends through a lower grid plate 18, through bearing sleeve 19. The base 15 of extension nozzle 14 terminates adjacent a base plate 21. The ex-

tension nozzle is keyed in position by a pin 29 connected to base plate 21. The nozzle 14, comprised of an outer concentric tube or housing 22, has in an ordered array, a series of orifices 23 therein equidistantly spaced about the periphery of outer tube 22. Inwardly of and spaced from outer tube 22 is a middle concentric tube 24. Middle tube 24 has a series of orifices 25 through the tube, the orifices being equidistantly spaced about the periphery of tube 24 in ordered arrays. An inner concentric tube 26 is spaced from the middle tube 24, the inner tube 26 having a similar series of orifices 27 through the inner tube 26.

Each of the concentric tubes 22, 24, and 26 are so positioned in housing 14 so that each orifice 23, 25, and 27 does not align one with another.

The space between the upper grid plate 16 and the lower grid plate 18 defines a high pressure plenum chamber 20 which is normally filled, for example, with liquid sodium, liquid sodium being an excellent medium for carrying away heat generated by the nuclear reactor. The high pressure plenum chamber 20 maintains a total pressure differential of approximately 100 psi relative to the pressure above or at the outlet of fuel assembly 10. The pressure differential then must be compensated for in order to properly cool the fuel element assemblies 10. Liquid sodium coolant enters through the outer concentric tube 22 through orifices 23. Since the orifices 23 do not align with the orifices 25 in the middle concentric tube 24, the coolant fluid must then either traverse axially upwardly or downwardly to traverse across the middle tube 24. Once the liquid sodium coolant enters the chamber defined by the middle tube 24 and the inner tube 26, the fluid must then again either traverse axially upwardly or downwardly to find access to orifices 27 in the inner tube 26. The number and size of the orifices in each concentric tube 22, 24, and 26 are so configured as to dissipate approximately 95 percent of the pressure energy available from the high pressure plenum 20. For example, if the depth of the high pressure plenum chamber is thirty inches between the upper grid plate 16 and the lower grid plate 18, the pressure is 100 psi and the outer tube 22 is 3 3/4 inches O.D., the middle tube 3 inches O.D., and the inner tube 2 1/4 inches O.D., with a nominal wall thickness of 0.120 inch for each tube, then each tube would have 24 1/4 inch holes and five 3/16 inch holes in each of the concentric tubes 22, 24, and 26. When the foregoing parameters are utilized, then approximately 95 percent of the 100 psi is dissipated through the fuel assembly extension 14. An additional means of varying the flow of high pressure liquid sodium to different fuel assemblies utilizing this throttling device would be to extend the skirt portion 17 of bearing sleeve 13 axially over the outer concentric tube 22. The length of the skirt depends on the amount of restriction required to limit the flow into the throttling device and fuel assembly. The skirt or bearing 13 is provided for the following reason. Since there is also a pressure differential of 100 psi across the upper grid plate 16, a potential leak path is provided between the interior bearing surface of the sleeve 13 and the outer casing 12. Leakage of sodium through the leak path just described could cause corrosive disintegration of the surface of the sleeve, thus a means must be provided to replace the sleeve rather than to replace the upper grid plate 16. Orifices 28, near the bottom of the fuel assembly 14, are drain holes to allow drainage of the fluid trapped between

tubes during removal of the fuel assembly 10 from the reactor.

Turning now to FIG. 3, the developed view of each of the concentric tubes 22, 24, and 26 clearly show the hole patterns in ordered array in each of the concentric tubes. It can be readily seen that orifices 23 in the outer tube 22 do not align with the orifices 25 in the middle tube 24, and similarly, the orifices in the middle tube do not align with the orifices 27 in the inner tube 26 when viewed through the same direction, for example, the 60° angular position in each of the concentric tubes. Thus, liquid sodium is forced to traverse axially in series from one annular gap to another annular gap defined by the concentric tubes. The tortuous path thus dissipates the pressure in the high pressure plenum chamber 20. The orifices 30, 32, and 34 are the smaller orifices in each of the concentric tubes 22, 24, and 26. The reduction in size of the orifices 30, 32, and 34 is a means to arrive at the total area of opening or number of orifices necessary to dissipate the high pressure. The hole size distribution is relatively non-critical as long as there are sufficient numbers of orifices to minimize the chances of plugging, yet dissipate the pressure energy.

Referring now to the alternative view as shown in FIG. 4, the groups of orifices 45, 47, and 49 are arrayed in sections or groups, for example, the group of orifices 45 in outer concentric tube 44 are positioned towards the bottom of the tube 44 to cause the liquid sodium from high pressure plenum chamber 42 to traverse axially upwardly towards the group of orifices 47 positioned near the top of the concentric middle tube 46, the fluid then subsequently turns downwardly to traverse through the group of orifices 49 near the bottom of the inner tube 48. Thus, the liquid sodium is caused to move unidirectionally axially and in series between the annular space defined by the concentric tubes 44, 46, and 48. The extension nozzle 40 offers an advantage in that the groups of orifices 47 in the middle concentric tube 46 may be displaced axially farther from the groups of orifices 45 and 49 in the outer tube 44 and the inner tube 48, by mechanically translating tube 46 (not shown) axially between tubes 44 and 48. A valving action is thus provided to either increase or decrease the flow through the throttling device. Thus, the extension 40 may act as a flow control valve.

The nozzle extension hereinabove described need not be limited to three concentric tubes, obviously, two or more tubes may be utilized while remaining within the scope of this invention.

I claim:

1. In a nuclear reactor having at least a primary fuel assembly and at least a low power fuel assembly relative thereto, said assemblies obtaining their supply of coolant from a common high pressure plenum chamber of said reactor,

a flow-throttling nozzle communicating said coolant flow from said high pressure plenum chamber of said reactor through said nozzle to an array of fuel elements of said relatively low power fuel assembly, said fuel elements being located downstream from the coolant flow leaving said nozzle, while dissipating a high pressure differential between said plenum chamber and said array of fuel elements so as to substantially reduce the rate of coolant flow from said plenum chamber through said nozzle to said array of fuel elements, said nozzle comprising:

a first elongated housing spaced between a pair of grid plates, said grid plates defining said high pressure plenum chamber, said housing forming a plurality of orifices therethrough, said orifices extending around said housing in spaced and ordered arrays, and

at least a second elongated housing spaced from and positioned within said first housing to provide a continuous annular space defining a continuous fluid flow path within said annulus of said nozzle, said second housing forming a plurality of orifices therethrough, said orifices extending around said housing in spaced, ordered arrays, said arrays being positioned out of alignment in both an axial and circumferential direction with respect to said arrays of said orifices as defined by said first elongated housing,

whereby fluid is caused to follow a tortuous path in series from said first elongated housing circumferentially and axially through said continuous annular space and then through said second elongated housing, said plurality of orifices in said first and second housing being so sized and positioned as to minimize their plugging by debris in the coolant while still serving to dissipate said high pressure differential between said high pressure plenum and said array of fuel elements so as to provide a substantial reduction in the rate of coolant flow through said nozzle to said array of fuel elements.

2. A flow throttling device for use in a nuclear reactor to dissipate a high pressure differential between a plenum chamber and an array of fuel elements comprising:

a first elongated housing spaced between a pair of grid plates, said grid plates defining a high pressure plenum chamber, said housing forming a plurality of orifices therethrough, said orifices extending completely around said housing in equidistantly spaced and ordered arrays,

a second elongated housing spaced from and positioned within said first housing, said second housing forming a plurality of orifices therethrough, said orifices extending completely around said housing in equidistantly spaced, ordered arrays, said arrays being positioned out of alignment with said arrays of said orifices defined by said first elongated housing, and

a third elongated housing spaced from and positioned within said second elongated housing, said third housing forming a plurality of orifices therethrough, said orifices extending completely around said housing in equidistantly spaced, ordered arrays, said arrays being positioned out of alignment with said arrays of orifices in said second elongated housing, whereby fluid is caused to follow a tortuous path in series from said first elongated housing through said third elongated housing, thereby dissipating said high pressure differential between said high pressure plenum and said array of fuel elements.

3. The invention as set forth in claim 2, wherein said first, second, and third elongated housings comprise three concentric tubes.

4. The invention as set forth in claim 2, wherein said orifices defined by said first elongated housing are in a group positioned at one end of said first housing, said orifices defined by said second elongated housing posi-

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tioned within said first housing are in a group positioned at an end opposite to said group of orifices in said first housing, and said orifices defined by said third elongated housing positioned within said second housing are in a group positioned at an end opposite to said group of orifices in said second housing, whereby fluid is caused to pass through said first array of orifices in said first housing, then axially traverse an annulus between said first and second elongated housings through said group of orifices positioned in said second housing, thence axially traverse an annulus between said second and third elongated housings through said group of orifices positioned in said third housing, thereby dissipating the pressure differential between said high pressure plenum and the array of fuel elements.

5. The invention as set forth in claim 4, wherein said second elongated housing is axially translatable relative to said first and third elongated housings, thereby positioning said group of orifices defined by said second housing away from or towards said group of orifices in said first and third housings, thus regulating the flow of fluid through said throttling device.

6. A flow-throttling device for use in a nuclear reactor to dissipate a high pressure differential between a plenum chamber and an array of fuel elements comprising:

a first elongated housing spaced between a pair of grid plates, said grid plates defining a high pressure

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plenum chamber, said housing forming a plurality of orifices therethrough, said orifices extending around said housing in spaced and ordered arrays, and

at least a second elongated housing spaced from and positioned within said first housing to provide an annular space defining a fluid flow path, said second housing forming a plurality of orifices therethrough, said orifices extending around said housing in spaced, ordered arrays, said arrays being positioned out of alignment with said arrays of said orifices defined by said first elongated housing, whereby fluid is caused to follow a tortuous path in series from said first elongated housing circumferentially and axially through said annular space and then through said second elongated housing, thereby dissipating said high pressure differential between said high pressure plenum and said array of fuel elements.

said flow-throttling device further comprising an annular sleeve spaced from and surrounding said first elongated housing, said sleeve being connected to one of said grid plates at its base, said annular sleeve extending axially part way over said first elongated housing to further restrict flow of said fluid into said first housing.

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