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(19) (CA) **CANADIAN PATENT** (12)

(54) CONTROL COMPONENT STRUCTURE

(72) Walton, Lewis A.,  
U.S.A.

(73) Granted to Babcock & Wilcox Company (The)  
U.S.A.

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No. OF CLAIMS 6

ABSTRACT OF THE DISCLOSURE

5 A technique is provided for engaging and dis-  
engaging burnable poison rods from the spider in a  
fuel assembly. The cap on the end of each of the  
burnable poison rods is provided with a shank that  
is received in the respective bore formed in the  
spider. In one illustrative embodiment, the shank  
10 is deformed to firmly secure the rod and attached  
shank in the spider bore. Pressing the shank in the  
direction of the bore axis overcomes the deforma-  
tion to release the particular rod from the spider.

TECHNICAL FIELD

This invention is directed to improvements  
5 in nuclear reactor fuel assemblies, and, more  
particularly, to methods and apparatus for securing  
and removing burnable poison rods from the spider  
in a fuel assembly, and the like.

BACKGROUND ART

10 To produce useful power from nuclear processes  
it is necessary to assemble a sufficient concentration  
of fissionable uranium, or other suitable material,  
in a physical configuration that will sustain a con-  
tinuous sequence of energy-producing reactions. This  
15 assembly, or reactor core, transfers the heat that  
is generated in the fission reactions to a working  
fluid. Frequently, pressurized water flowing through  
the core at high velocities is used for this purpose.

Because the heat, vibration and radiation that  
20 is generated within a power reactor core creates a  
generally hostile environment, the structural integrity  
of the core components is an important consideration.  
Consequently, pressurized water power reactor cores  
frequently are comprised of groups of fuel assemblies  
25 that are arranged in a generally right circular cylindrical  
configuration. Each fuel assembly, moreover usually  
comprises an array of about two hundred long slender  
fuel rods that are parallel to and spaced from each other.



Each of these fuel rods contains a stack of generally cylindrical uranium dioxide pellets in which the uranium provides the fissionable fuel for the power reactor.

5           These fuel assemblies are not limited to fuel rods but also support a number of other components. For example, instrumentation tubes for observing temperature and neutron flux conditions within the core; 10 end fittings and fuel element grids for stabilizing the fuel assembly components; and control rods and control rod guide tubes for regulating the power output from the reactor through the selective absorption of fission inducing neutrons within the reactor core 15 often are made a part of the fuel assembly structure.

          Clearly, the neutron distribution will vary from place-to-place within the reactor core. Illustratively, near the core perimeter it can be expected that the neutron population will be small relative to the center 20 of the reactor core because the concentration of neutron producing uranium is lower at the core perimeter than it is in the center of the core. Neutrons at the core perimeter can "escape" from the core more readily through the core surface than they can from the center of the 25 core, further tending to reduce the neutron concentration near the reactor core surface. Because heat generation within any specific portion of the reactor core is related to the neutron population within that portion, there is a definite tendency to produce higher temperatures at the center of the reactor core than at its 30 margin. This inclination toward producing local temperature maxima in different regions within the reactor core is generally undesirable for a number of reasons. Primarily, the reactor is designed for core operation 35 that will not exceed a predetermined temperature. If this core temperature is reached in just one or in a

few local points within the reactor core, the over-  
all heat generating potential of the core can not  
be realized. This effect results because the  
5 temperatures elsewhere in the core must be kept  
to lower values in order not to exceed the design  
temperature at those limited points or "hot spots"  
in which the maximum design temperature has been  
reached.

10 Accordingly, in the simplified example under  
consideration, over-all reactor power can be increased  
if the neutron population (and hence, heat) in the  
central portion of the core is depressed and the neutron  
population in the larger volume that characterizes  
15 the peripheral reactor core annulus is allowed to  
increase. In this way, by "flattening" the power distri-  
bution in the reactor core, the core actually is able  
to generate more power than it would be able to generate  
if the neutron concentration, temperature and power  
20 was allowed to reach a peak in the center of the core,  
or in some other location, as the case may be. In order  
to achieve this "flat" power distribution, it has been  
the practice to insert "burnable poison" rods in the  
fuel assemblies. Typically, a burnable poison rod is  
25 a tube filled with a material that has a very high  
probability for absorbing neutrons. For example, a  
sintered dispersion of boron carbide in an alumina  
matrix is suitable for this purpose.

30 Neutrons, absorbed in this manner by means of  
the material within the rod are, in effect, withdrawn  
from the fission and power generation process. And  
so, to "flatten" the power distribution with a reactor  
core, burnable poison rods are concentrated in those  
fuel assemblies that are located in the central portion  
35 of the reactor core.

Depending on a number of subtle effects it also might be advisable to provide burnable poison rod concentrations in other portions of the reactor core in which specific design or operational features produce large local neutron populations.

Not only must the fuel assembly support all of these diverse structural components in spite of the generally hostile environment within a reactor core, but the fuel assembly also must be capable of the somewhat conflicting need for swift and easy disassembly. For instance, it should be noted that fuel assemblies become radioactive after exposure in an operating reactor core. This radiation is so intense that inspection and repair can be accomplished only with remote handling equipment behind adequate radiation shielding.

Consequently, because disassembly procedures are expensive and time consuming, the need for a sturdy, yet readily dismountable structure is of considerable commercial importance.

The burnable poison rods that are used in many fuel assemblies are a part of this structural picture. Generally, the burnable poison rods that have characterized the prior art are mounted for movement in a direction that is parallel to the longitudinal orientation of the fuel rods. A "spider", in the form of a centrally disposed hub from which a number of arms radiate often is used to couple the burnable poison rods together for longitudinal movement relative to the balance of the fuel assembly. This motion is required to permit the power reactor operator to insert or withdraw the burnable poison rods from the reactor core in response to power flattening needs.

Eventually, lumped burnable poison rods must be removed from operation, packaged in a cask that provides adequate radiation shielding and then shipped for disposal at a suitable site. It is desirable to remove each of the rods from the spider in order to economize on the volume of the shipping cask. Unfortunately, removing the burnable poison rods from the spider is complicated and potentially hazardous for a number of reasons. The irradiated poison rods have developed, after sufficient irradiation in the reactor core, an internal gas pressure. The cladding or tubing in which the burnable poison has been loaded also becomes quite brittle as a result of a period of irradiation. The burnable poison rods usually are joined to their respective spider arms by means of threaded fasteners. In these circumstances, the most frequently suggested techniques for removing the rods from the spider are by means of shearing or sawing. Sawing the rods permits these rods to be handled more gently - an important consideration in view of the gas pressure within the rods - but the sawing process generates radioactive chips. Shearing overcomes this problem to a large extent, but does nevertheless result in undesirably rough handling.

There is, then a need for some suitable means for joining burnable poison rods to the spider arms in a manner that is proof against the reactor core environment but permits these rods to be removed from the spider simply, swiftly and delicately.

According to the invention, there is provided a control component structure comprising a spider having a

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plurality of arms, at least one spider bore formed in said plurality of arms, said spider bore including an enlarged recess and a small recess with an upright truncated conical section forming a transition from the enlarged recess to the small recess, and a burnable poison rod including a tube 5 terminating in transverse end, a plug with a chamfered end that leads into a cylindrical portion, said cylindrical portion of the plug snugly fitting within the tube and terminating in a radially protruding shoulder which engages the 10 transverse end of the tube to which it is welded, and a stem protruding in the longitudinal direction from the central portion of the shoulder having a longitudinal stem bore extending through about half of the length of the stem, at least part, of the stem which defines the stem bore being 15 fixed within the truncated conical section, the enlarged recess and the small recess of the spider by outward deformation of that part of the stem in order to releasably attach the rod to the spider, said stem being adapted to substantially reshape itself by movement of the rod in a longitudinal 20 direction with respect to the spider bore, while maintaining the structural integrity of the poison rod and maintaining the structural integrity of the spider.

The invention also extends to a method of assembling and disassembling a control component structure for a 25 nuclear reactor comprising the steps of providing a spider having a plurality of arms, at least one spider bore formed in said plurality of arms for receiving a burnable poison rod having a deformable stem protruding from one end thereof,



inserting the stem into the spider bore, fastening the stem within the spider bore by deforming a portion of the stem into engagement with a taper in said bore, and separating the burnable poison rod from the spider by applying a longitudinal force to the stem of the burnable poison rod sufficient to extrude the deformed portion through the taper while maintaining structural unity of the burnable poison rod and maintaining structural unity of the spider. Preferably the stem has an axial bore, and a mandrel of smaller diameter than the spider bore is inserted within the stem bore to apply the longitudinal force.

In these circumstances, although considerable force

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may be applied to press the stem through the spider arm bore, it will be noted that the force is applied in a longitudinal direction relative to the stem. This feature of the invention not only protects the brittle, pressurized burnable poison rod  
5 from risk of fracture or other damage due to the rough handling that characterizes shearing but also avoids producing a mass of radioactive chips if the rod is to be sawed free from the spider.

There are a number of more subtle advantages that  
10 accrue through the practice of the invention. Manufacturing costs, for example, are relatively low in comparison to the threaded fasteners that have characterized the prior art. Joint performance, moreover, is superior at the temperatures commonly reached within nuclear reactor cores. For instance, the greater  
15 thermal expansion of the spider arm (frequently made from stainless steel) relative to a zircalloy pin on the burnable poison end plug causes undesirable axial stress that must be compensated for by other means. This is achieved in the invention by a corresponding radial loosening, thereby reducing the  
20 chance for generating undesirable thermal stresses in this region. Without this automatically provided stress relief, these thermally induced forces otherwise might cause the stem to shear and thus permit the burnable poison rod to become an undesirable loose object within the reactor core.

25 The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be

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had to the accompanying drawing and descriptive matter in which there is illustrated and described a preferred embodiment of the invention.

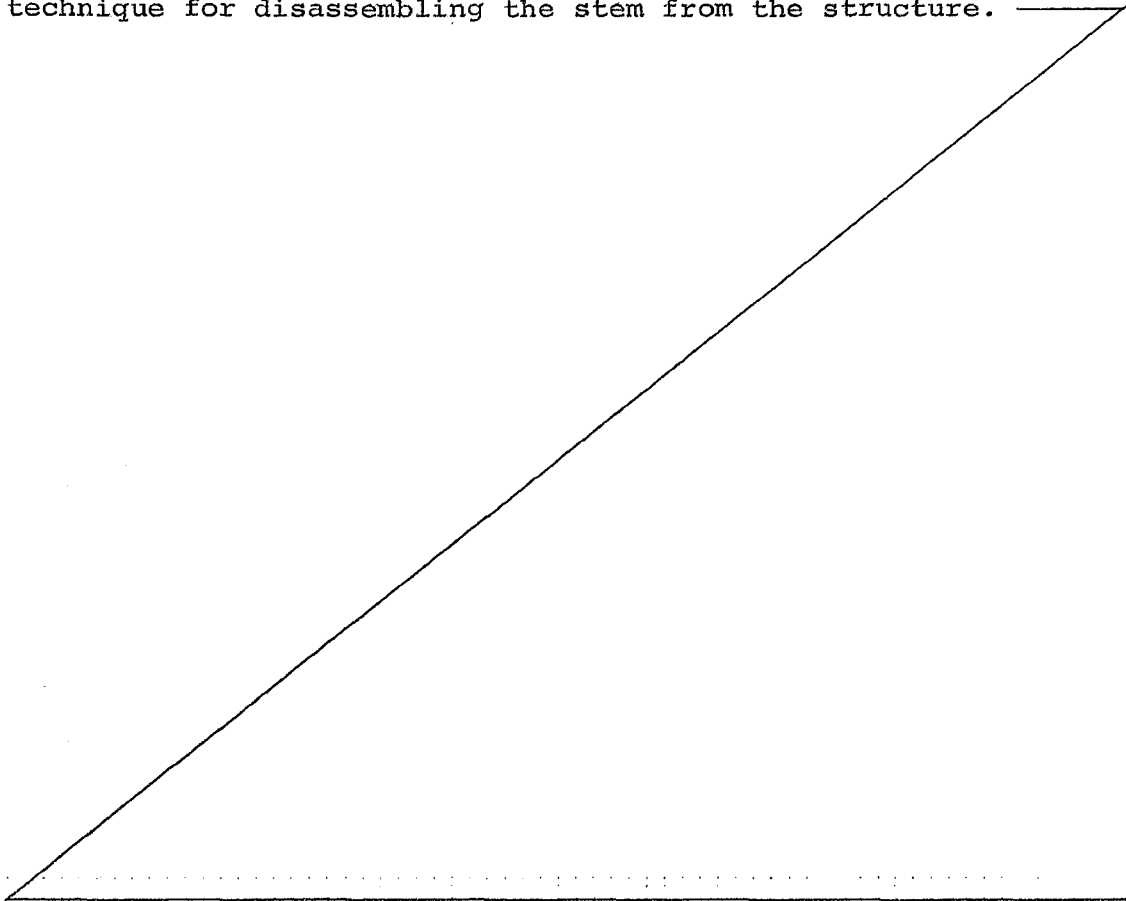
BRIEF DESCRIPTION OF THE DRAWING

5            Fig. 1 shows a typical spider and burnable poison rod combination, to which the invention may be applied;

            Fig. 2 illustrates in full section a typical embodiment of a portion of a stem of a rod in a partially assembled condition in accordance with the invention;

10           Fig. 3 shows in broken section the stem fully assembled in a portion of a spider of the invention; and

            Fig. 4 is a drawing in broken section illustrating a technique for disassembling the stem from the structure.



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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

For a more detailed understanding of the invention, attention is invited to Fig. 1. As illustrated, a spider 10, formed from stainless steel, or the like, is provided with a centrally disposed, generally cylindrical hub 11 that has a longitudinal axis 12. The spider 10 has a number of spider arms that extend radially from the hub 11 in a plane that is perpendicular to the axis 12. For purposes of simplified description, only spider arms 13, 14, 15, 16, 17, 20 and 21 which are viewed in the plane of of Fig. 1 of the drawing are shown.

A group of burnable poison rods 22, 23, 24, 25, 26, 27 and 30 are attached to their respective spider arms. All of these burnable poison rods are long, slender tubes in which the longitudinal axis of each of these tubes is parallel with the longitudinal axis 12 of the hub 11. As illustrated in more detail with respect to the burnable poison rod 30, a hollow tube 31 forms the outer surface of the rod. On longitudinal end of the tube 31 is sealed by means of a solid plug 32 that is welded or otherwise secured in the open tube end. Within the tube 31 and bearing against the plug 32 is a stack of short cylindrical burnable poison pellets 33. The individual cylindrical pellets in the stack 33 are pressed together in a longitudinal direction by means of a spring 34 which is lodged between the last pellet in the stack 33 and a plug 35 that is secured in the other open end of the hollow tube 31.

Turning now to Fig. 3, it can be seen that the plug 35 is provided with a chamfered end 36 that provides a lead in for a cylindrical portion 37. The inside diameter of the hollow tube 31 matches the outside diameter of the cylindrical portion to an extent that a snug fit is achieved.

As shown in the drawing, the cylindrical portion, 37 terminates in a radially protruding shoulder 40 that engages the transverse end of the hollow tube 31 to which it is welded. In the illustrative embodiment of the invention, the diameter of the hollow tube 31 in order to establish a flush relationship between an exposed cylindrical portion 41 of the plug 35 that extends beyond the transverse end of the tube 31 and the outer surface of the tube.

A transverse flange 42 that is spaced longitudinally from the shoulder 40 terminates the exposed cylindrical portion 41 of the plug 35. A stem 43 protrudes in a longitudinal direction from the central portion of the transverse flange 42. Most of the shank that forms the stem 43 is formed from solid metal stock. A longitudinal bore 44 is formed, however, in the stem 43 for a depth that extends from the free end of the stem through a distance that is about half of the stem length.

A portion of a stem 45 as manufactured, and before full installation on a spider arm 46, is shown in Fig. 2. Thus the stem 45 has a generally cylindrical exterior configuration. Bore 47, that extends from the free end of the stem 45 to about half its length, also is of a generally cylindrical shape with the exception of the bottom of the bore which is formed into the shape of a shallow cone.

It will be recalled that the stem 45 is received in the spider arm 46. To accomplish this end, the spider arm 46 is provided with a generally cylindrical passageway 50 that has a longitudinal axis 51 which is essentially coincident with the longitudinal axis of the stem 45 and the burnable poison rod (not shown in Fig. 2). In accordance with a characteristic feature of the invention, an enlarged recess 52 is formed within the passageway 50. Note in this respect, that the recess 52 overlaps only a portion of the bore 47 in the stem 45.

A truncated conical surface 53 affords a transition from the recess 52 to a bore 54 which forms the balance of the passageway 50. As shown in Fig. 2, the bore 54 has a slightly larger diameter than the outside diameter of the stem 45 that is lodged in the passageway 50.

In operation, the stem 45 is inserted into the appropriate passageway 50. The stem is mechanically deformed through hydroforming, mechanical flaring or other suitable means, to match the contour of the truncated conical surface 53 and the enlarged recess 52 and to provide a designed "weak point" for poison rod removal, as illustrated in Fig. 3. In this manner, the burnable poison rod is secured to the associated spider arm without making use of costly and difficult to handle weld fittings, and the like.

It will be recalled, moreover, that different metals often are used for the spider arm and for the burnable poison rod. The truncated conical surface 55, however, provides a tapered surface that alleviates the effect of the different coefficients of thermal expansion. Typically, as the temperature increases, the exemplary stainless steel spider arm expands in an axial direction more than the poison rod end plug 35 (usually Zircalloy). In this manner, the axial stresses that otherwise would have been generated are alleviated because of the radial loosening of the parts. Thus, because the spider arm also expands radially more than the plug 35, the conical interface between the adjacent deformed portion of the stem 43 and the conical surface 53 shifts axially downward. The two parts remain in intimate contact radially and axially, but the strain in the stem 45 has been materially reduced relative to the stresses that otherwise would have been generated.

Thus, although a tight joint is maintained throughout the entire range of reactor operating temperatures, the structure nevertheless provides a predetermined design "weak point" to facilitate removal of the  
5 burnable poison rod as described subsequently in more complete detail.

A further salient feature of the invention is shown in Fig. 4. As illustrated, a plug 56 seals an end of a burnable poison rod 57. The plug 56 has a stem 60,  
10 the longitudinal axis of which is coincident with longitudinal axis 61 of the burnable poison rod 57.

A bore 62 extends longitudinally through about half the length of the stem 60. As shown in the drawing, this bore has been expanded or upset through about  
15 half of its length to produce an enlarged cavity that enables the outer diameter of the adjacent portion of the stem 60 to bear against an enlarged recess 64 in a spider arm 65.

The bore 62 has a truncated conical taper 63 that  
20 also provides a transition to a smaller diameter bore portion 66. The smaller diameter bore portion 66, moreover, terminates in a cone 67.

In accordance with a salient feature of the invention, a mandrel 70 is pressed into the bore 62 in  
25 the direction of arrow 71. The mandrel 70, preferably formed in the shape of a slender, cylindrical metal shaft, has a diameter that is slightly smaller than the diameter of the smaller diameter bore portion 66. The longitudinal axis of the mandrel 70 is generally  
30 coincident with the longitudinal axis 61 of the burnable poison rod 57.

To remove the burnable poison rod 57 from the spider arm 65 in a manner that will avoid undesirable shearing or sawing procedures it is only necessary to press the mandrel 70 in the direction of the arrow 71 with

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force sufficient to extrude the stem 60 through small diameter recess 72, thereby freeing the stem 60 from the spider arm 65.

5 Naturally although not shown in the drawing,  
a group of mandrels can be ganged together on a plate  
These mandrels, aligned with and inserted into corresponding bores on respective burnable poison rods  
10 mounted in a spider, can press all of the rods out  
of the spider in one operation. In this way, a potentially  
hazardous, expensive and tedious process of shearing or  
sawing each burnable poison rod from the spider is  
avoided.



THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A control component structure comprising:
  - a spider having a plurality of arms, at least one spider bore formed in said plurality of arms, said spider bore including an enlarged recess and a small recess with an upright truncated conical section forming a transition from the enlarged recess to the small recess, and
  - a burnable poison rod including a tube terminating in transverse end, a plug with a chamfered end that leads into a cylindrical portion, said cylindrical portion of the plug snugly fitting within the tube and terminating in a radially protruding shoulder which engages the transverse end of the tube to which it is welded, and a stem protruding in the longitudinal direction from the central portion of the shoulder having a longitudinal stem bore extending through about half of the length of the stem, at least part of the stem which defines the stem bore being fixed within the truncated conical section, the enlarged recess and the small recess of the spider by outward deformation of that part of the stem in order to releasably attach the rod to the spider, said stem being adapted to substantially reshape itself by movement of the rod in a longitudinal direction with respect to the spider bore, while maintaining the structural integrity of the poison rod and maintaining the structural integrity of the spider.

2. The control component structure according to Claim 1, wherein the spider is made of material which has

a greater coefficient of thermal expansion than that of the stem.

3. The control component structure according to Claim 2, wherein the material of the spider is stainless steel.

4. The control component structure according to Claim 2, wherein the material of the stem is zircalloy.

5. A method of assembling and disassembling a control component structure for a nuclear reactor comprising the steps of:

providing a spider having a plurality of arms, at least one spider bore formed in said plurality of arms for receiving a burnable poison rod having a deformable stem protruding from one end thereof,

inserting the stem into the spider bore,

fastening the stem within the spider bore by deforming a portion of the stem into engagement with a taper in said bore, and

separating the burnable poison rod from the spider by applying a longitudinal force to the stem of the burnable poison rod sufficient to extrude the deformed portion through the taper while maintaining structural unity of the burnable poison rod and maintaining structural unity of the spider.

6. A method according to Claim 5, wherein the stem has an axial bore, and a mandrel of smaller diameter than the spider bore is inserted within the stem bore to apply the longitudinal force.



FIG. 1

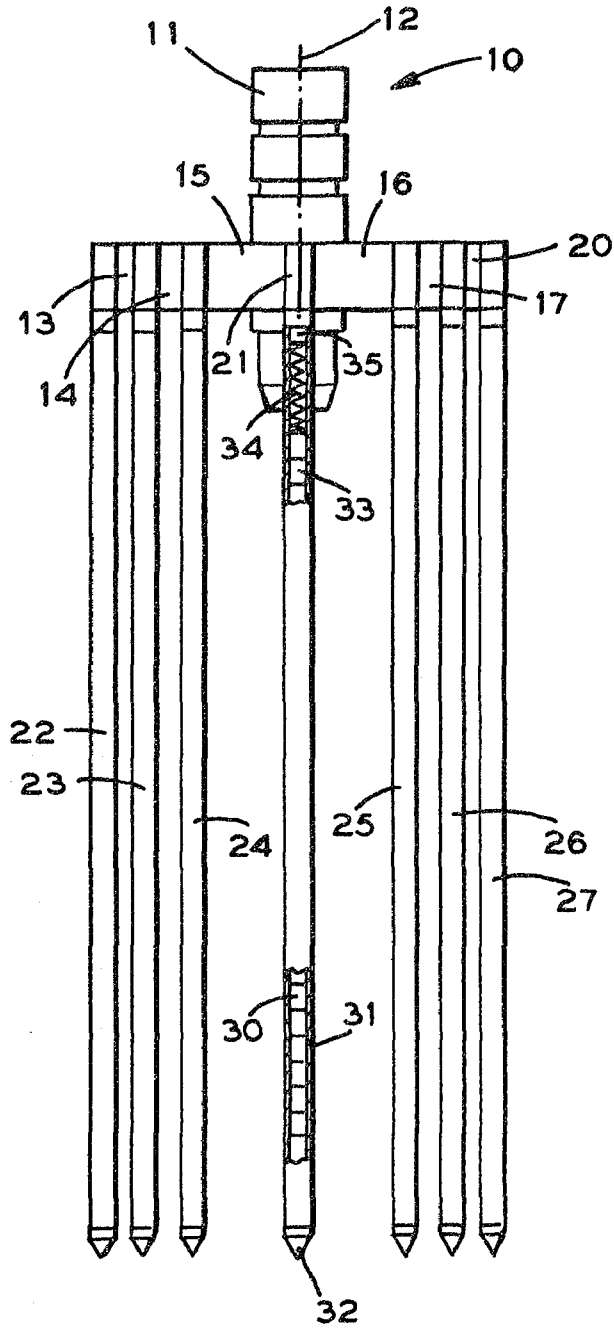


FIG. 2

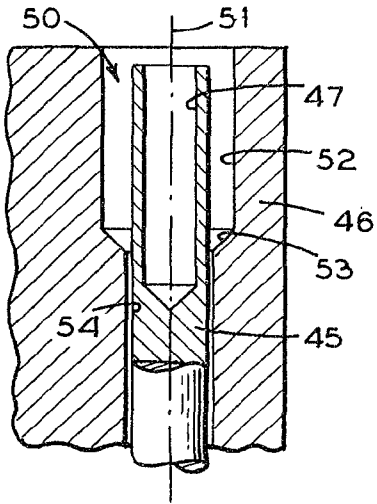


FIG. 3

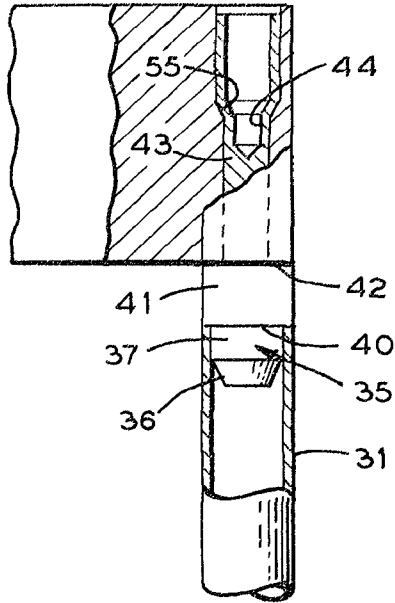


FIG. 4

