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Le commissaire aux brevets a reçu une demande de délivrance de brevet visant une invention. Ladite requête satisfait aux exigences de la *Loi sur les brevets*. Le titre et la description de l'invention figurent dans le mémoire descriptif, dont une copie fait partie intégrante du présent document.

Le présent brevet confère à son titulaire et à ses représentants légaux, pour une période expirant vingt ans à compter de la date du dépôt de la demande au Canada, le droit, la faculté et le privilège exclusif de fabriquer, construire, exploiter et vendre à d'autres, pour qu'ils l'exploitent, l'objet de l'invention, sauf jugement en l'espèce rendu par un tribunal compétent, et sous réserve du paiement des taxes périodiques.

The Commissioner of Patents has received a petition for the grant of a patent for an invention. The requirements of the *Patent Act* have been complied with. The title and a description of the invention are contained in the specification, a copy of which forms an integral part of this document.

The present patent grants to its owner and to the legal representatives of its owner, for a term which expires twenty years from the filing date of the application in Canada, the exclusive right, privilege and liberty of making, constructing and using the invention and selling it to others to be used, subject to adjudication before any court of competent jurisdiction, and subject to the payment of maintenance fees.

BREVET CANADIEN 2,307,402 CANADIAN PATENT

Date à laquelle le brevet a été accordé et délivré	2012/03/20	Date on which the patent was granted and issued
Date du dépôt de la demande	2000/05/02	Filing date of the application
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Commissaire aux brevets / Commissioner of Patents

Canada

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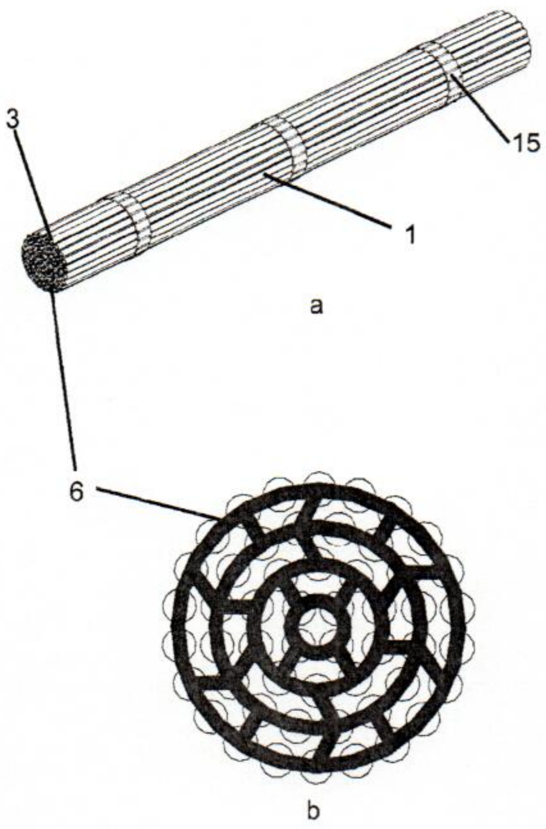
(54) Title: MODULAR FUEL ELEMENT ADAPTABLE TO DIFFERENT NUCLEAR POWER PLANTS WITH COOLING CHANNELS



(57) Abrégé/Abstract:
The present invention relates to a modular nuclear fuel element, which can be adapted by an assembly system allowing it to be used in different nuclear power plants with horizontal and vertical cooling channels. The module is a cluster of parallel fuel rods

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(57) Abrégé(suite)/Abstract(continued):

mounted as circular concentric crowns and supported by a structural system. It has a single diameter fuel rod array where the ratio of the heat transfer surface defined per unit length to the transverse rod cross section is higher than 330. It also has self-supporting fuel element spacer grids, which are collapsible sheaths attached to them with fewer than 13 welded end stoppers. The number of these fuel rods is higher than 43. The length of the module is the largest compatible length with the refuelling machine, to reduce the hydraulic restrictions caused by structural endings, and to be able to balance this by providing a fuel element having a larger cooling area. This will maintain the hydraulic restriction and the current total fuel mass in the channel. The modular fuel element may contain fuel material combinations with different uranium and/or plutonium isotopic concentrations, and/or any other nuclear fuel material (actinides, nuclear poisons, fission products or fuel material coming from other nuclear reactors). The utilisation of the fuel modules individually in the pressurised heavy water reactors with horizontal fuel channels is an application of the present invention. Another application would involve the assembling of several fuel modules in nuclear reactors with vertical fuel channels.

The present invention relates to a modular nuclear fuel element, which can be adapted by an assembly system allowing it to be used in different nuclear power plants with cooling channels. The module is a cluster of parallel fuel rods mounted as circular concentric rings and supported by a structural system. This assembly system in turn makes it possible to arrange a group of fuel elements having a length and a hydraulic pressure loss that can be adapted.

The possibility of using these modules individually in the pressurized heavy water reactors with horizontal fuel channels must be mentioned as the first application of this invention. In this case, the fuel elements are simply supported in the channels and placed one after the other in such a way so as to complete the required length. It is also possible to assemble several modules and to use them in the pressurized heavy water reactors with vertical fuel channels, as yet another application.

Although the Argentine nuclear power plants are of a similar (physical) conception with heavy water cooled fuel channels, they have two quite different designs particularly for the fuel elements. The designs of the fuel elements currently being used in the Embalse and Atucha I nuclear power plants belong to the Argentine National Atomic Energy Commission. These designs, which are included in this description, are the immediate antecedents and the state of the prior art of the fuel elements whose patent is applied for. The fuel used in both designs is natural uranium, therefore, the (replacement) burn-up and consequently the thermomechanic requirements were less than 8 000 Mwd/Ton UO_2.

In accordance with one aspect of the invention, there is provided a modular fuel element for a nuclear power plant with cooling channels comprising a cluster of parallel, cylindrical fuel rods of zircaloy sheaths whose ends are sealed by welded plugs, mounted as circular concentric crowns and said element being supported at endings by structural end-plates welded to the plugs; structural spacers at intermediate longitudinal positions between said endings to separate the fuel rods; and rigid appendices to provide support on a fuel channel of a nuclear power plant; said structural spacers being self-supporting spacer grids whereby the fuel rods are bounded altogether and their relative positions are fixed at intermediate positions between endings, avoiding rod overlapping by bowing; said self-supporting grids being of low hydraulic pressure drop and being attached to fuel rods by end stoppers welded to the sheaths; said cylindrical fuel rods having a length greater than 0.5 meter and smaller or equal to approximately 1.0 meter, and having a single diameter, each fuel rod having a ratio of heat transfer surface, defined per unit length, to fuel rod transverse cross section, of greater than 330.

In one embodiment of the invention, there is provided in a nuclear power plant having cooling channels; and horizontal fuel channels housing fuel elements; the improvement wherein the fuel elements comprise fuel elements of the invention.

In another embodiment of the invention, there is provided in a nuclear power plant having heavy water cooling channels; and vertical fuel channels housing fuel elements; the improvement wherein the fuel elements comprise fuel elements of the invention.

A detailed description is provided together with the included drawings to illustrate better this invention.

In Figures 1(a) and 1(b), respectively, the side and the three-dimensional views of a fuel element from the Embalse nuclear power plant with fuel element horizontal type according to PRIOR ART. This element will be called fuel element 1 (FE 1) [Ref.: Teed D.E. and W.R. Tarasuk "Structure of the Candu Fuel bundle", CNS International Symposium on The Complete Nuclear Fuel Cycle, Saskatoon Sep 18-21 1988].

In Figures 2(a) and 2(b) the main view and the cross-section of a fuel element in Atucha nuclear power plant with fuel element vertical type. This second fuel element [Ref.: Holzer R et al, Considerations for the mechanical design of fuel assemblies for pressurized heavy water reactors, IAEA/CNEA international Seminar on Heavy Water Reactor Fuel Technology, San Carlos de Bariloche, 27 Jun – 1 Jul 1983, Argentina.] will be called fuel element 2 (FE 2). In Figures 2(a) and 2(b) the FE 2 is shown according to PRIOR ART.

In Figures 3(a) and (b) can be seen the three-dimensional and side views, respectively, of the invention scheme.

In Figures 4(a), (b) and (c) the side view as well as the main view of one self-supporting spacer grid are shown.

In Figure 5 it is shown a coupling system base on an outer supporting body formed by straps that assemble these five fuel modules.

In Figure 6(a) it is shown a coupling systems based on fitting body to joint two structural end grids.

In Figure 7, it is seen an outer supporting tube with windows or openings that would be another alternative to bind the fuel elements.

The FE 1 is a group of 37 cylindrical tubes or zircaloy sheaths (1) with an outer diameter approximately 13 mm with thin walls so that will collapse onto the uranium dioxide pellets (2) during normal operation. Each sheath is sealed at both ends by a plug (3), thus forming a fuel rod of 0.5 meter length. Also welded to these sheaths are rigid appendices to provide support on the fuel channel - so-called bearing pads- (4) and other pads – so-called spacers- (5) to keep a minimal fuel rod distance. To hold the cluster of fuel rods in place a grid (6) is attached to each end of the array. These two elements are the structural system, which hold the module together, and the spacer keeps the fuel rod separations. The external diameter of the FE 1 is approximately 103 mm.

In Figures 2(a) and 2(b) the FE 2 is shown. This fuel element has 37 non-collapsible rods (7) with an outer diameter of approximately 12 mm and 5.25 m length, attached to a supporting plate (8) by the upper end, which is joined to a cluster of 6 tubes or lower rods (9) that are in turn attached to an intermediate ring (10). Three stainless steel rods (11) or upper rods are mounted on this ring, and they are joined to the coupling element (body) (12) which supports the whole array by its upper end. To fasten them to the fuel channel, rigid pads (13) and flexible pads (14) are provided. The external diameter of the FE 2 is approximately 109 mm. The cluster of fuel rods is held together by self-supporting spacer grids (15), which are built by adjacent concentric rings placed in intermediate longitudinal positions. These spacer grids fix the rods transversally and fasten the cluster of rods tightly, thus providing greater mechanical strength suitable to withstand the mechanical requirements due to the vertical position.

In both nuclear power plants, Atucha I and Embalse, the fuel channels are also different. The internal diameter of the fuel channel in the first nuclear power plant is greater than that in the second one. The fuel channels in Embalse are horizontal and the fuel elements are supported on the pressure reactor vessel by bearing pads, whereas the fuel channels in Atucha I are vertical and the fuel elements are suspended from the upper lid of the pressure reactor vessel.

Although both nuclear power plants use on-load refuelling, they differ in the number and length of the refuelled elements. In Embalse, out of a total of twelve fuel elements, which form the 6-meter-long channel, two fuel elements are refuelled at a time. This enables their axial exchange. On the contrary, this axial exchange (shuffling) is not possible in Atucha I, where the active portion is a single 5,25-meter-long fuel element.

Nowadays a new fuel element, which will be known as fuel element 3 (FE 3) [Ref.: Hasting, I.J., Boczar P.G. and Lane A.D. "CANFLEX – an advanced bundle design for introducing slightly enriched uranium into CANDU, Int. Symp on Uranium and Electricity, Saskatoon International Symposium on The Complete Nuclear Fuel Cycle, Saskatoon Sep 18-21 1988, AECL report AECL-9766], has been proposed to be used in nuclear reactor with horizontal channels with two different fuel rod diameters, while maintaining the same length (approximately 0.5 meter) of the first fuel element (FE 1).

The fuel element 3 (FE 3) maintaining the same length of the first fuel element (FE 1), has two different fuel rod diameters, to be able to fulfil the above-mentioned requirements. This design enlarges a 5.4 per cent of the fuel and coolant exchange surface as compared to the FE 1, but maintains the hydraulic restriction in the channel. Nevertheless, the fuel mass will be more reduced than that in the FE 1; consequently, the previous problems will not be totally solved. While maintaining the spacers welded to the sheaths, the FE 3 has more collapsible fuel rods and, therefore, more welds on the sheaths, which reduces the mechanical strength. On the other hand, the constituents of this fuel element are more varied, as they will require two different kinds of sheaths, pellets, fuel elements and plugs, among other elements.

The design of the fuel element is a fundamental step in the nuclear reactor layout and it is the result of a compromise mainly among neutron, thermohydraulic and thermomechanic phenomena. The thermomechanic phenomena are related to the pellet cladding interaction caused by thermal effects of the pellet heat generation and the time irradiations effects. In short, the neutron performance will improve when the fuel mass is increased, since the neutrons generated in a fuel atom have a greater probability of producing fission in another one. On the contrary, to improve the thermohydraulic and thermomechanic performances, it is advisable to reduce the fuel mass and to spread out the fuel elements (i.e., a far greater coolant transfer surface and flow, and a smaller rod diameter). It should be pointed out that an opposite trend to these phenomena appears if the cluster of fuel elements is more spread out (smaller diameter) to increase the heat transfer surface, while at the same time maintaining the fuel mass (more fuel rods). This causes a reduction in the coolant flow because there will be greater hydraulic restrictions and, consequently, a reduction in the thermohydraulic safety limits of the nuclear power plant.

A new fuel element devised to be used in the current nuclear power plants with channels should simultaneously enhance the three above-mentioned requirements. However, the fuel mass and the hydraulic loss in the channels must be maintained so that the distribution of the neutron flux and the coolant flow in the reactor core will not be disturbed. This enables the presence of several types of fuel elements in the core and their progressive exchange during the routine replacement without upsetting the operating time and the operation of the reactor.

In the first fuel element (FE 1), the ratio of the heat transfer area to the rod transverse area approximately equals 300, whereas in the second fuel element (FE 2) is 313, and in the third one is 327. From this it can be inferred that with the previous designs it does not achieve a higher ratio than 330.

The problem to solve with a single design of the high performance fuel element, is to have higher ratio of the heat transfer surface to the rod transverse cross section than 330 to enhance the thermohydraulic and thermomechanic safety limits to obtain larger fuel burnups with enriched uranium, which can be adapted to the different current nuclear power plants, and simultaneously maintain the neutron and hydraulic compatibility, as well as the compatibility with the refuelling machine in every plant, and with a structural spacer to fix the relative fuel rod position at intermediate positions between endings.

With the fuel element and the assembly system of the invention herein described, these obstacles are eliminated, and substantial improvements are also made in the neutron, thermohydraulic and thermomechanic performances when compared to the previous fuel elements (FE 1, FE 2 and FE 3). The coolant area is enlarged, while the fuel rod diameter is reduced, and at the same time it is possible to maintain the mass of the fuel element which is denser (FE 1). In this case the fuel mass equals that of the first fuel element (FE 1); and it is 21% and 1% higher than that of the second (FE 2) and third (FE 3) fuel elements respectively. As regards the contact area with the coolant, it is 20%, 18% and 12% higher than that in FE 1, FE 2 and FE 3 respectively. These (values) are reached, however, maintaining both reactors in operation.

The thermomechanic requirements of the fuel element, whose patent is applied for, are reduced because of a smaller pellet diameter and a larger quantity of fuel rods and, consequently a lower operating temperature. Besides, by using self-supporting spacer grids instead of the appendices welded to the sheaths, it is possible to avoid degradation of the fuel rods mechanical properties caused by the welds. Thus, the number of welds on the sheaths is reduced twenty times when compared with the first fuel element and that is one of the factors enabling to increase the fuel burnup of the array. Moreover, with the innovative incorporation of the self-supporting spacer grids on collapsible rods, it is possible to fasten the whole array. From the mechanical point of view, this is very convenient, since it can be included in the vertical channels suspended by one end, as is the case with the FE 2.

This characteristic is used in the fuel element assembly system of this invention to provide longer fuel modules and an adaptable hydraulic pressure loss by regulating the azimuthal disalignment angle among modules. Thus, the group of fuel elements can conveniently be used in nuclear reactors with vertical channels and a more restricted pressure loss, as is the case in Atucha I.

The principal purpose of this invention is to obtain a modular fuel element having a ratio of the heat transfer area to the rod transverse area higher than 330 and roughly equal to 364 for a cooling channel diameter of 103 mm, compatible with the hydraulic pressure drop of present horizontal heavy water reactors, and with structural endings to avoid mechanical interference between fuel elements when it is loaded in cooling channels.

The second purpose of the invention is to obtain a modular fuel element, which, when compared to the current designs, will increase the thermohydraulic and thermomechanic safety limits and the fuel burnup. At the same time it will maintain the fuel mass and the total hydraulic restrictions in the channel, especially in those nuclear plants with horizontal channels, providing a collapsible single diameter fuel rod array.

The third purpose of the invention (again having the current designs as a reference) is to reduce the number of welds not only in the fuel sheaths, but also in every structural component, thus simplifying the manufacturing process.

A further purpose of this invention is to adapt the fuel element to nuclear power plants with longer vertical fuel channels and lower hydraulic restrictions. It will be attached to a single end by an assembly system of modular fuel elements enabling them to be reused and improving the fuel burnup.

To accomplish all these purposes, some very innovative improvements were used, as the incorporation of the self-supporting spacer grids on collapsible rods. Among them it can be mentioned the reduction of the structural endings between adjacent elements to maximise (and thus to double) the length of the fuel modules so as to obtain the compatibility with the refuelling machine in every nuclear power plant with channels. In this way it is possible to reduce the hydraulic pressure loss in the structural element of the channel. This improvement enables the construction of a new rod array having the same fuel mass and a more spread out layout (more rods of smaller diameter). That in turn balances the pressure loss increase along the rods (due to a larger heat exchange surface) causing a reduction in structural elements. Therefore, by maintaining the coolant flow and increasing its transfer surface, it is possible to reduce the heat flux per unit area (superficial heat flux) and enhance the thermohydraulic safety limits. Moreover, if there are more fuel rods of smaller diameter, the linear power density and the temperature difference within the fuel pellet decrease. Consequently the thermomechanic performance is improved (it reduces thermal expansion, fission gas release, and the mechanical interaction/reaction between the fuel pellets and the sheath) and the fuel burnup can be notably prolonged. Furthermore, the innovative inclusion of the self-supporting spacer grids with collapsible rods (rods with a thickness/diameter ratio lower than 3.2%) during operation greatly reduced the number of welds in the sheath (improving thermomechanic safety limits) and favours the fuel element utilisation in the vertical channels. The number and mass of the structural components is also reduced when the length of the fuel rod for horizontal channels is twice the current. For example, the number of plugs welded per unit length to the end plates is reduced 30%, the number of end plates 50%, and so on, when compared with FE 1. Both these last characteristics simplify the manufacturing process, as there will be fewer steps involved in the fuel rods making.

It can be concluded, therefore, that the degree of dispersion of a fuel element, if the fuel mass and hydraulic restrictions are maintained, is the defining parameter of the design that has been attained. To this it may be added that in the case of the ratio of the heat transfer area between the fuel and the coolant to the transverse area of the rod array, both areas are defined per unit length in the channel. Indeed, in those fuel elements maintaining the fuel mass encapsulated, it is advisable to maximise the heat transfer surface and to minimise the transverse area of the fuel array (by using collapsible thin sheaths and by enlarging the active portion when the number of structural endings is diminished), since the heat flux will be reduced and the coolant area will be enlarged. Accordingly, it will be extremely advantageous to obtain a fuel element design having higher values for this area relationship, as long as they maintain the hydraulic loss in the channel. The ratio of the heat transfer area to the transverse area of the newly invented fuel element is higher than 330 and roughly equal to 364. When these values are compared with those for the FE 1, FE 2 and FE 3, which were 300, 313 and 327, respectively, it can be concluded that with the previous designs it was impossible to obtain a higher ratio than 330 for this area relationship keeping the hydraulic compatibilty.

In the case of the nuclear power plants with vertical channels, if an assembly system with several modules is used, it will enable the attainment of a longer fuel element supported on a single end. Besides, with the devised assembly system, it is also possible to fix the azimuthal disalignment angle among adjacent modules and to adapt the fuel to coolant channels with different hydraulic pressure loss. If the modules are completely aligned, the hydraulic pressure loss in the channels will be reduced to the values obtained in Atucha I.

As a result of all this, when compared with the previous designs, the fuel element and the assembly system described herein have the following advantages:

- the thermomechanic and thermohydraulic safety limits can be increased;

- it is possible to extend the fuel burnup up to 35 000 Mwd/TonUO_2;
- the pressure loss can be adapted to different channel reactors;
- the density of the currently most dense fuel element can be maintained (FE 1);
- there is compatibility with the refuelling machine of the vertical and horizontal channel reactors;

the number of structural components as well as the manufacturing process is reduced by using a single diameter fuel element and less welds on the sheaths.

With this invention a single diameter fuel rod array satisfying every consideration formerly mentioned and which has not been improved by the previous designs, is devised. The module is a cluster of 52 parallel fuel rods (this is only one of the many different possible arrays) mounted as four compact concentric rings. It is attached by a structural system to a couple of grids placed at both ends and to self-supporting spacer grids having rigid and flexible spacers located in intermediate axial positions. Flexible and rigid pads welded to the spacers or to the assembly system are also provided to fix the position of the fuel element to the channel.

A detailed description is provided together with the included drawings to illustrate better this invention.

In Figures 3(a) and (b) the three-dimensional and side views, respectively, of the invention scheme can be seen. The fuel elements are a group of zircaloy collapsible sheaths (1) whose ends are sealed by plugs (3) welded to an end plate (6). The total length of this fuel element is exactly the same as two FE 1 or FE 3 added together. Self-supporting spacer grids (15) of low hydraulic pressure loss have been attached to separate the fuel rods.

In Figures 4(a), (b) and (c) the side view as well as the main view of one self-supporting spacer grid are shown. The spacer grids consist of supporting structures (16) to which rigid (17) and flexible (18) spacers that hold the sheath in place are attached. In the nuclear power plants with horizontal channels, the channels rest on several pads (19) which have been welded to the outer supporting structures, whereas the axial position of each spacer has been secured by a weld of less than 13 stoppers on the rods.

The active portion of the FE 2 (the portion containing the fuel pellets) is longer than that of the invented fuel module. It also differs with the Embalse nuclear power plant, because it has vertical channels. In Atucha I to assemble the fuel element, five-fuel modules like the one being described were axially coupled, before its inclusion inside the core.

There are several possible methods to assemble these five fuel modules.

The modules can be fastened with outer straps (20), as shown in Figure 5. In this case the total length is obtained by adding the five fuel elements together and attaching them to a low hydraulic loss stopper (21) by its lower end. In the other end there is an intermediate coupling system (22) containing a spring, which binds the module together. There is also a coupling element (body), which is similar to that in the current FE 2 design; to ensure its adaptability with the intermediate body, which is also incorporated in the upper part of the channel. The section of the intermediate coupling is characterised by having low hydraulic pressure loss. Mixing fins can also be added to the outer straps. This type of assembly would enable the axial relocation of the fuel elements which are not totally burned in a pool outside the core. Rigid or flexible spacers (23) can be attached to the straps or to the spacer grids of the channels in Atucha I. In Figure 5 a fuel module like the one being outlined is shown. It depicts the outer straps, the stopper at the lower end, and the intermediate coupling system and the coupling body.

Another method to fasten the fuel modules is by placing a low hydraulic pressure loss fitting piece or body between the end plate grids or around them. In Figure 6, one end of the fuel element and a fitting body located around the grids (24) are shown. In this case, the sheaths of the fuel elements would be the supporting elements of the whole assembly, since they are welded to the grids. A fitting body is attached to one end of the assembly, between the grid and an intermediate low hydraulic pressure loss coupling having the fitting body at the other end, as in the FE 2.

An outer supporting tube with windows or openings (25) would be another alternative to bind the fuel elements (see Figure 7). It has been designed to support all the fuel elements together and it enables the coolant to circulate lightly through the fuel elements and the channel. At the same time, it would be able to reduce the mean coolant flow rate and, consequently, to balance the pressure losses. These windows or openings would provide a physical space big enough to place fixed and flexible pads, in the improbable event that the gap between the tube and the channel would be insufficient for these bodies. A stopper and an intermediate coupling mechanism with a fitting system and a coupling body are attached to both ends of the tube, in a fashion similar to that described for the outer straps.

A further alternative would be to use one or several inner rods, which by benefiting from the sections of least generated power, or by changing one or more fuel rods would provide further rigidity to the whole assembly. In this case, the best option would be to place the module in the centre of the assembly, which is the portion with least linear power density and, therefore, its cooling ability is not overloaded. Such fuel rods have a stopper attached to one end, and in the other end a low hydraulic pressure loss fitting mechanism is provided holding the assembly together. A coupling body is mounted to this mechanism, as the one in the current FE 2 design.

CLAIMS:

1. A modular fuel element for a nuclear power plant with cooling channels comprising a cluster of parallel fuel rods of zircaloy sheaths whose ends are sealed by welded plugs, mounted as circular concentric crowns and said element being supported at endings by structural end-plates welded to the plugs; structural spacers at intermediate longitudinal positions between said endings to separate the fuel rods; and rigid appendices to provide support on a fuel channel; said structural spacers being spacer grids whereby the fuel rods are bounded altogether and their relative positions are fixed at intermediate positions between endings, avoiding rod overlapping by bowing; said spacer grids being attached to fuel rods by end stoppers welded to the sheaths; said cylindrical fuel rods having a length greater than 0.5 meter and smaller or equal to approximately 1.0 meter, and having a single diameter, each fuel rod having a ratio of heat transfer surface, defined per unit length, to fuel rod transverse cross section, of greater than 330.

2. The modular fuel element as claimed in claim 1, wherein said sheaths have a sheath thickness collapsible at reactor pressure, and the spacer grids are attached to fewer than 5 fuel rods by fewer than 20 welded end stoppers, and other fuel rods have none welded appendence on the sheaths.

3. The modular fuel element as claimed in claim 2, wherein the number of welded end stoppers is less than 13.

4. The modular fuel element as claimed in any one of claims 1 to 3, wherein the number of the fuel rods is higher than 43, and each rod has a diameter of less than 11 mm.

5. The modular fuel element as claimed in claim 4, further comprising 52 parallel fuel rods, which are arranged in four concentric rings, said arrangement comprising three spacer grids with rigid and flexible fuel rod pads fixing their relative position.

6. The modular fuel element as claimed in claim 5, wherein said rigid pads are welded to said spacer grids therein providing a supporting place on the fuel channels, when used in a horizontal channel nuclear power plant.

7. The modular fuel element as claimed in any one of claims 1 to 5, wherein the fuel element is adapted to a nuclear power plant with heavy water vertical channels, by using a fitting media between contiguous end-plates, said fitting comprising a detachable coupling between modular fuel elements, further enabling several fuel elements to be bound together increasing the fuel length of said fuel elements.

8. The modular fuel element as claimed in any one of claims 1 to 5, wherein the fuel element is adapted to a nuclear power plant with heavy water vertical channels, by using an outer body as coupling system, forming a longer fuel element by attaching several said modular fuel elements.

9. The modular fuel element as claimed in any one of claims 1 to 5, wherein the fuel element is adapted to a nuclear power plant with heavy water vertical channels, by using an inner-fitting element as coupling system to assemble the element to another said modular fuel element, therein forming a longer fuel element.

10. A modular fuel element as claimed in claim 5 or 9, wherein the fuel rods contain different ceramic pellets, and said ceramic pellets contain nuclear fuel material, said nuclear fuel material being a blend of at least one of uranium and plutonium.

11. A modular fuel element as claimed in claim 5 or 9, wherein the fuel rods contain different ceramic pellets, and said ceramic pellets contain a combination of nuclear fuel material being a blend of at least one of uranium and plutonium; and a nuclear material selected from actinides, fission products and fuel material coming from other nuclear reactors.

12. In a nuclear power plant having cooling channels; and horizontal fuel channels housing fuel elements; the fuel elements comprise fuel elements as defined in any one of claims 1 to 6 or 11.

13. In a nuclear power plant having heavy water cooling channels; and vertical fuel channels housing fuel elements; the fuel elements comprise fuel elements as defined in any one of claims 7 to 11.

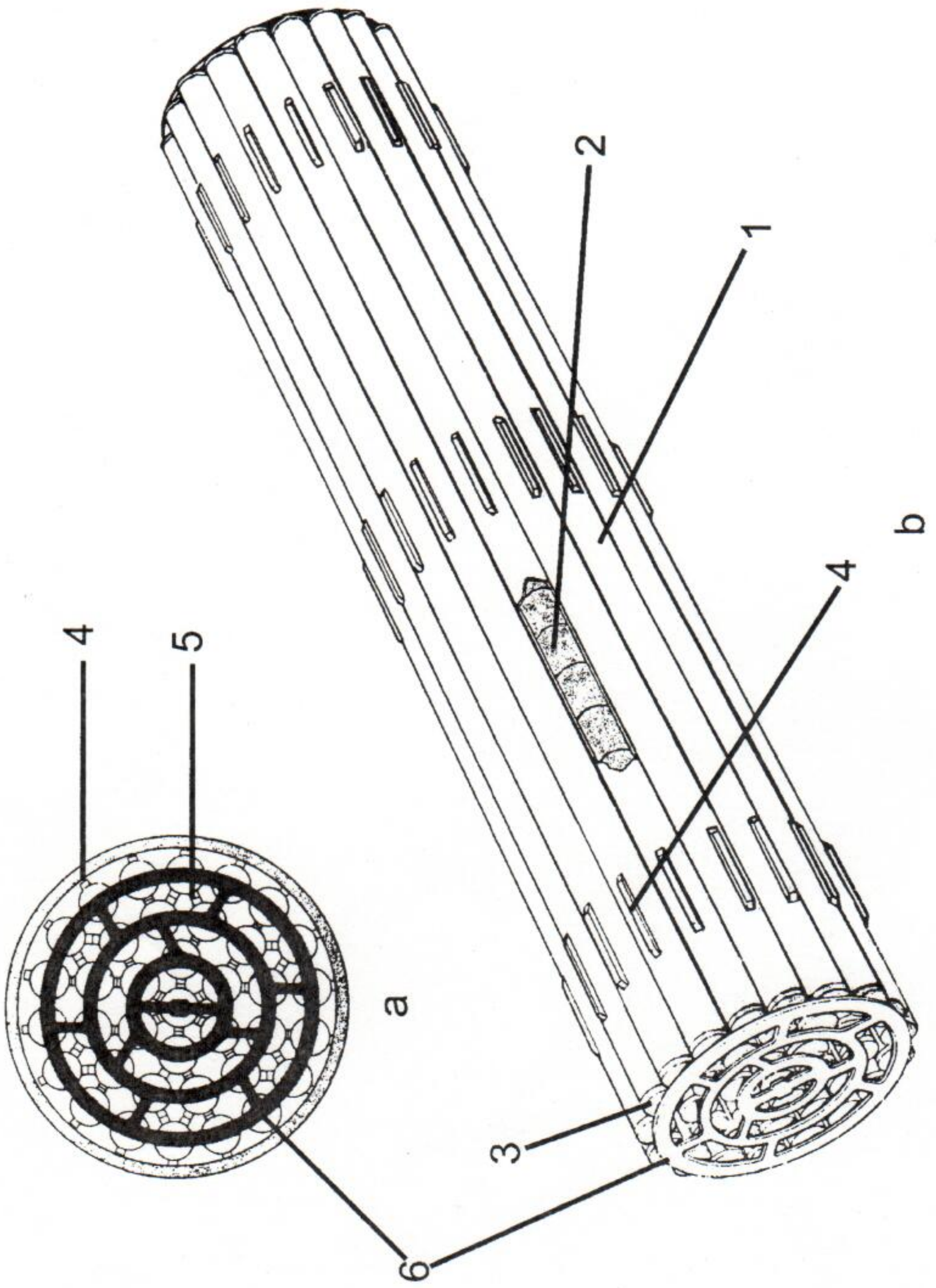

Figure 1 Prior Art

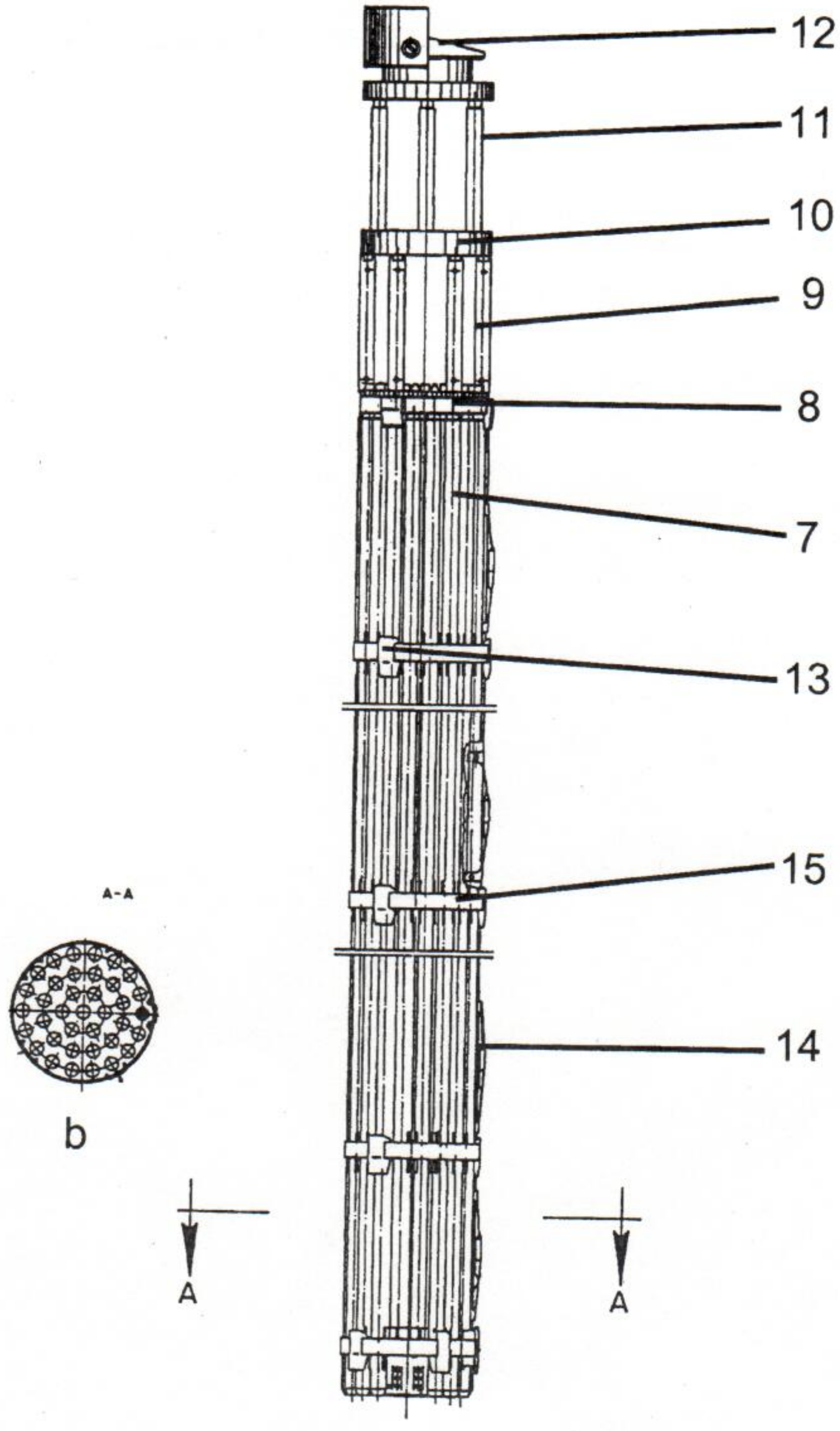

Figure 2 Prior Art

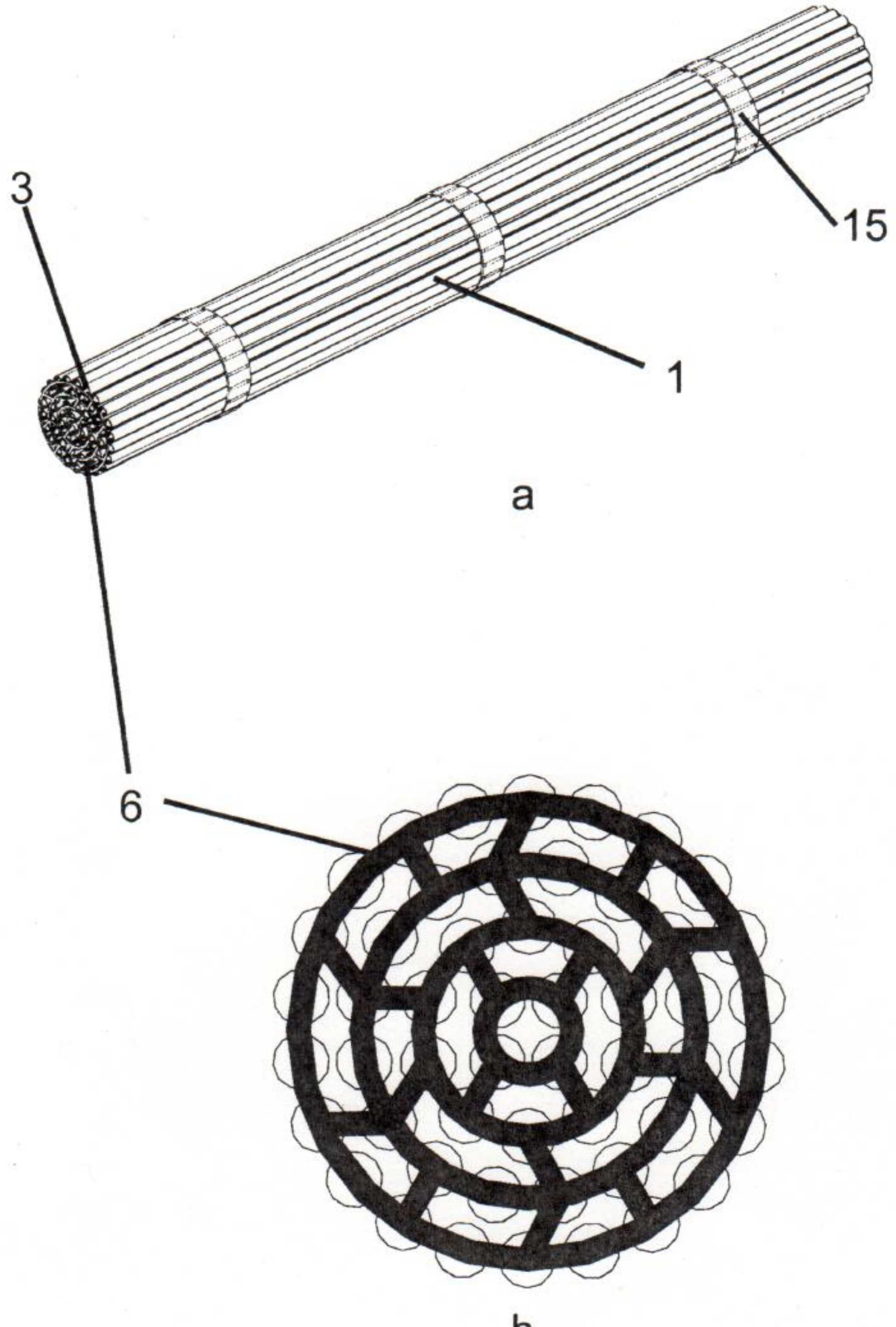

Figure 3

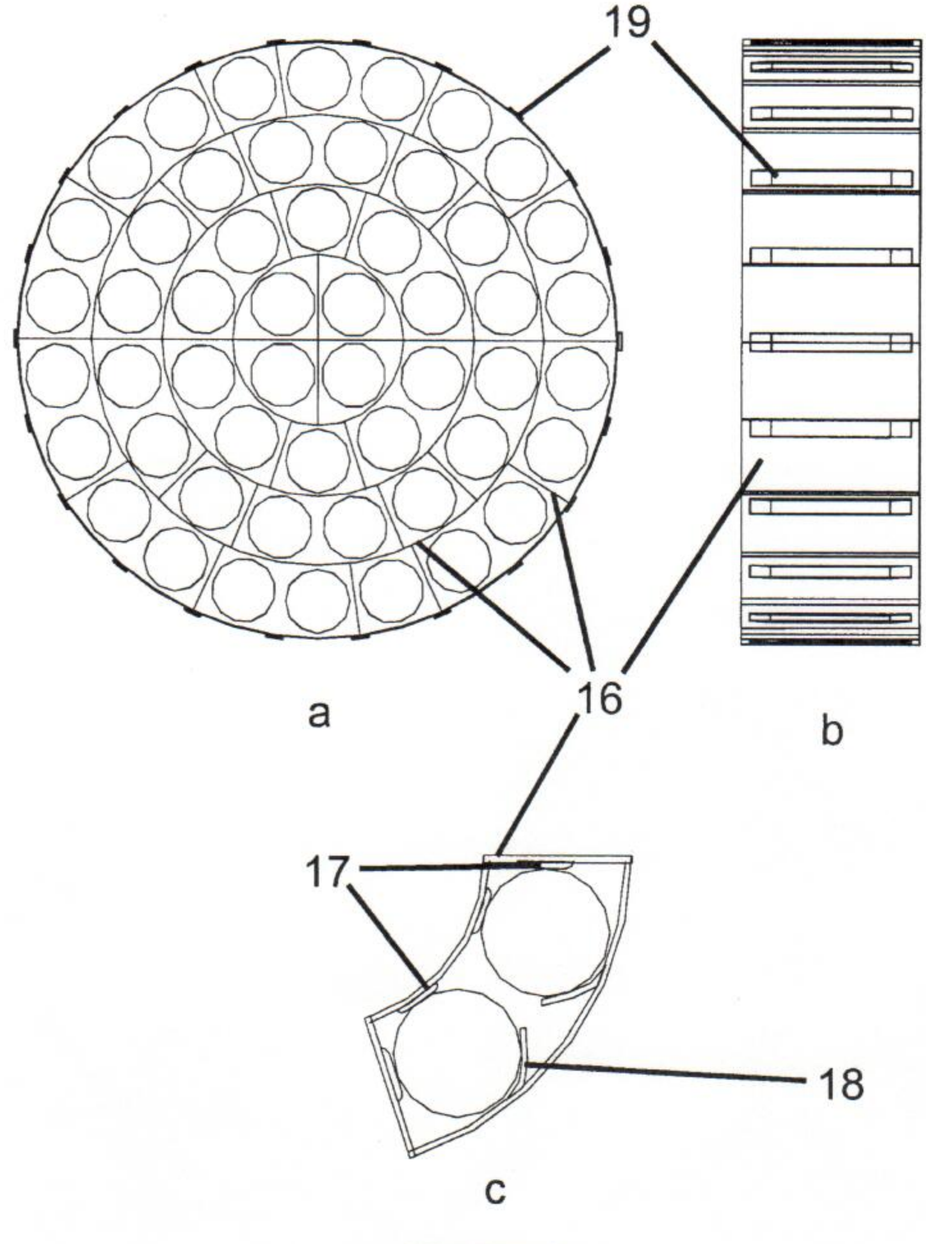

Figure 4

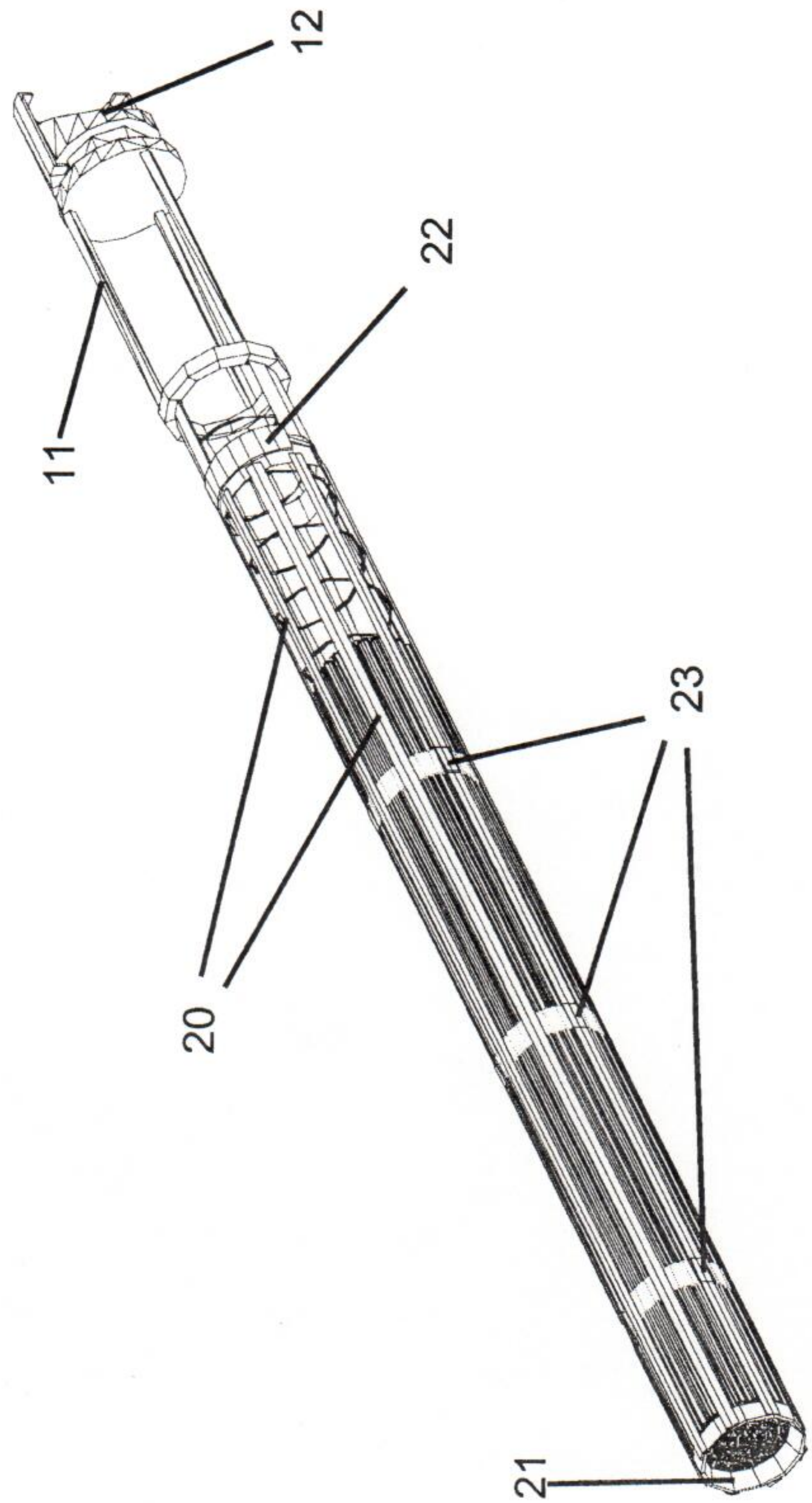

Figure 5

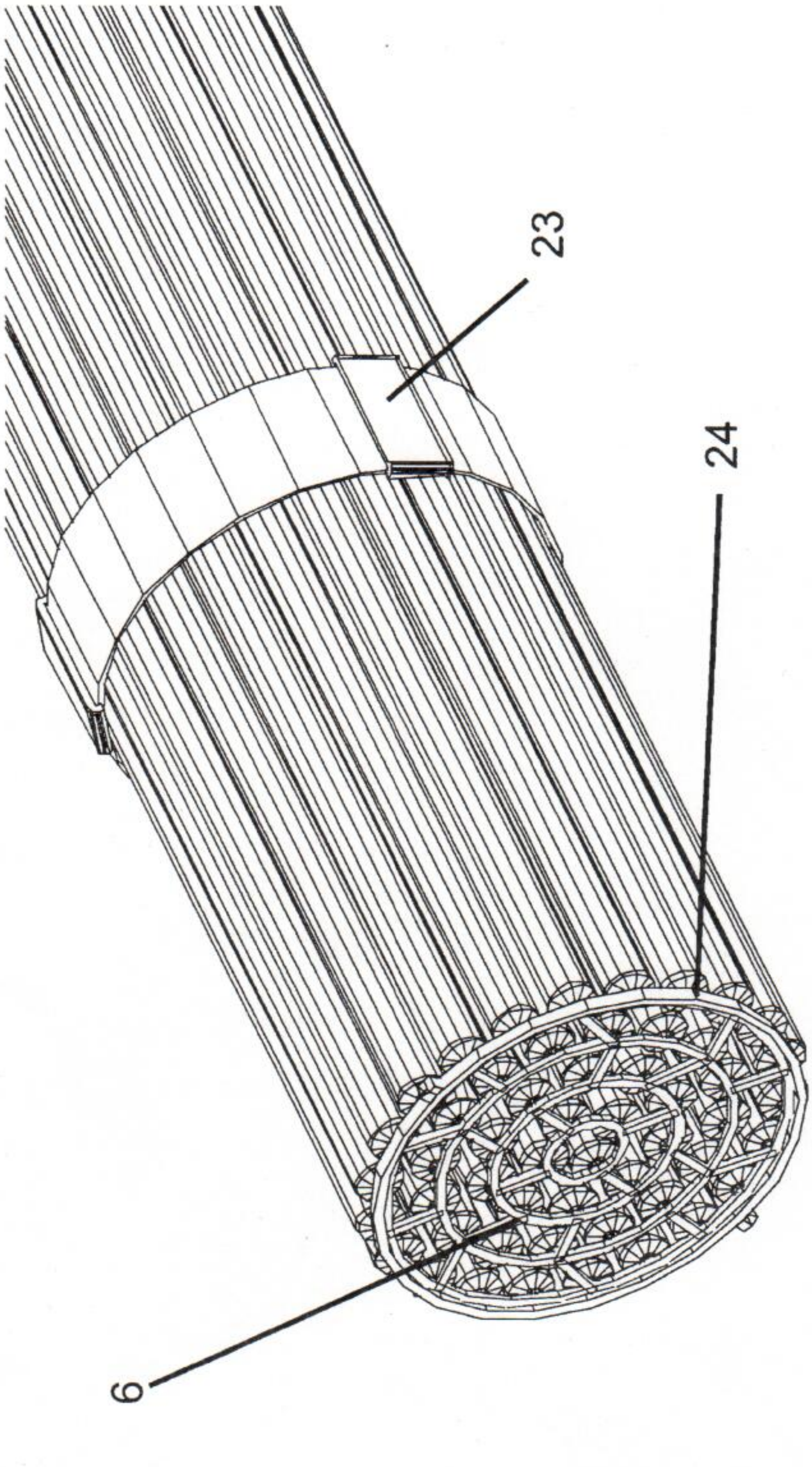

Figure 6

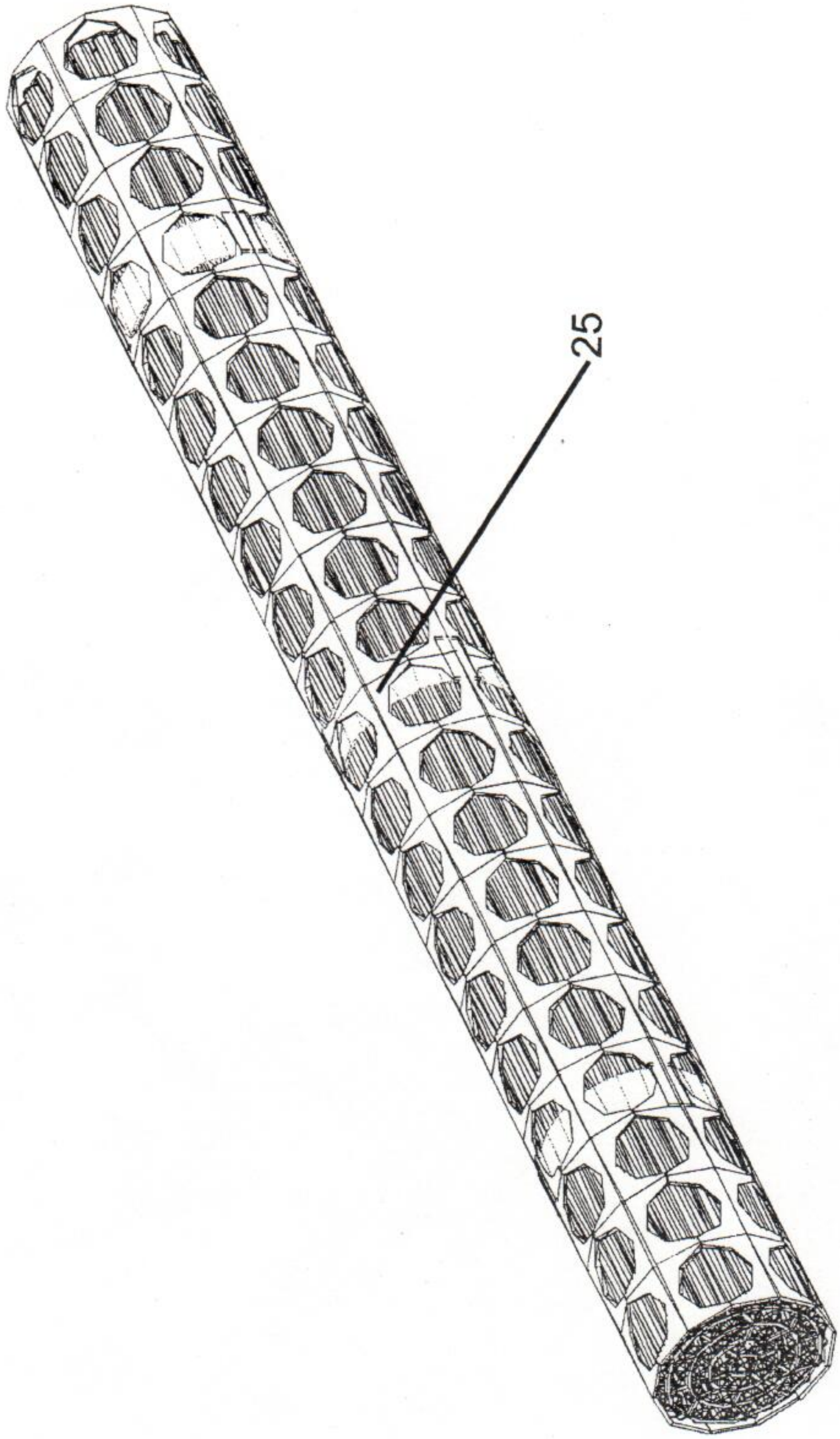

Figure 7