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(54) Control rod guide tube assemblies

(57) A nuclear fuel assembly including sleeves 17 telescoped over end portions of control rod guide tubes 12 (only one shown) which bear against internal shoulders 32 of the sleeves. Upper ends of the sleeves 17 protrude beyond a control rod guide tube spider 20 and are locked in place by means of a resilient cellular lattice or lock 21 that is seated in mating grooves 44 in the outer surfaces of the sleeves. A grapple is provided for disengaging the entire lock structure 21, spider 20 and associated washers 40, 41, springs 22 and a grill 14 from the end of the fuel assembly in order to enable these components to be removed and subsequently replaced on the fuel assembly after inspection and repair.

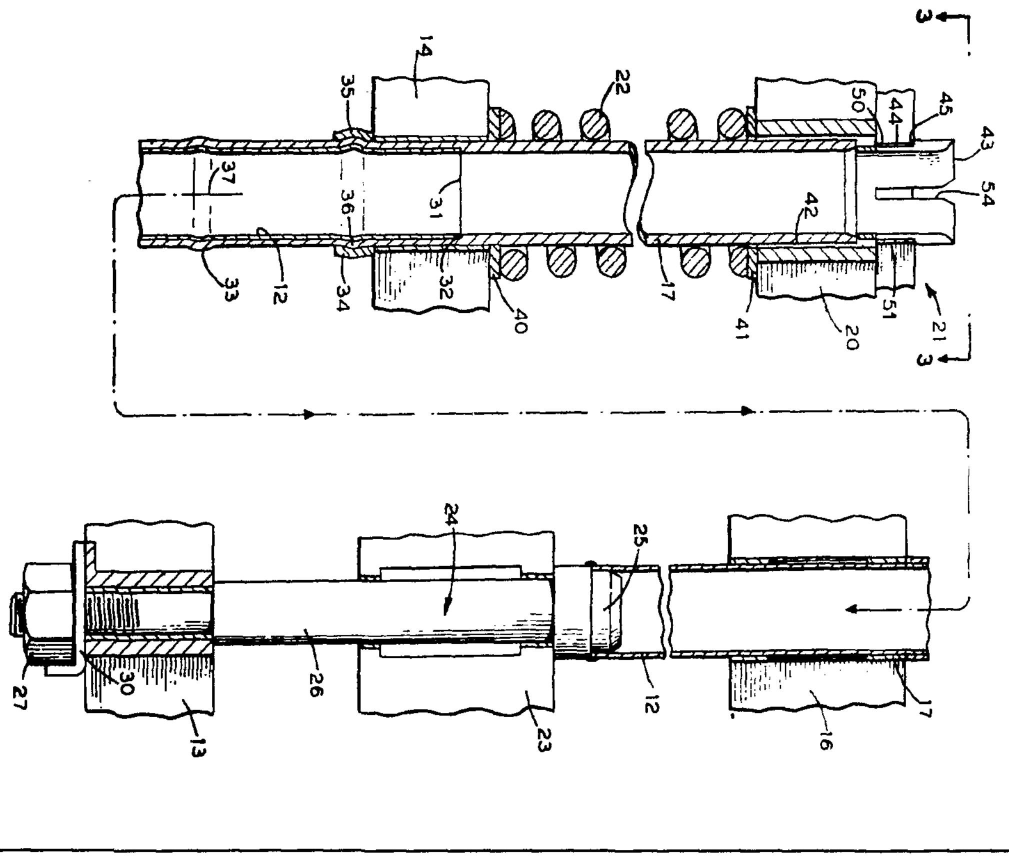

FIG. 2

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FIG. 1

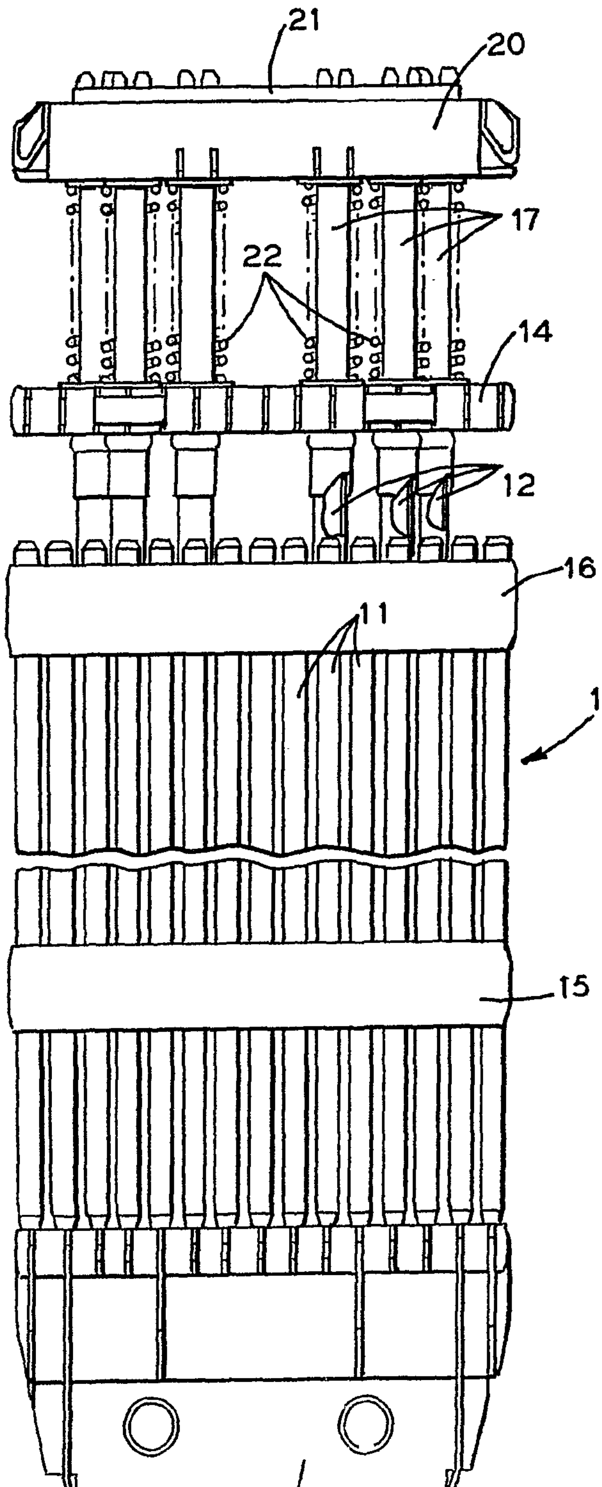
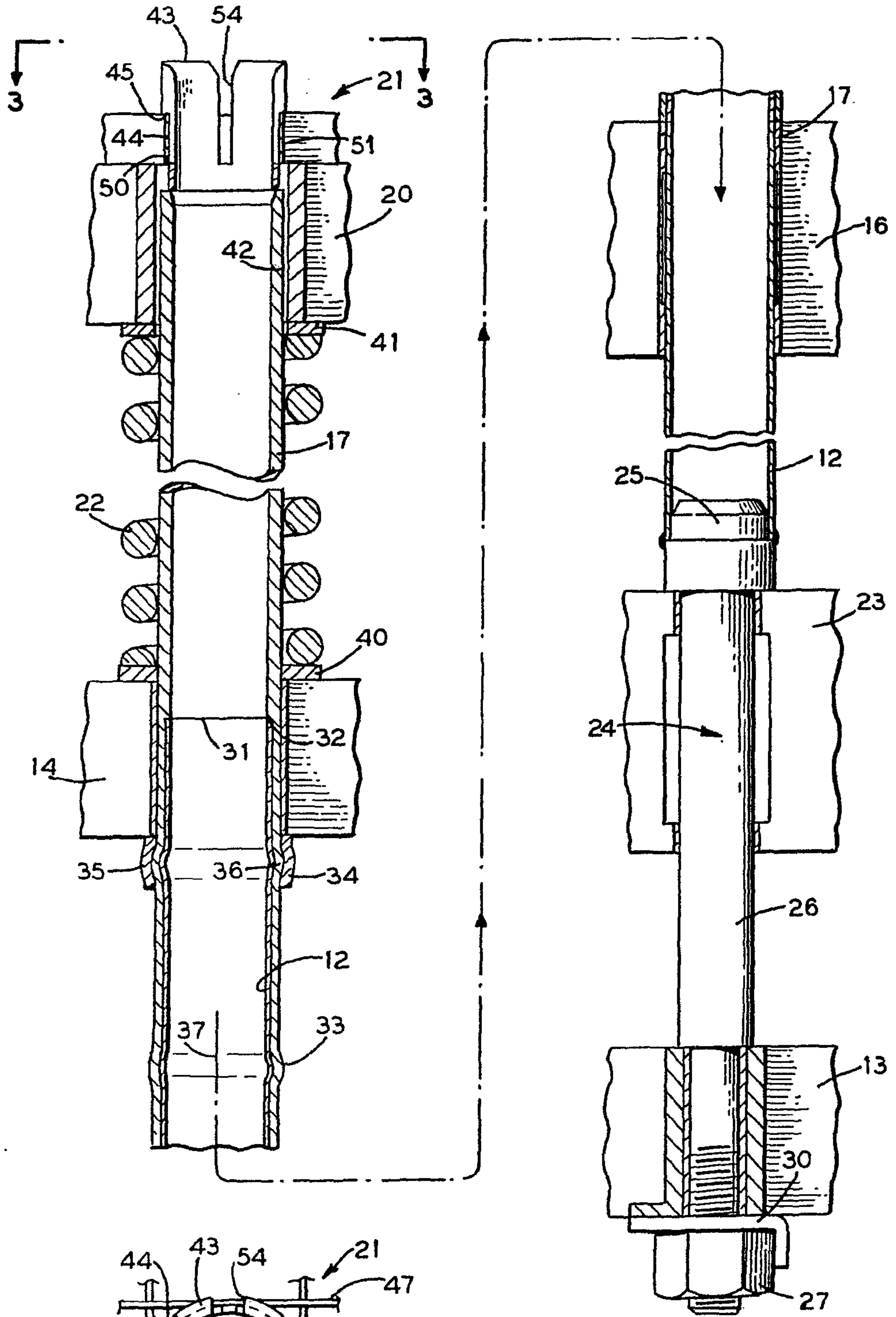


FIG. 2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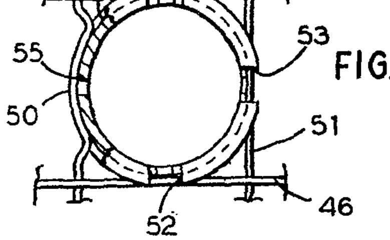
44
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FIG. 3

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FIG.5

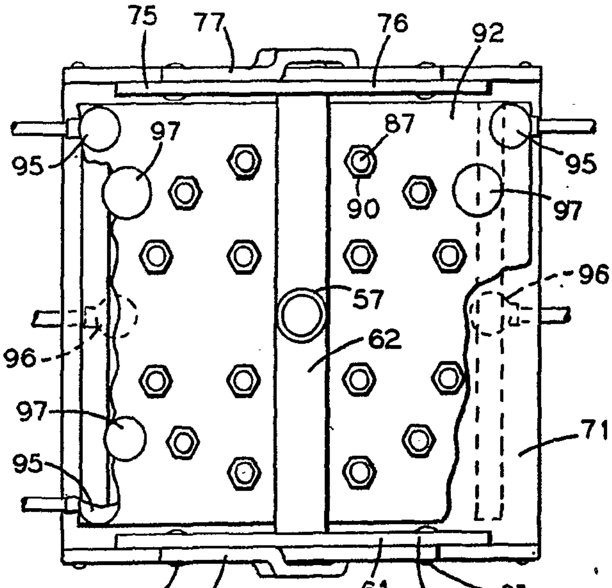


FIG. 4

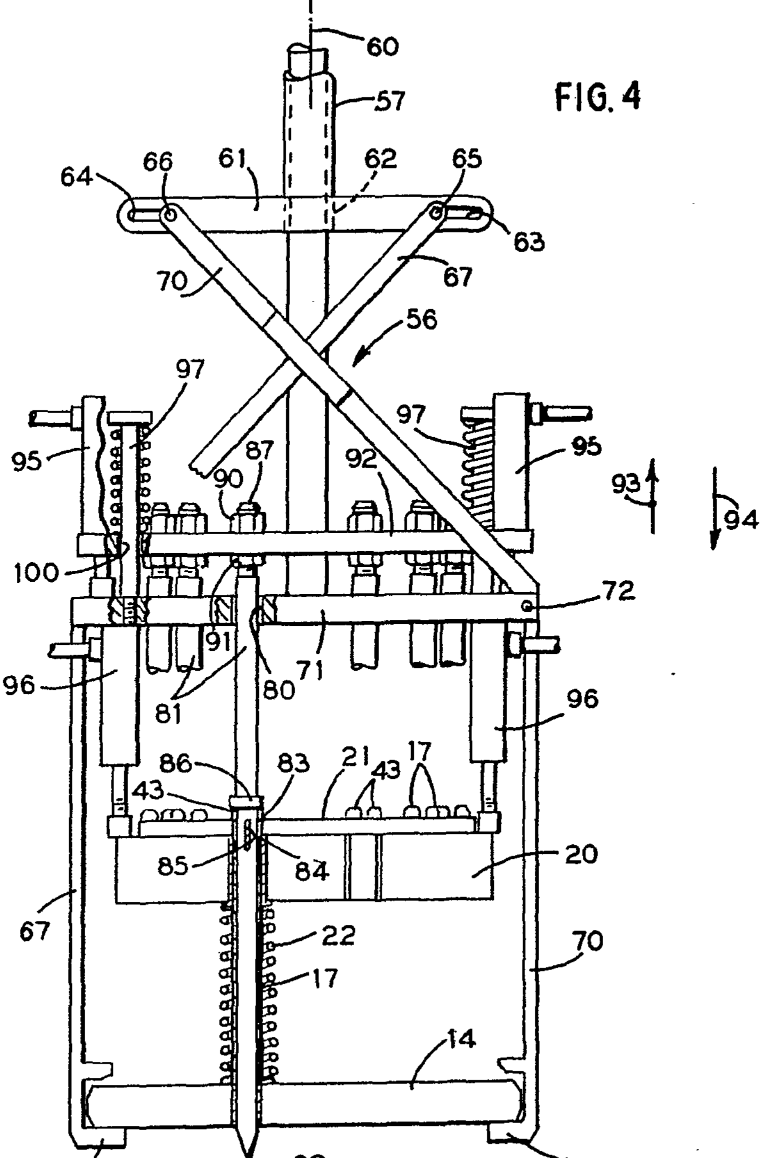


FIG. 6

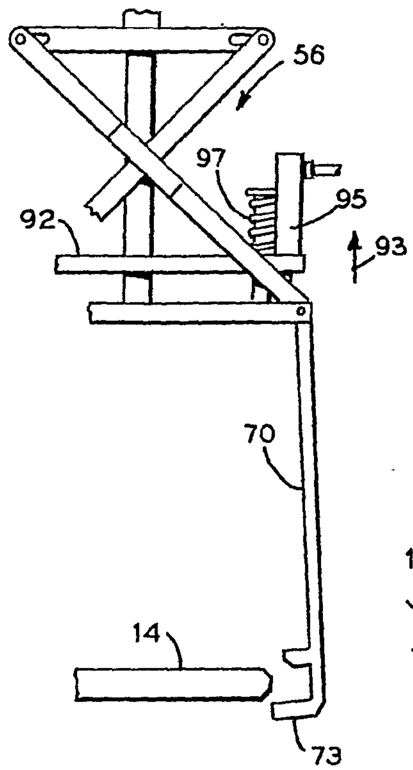


FIG. 7

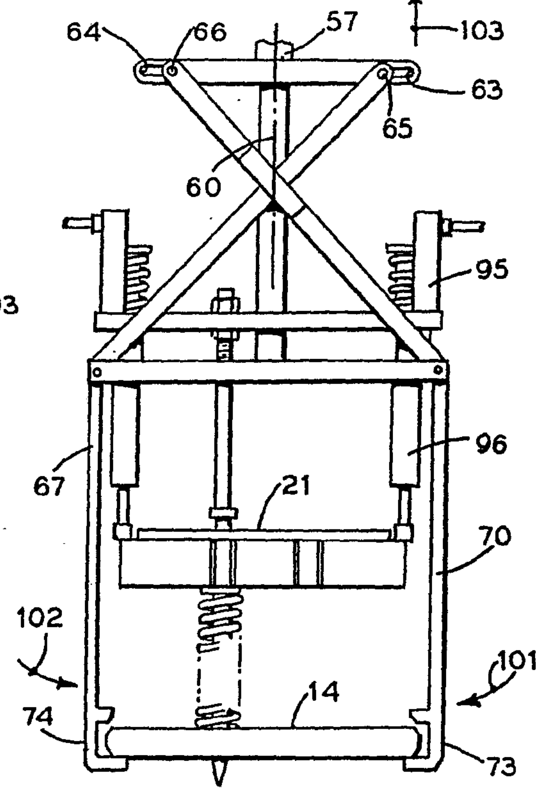


FIG. 8

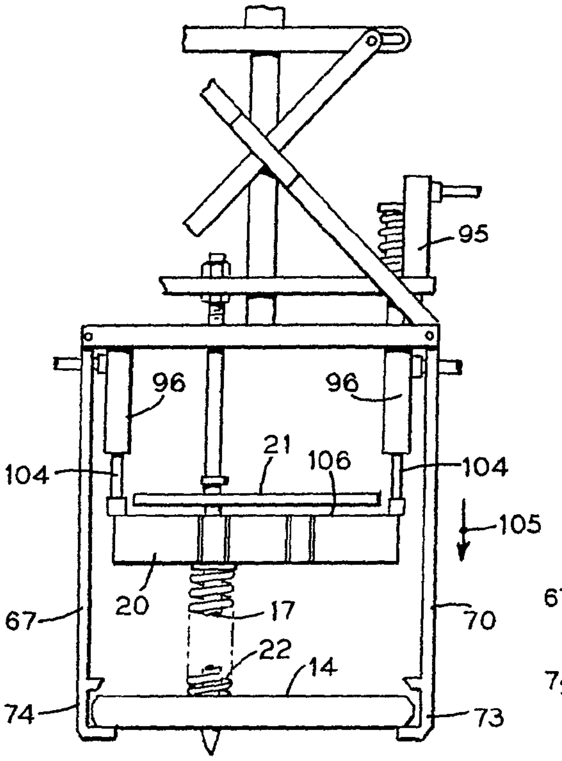
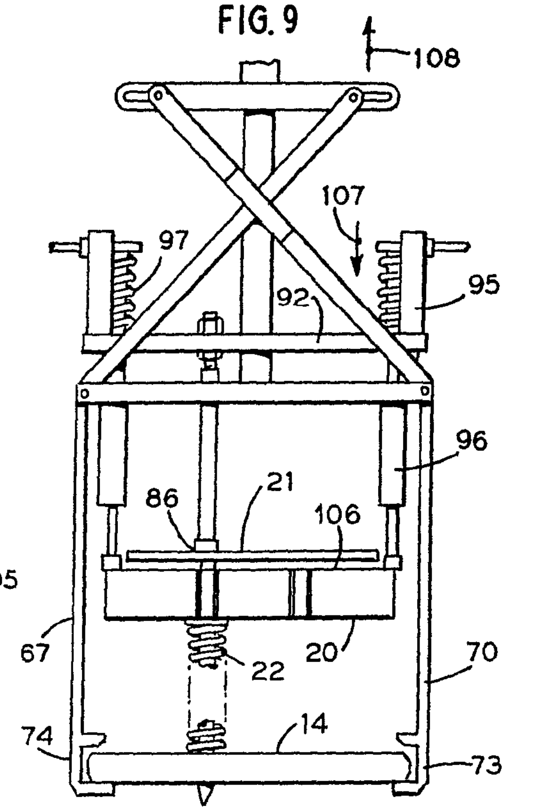


FIG. 9



SPECIFICATION

Control rod guide tube assemblies, end fittings for nuclear reactor fuel assemblies, fuel assemblies and grapples for manipulating end fitting for fuel assemblies

This invention relates to control rod guide tube assemblies, end fittings for nuclear reactor fuel assemblies, fuel assemblies and grapples for manipulating end fittings for fuel assemblies.

To produce useful power from a nuclear reactor it is necessary to assemble fissionable material in a concentration that is sufficient to sustain a continuous sequence of neutron-induced fissions. Frequently, this concentration is attained by sealing uranium dioxide pellets in long, slender hollow rods. These rods, when filled with a charge of nuclear fuel and sealed at the ends, are called "fuel rods".

The fuel rods are arranged in a generally cylindrical array, or reactor core, to form the required concentration of fissionable material. In order to extract the heat generated in these fuel rods through the fission process, the fuel rods are usually spaced laterally from each other and water is pumped under pressure through the reactor core. The water absorbs the fission process heat and transfers this heat to secondary cooling water. The secondary cooling water rises into steam that is used to drive power generating turbine machinery.

In the reactor core, the radiation, pressures, temperatures and cooling water flow velocities create an environment that is quite hostile to the structural integrity of the reactor core. To cope with this environment, it has been customary to arrange the fuel rods that comprise the reactor core into a number of groups each of about two hundred fuel rods. These groups are frequently called fuel assemblies.

To enhance the structural integrity of each of the fuel assemblies and to stabilise the fuel rods in the assembly, it is common to mount the fuel rods between "end fittings" and to engage the mid-portions of each of the rods in the fuel assembly by means of cellular grid structures that are positioned at predetermined intervals along the lengths of the rods.

The structure of the fuel assembly, moreover, is not restricted to fuel rods, end fittings and grids. As a general rule, one or more control rod guide tubes are usually also accommodated in the fuel assembly. Typically, to control the power generated in a nuclear reactor it is customary to add neutron absorbing materials to the reactor core. These materials have the effect of decreasing the fission activity within the core and thereby decreasing the power output from the reactor. As might be expected, there are a number of ways in which these neutron absorbing materials are introduced into the reactor core. Quite frequently, for example, the neutron absorbing materials are loaded into control rods. These control rods are received in hollow metal control rod guide tubes that extend through the length of the respective fuel element. In there circumstances, the depth of the penetration of the control rods into the associated fuel element determines, to some extent, the level of neutron fission activity and associated power output from the reactor core.

Some fuel assembly designs have a further use for the control rod guide tubes beyond aligning the individual control rods within the respective fuel assembly. Typically, in this regard, the control rod guide tubes are often used to space the two end fittings from each other and, essentially, to clamp the fuel rods in proper relative position between these end fittings through enabling the end fittings to engage the extreme ends of the fuel rods.

This foregoing fuel assembly construction produces a rugged, sturdy structure that is able to cope with the forces that characterise a reactor core environment. There is, however, a somewhat countervailing need to provide a fuel assembly structure that can be assembled and dismantled with ease in order to reduce manufacturing costs, improve quality assurance and facilitate inspection and replacement. If it is realised that fuel assemblies, once having been made radioactive, must subsequently be manipulated behind shielding with remote handling equipment, the importance of the need for simple disassembly techniques becomes immediately apparent.

In this respect, the typical fuel element is dismounted by unthreading nuts that connect the control rod guide tubes to the end fittings, releasing one or more springs and, in general, taking the entire fuel assembly apart piece-by-piece. Not only is this a very laborious and expensive practice, but it also introduces the possibility that one or more of the smaller fittings might go astray, leading to further lost time and expense, or damage if not discovered.

Thus, there is a clear need for an improved fuel assembly that will, to a large extent, overcome many of these inadequacies that have characterised the prior art.

According to a first aspect of the invention there is provided a control rod guide tube assembly comprising a control rod guide tube having at least one open end, a cylindrical sleeve telescoped over a portion of said guide tube and having a flange formed on the inner surface thereof to engage said control rod guide tube, an annular groove formed in the outer surface of said sleeve, said sleeve having an end portion having at least one longitudinally arranged slot that extends through said annular groove, and a collar circumscribing a portion of said telescoped guide tube and sleeve, said collar and circumscribed guide tube and sleeve portion being joined together to form an integral control rod guide tube assembly.

According to a second aspect of the invention there is provided an end fitting for a nuclear reactor fuel assembly, the end fitting comprising a plurality of control rod guide tubes in parallel longitudinal alignment, a plurality of cylindrical sleeves, each said sleeve having a flange formed in the interior thereof and each said sleeve being telescoped over a portion of a respective one of said guide tubes in order to engage said flanges with said guide tubes, a cellular grill transversely disposed relative to said guide tubes and said sleeves, at least some of the cells in said grill engaging adjacent surfaces of respective said sleeves lodged therein in the plane of said telescoped engagement, a plurality of collars each circumscribing a respective one of said sleeves adjacent to said transversely disposed grill, a spider spaced longitudinally from said grill, said spider being transverse to said sleeves and having a plurality of cells formed therein, each of said cells receiving a respective one of said sleeves to enable an end portion of each of said sleeves to protrude in a longitudinal direction beyond said spider, a lock engaging each of the protruding sleeve end portions to restrict the movement of said spider between said lock and said grill, and at least one spring interposed between said grill and said spider to permit said end fitting to absorb longitudinal forces.

According to a third aspect of the invention there is provided a grapple for manipulating an end fitting for a fuel assembly that includes control rod guide tubes, the grapple comprising a longitudinally movable member, a transversely disposed crosspiece coupled to said member for movement therewith in a longitudinal direction, a transversely disposed linkage secured to said crosspiece and having transversely oriented slots formed therein, two jaws each slidably pinned to a respective one of said slots of said transversely oriented linkage, a tool frame transversely disposed relative to said member, said jaws being pivotally connected to said tool frame, and a respective clamp formed on each of said jaws to selectively grasp the fuel assembly end fitting, the arrangement being such that said clamps on said jaws swing into engagement with the end fitting as said member, crosspiece and linkage are moved in a longitudinal direction.

A fuel assembly embodying the invention and described below comprises sleeves that each engage one end of a respective control rod guide tube, essentially fixing the guide tubes to one of the fuel assembly end fittings. An end of each sleeve protrudes above a surface of the one end fitting. The outer surface of each sleeve has a peripheral groove that engages the resilient sides of a cellular grid or lattice shaped lock. This lock fixes the sleeves in position between the various elements that comprise the end fitting, thereby eliminating a profusion of costly and potentially troublesome nuts, threaded studs and the like that frequently are employed in the fuel assemblies that are typical of the prior art. To dismount the end fitting from the fuel assembly, there is employed a special grapple that has jaws that engage a portion of the end fitting. The jaws first clamp an upper grill that supports the ends of the control rod guide tubes and their respective sleeves. A spider which engages the control rod guide tube sleeves is then pressed against springs that circumscribe these sleeves in order to establish some degree of longitudinal clearance between the spider and the lock. After this clearance is established individual tools are pressed into the respective open, protruding ends of each of the sleeves to engage exposed portions of the grid-shaped lock. The tools press these sides out of the groove and so engage the lock that the lock will be withdrawn from the sleeve when the grapple is withdrawn from the end of the fuel assembly. This permits the upper end fitting to be removed as a unit that captures the components which are associated with the end fitting as an assembled unit, while leaving the control rod guide tubes and the associated sleeves with the balance of the fuel assembly. In this way, end fitting components that are captured by the grapple in this manner can subsequently be replaced intact on the fuel assembly without indulging in the cumbersome and expensive remote manipulator detailed disassembly and assembly of scores of small parts that has characterised the prior art. Thus, the number of parts required for fuel assembly construction and manufacturing costs are reduced, and quality assurance and inspection problems are simplified.

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a front elevation in part section of a typical fuel assembly that embodies the invention;

Figure 2 is a front elevation in full section of a control rod guide tube structure incorporated in the fuel assembly that is shown in Figure 1;

Figure 3 is a plan view in part section of the control rod guide tube structure that is shown in Figure 2, taken along the line 3–3 of Figure 2 and viewed in the direction of the arrows;

Figure 4 is a front elevation of a grapple engaging a portion of the fuel assembly that is shown in Figure 1;

Figure 5 is a plan view in broken section of the grapple that is shown in Figure 4;

Figure 6 is a schematic drawing of a portion of the grapple in an initial operational position;

Figure 7 is a schematic drawing of a portion of the grapple in another operational position;

Figure 8 is a schematic drawing of a portion of the grapple in still another operational position; and

Figure 9 is a schematic drawing of a portion of the grapple after the lock of the fuel assembly has been disengaged.

Figure 1 shows a fuel assembly 10 that comprises an array of more than two hundred fuel rods 11. The fuel rods 11 are made from long, slender, thin-walled tubes that enclose pellets of uranium dioxide or other suitable nuclear fuel, and the fuel rods are grouped together within the fuel assembly 10 with the longitudinal axes of the fuel rods in general parallel alignment. Control rod guide tubes 12 are nested within the fuel rods 11. The control rod guide tubes 12 are thin-walled tubes that extend through the entire fuel assembly 10 in directions that are parallel to the longitudinal axis of the fuel assembly.

An end support fitting 13 that is transversely disposed relative to the longitudinal axes of the fuel rods 11 engages the abutting ends of the fuel rods. As described subsequently in more complete detail, the control rod guide tubes 12 pass through the end fitting 13 in order to secure the end fitting to the fuel assembly structure.

Ends of the control rod guide tubes 12 protrude above a plane established by sealed upper ends of the fuel rods 11. These protruding ends of the control rod guide tubes 12 terminate, as shown in Figure 2, within the confines of a transversely disposed grill 14. The grill 14 is assembled from a parallel array of generally flat, slotted plates that are meshed with mating slots in a perpendicular array of essentially flat plates in order to form a cellular grill structure. The parallel grouping of the fuel rods 11 and the control rod guide tubes 12 is established and stabilised by means of transversely disposed grid structures 15 that are similar in construction to the grill 14 described above. Toward the ends of the fuel rods 11 that are close to the protruding portions of the control rod guide tubes 12, however, a transversely disposed upper grid 16 is positioned. The upper grid 16 has a somewhat greater depth in the direction of the longitudinal axes of the fuel rods 11 than the grid structures 15 in order to enhance the structural integrity of this portion of the fuel assembly 10.

A parallel array of hollow cylindrical sleeves 17 telescope over the respective protruding ends of the control rod guide tubes 12 in order to extend from within the confines of the upper grid 16, through the grill 14, through a transversely disposed cellular spider 20 and an immediately superadjacent control rod guide tube assembly lock 21. Individual coil springs 22, each associated with a respective one of the sleeves 17, are interposed between the grill 14 and the spider 20 in order to provide some means for compensating and absorbing movement of the fuel assembly 10 in the direction of the longitudinal axes of the fuel rods 11. Note that in the illustrative embodiment of the invention shown in Figure 2, each sleeve 17 is in general axial alignment with the associated guide tube 12, and that the sleeve serves as a guide for the coil spring 22. The coil spring 22, moreover, also has a longitudinal axis that generally coincides with the longitudinal axis of the guide tube 12.

Referring now to Figure 2, each control rod guide tube 12 is secured to a lower grid 23 by means of a bolt structure 24. The bolt structure 24 has a head 25 that is received within the adjacent open end of the control rod guide tube 12. A bolt shank 26 extends through the lower grid 23 in order to protrude from the end support fitting 13. The protruding portion of the shank 26 is threaded in order to receive a fastening nut 27. A nut retainer 30 is interposed between the end fitting and the nut 27 in order to prevent the nut from working loose and becoming disengaged from the fuel assembly.

As shown in Figure 2, the control rod guide tube 12 extends through the main portion of the fuel assembly and through the upper grid 16. Within the upper grid 16 the guide tube 12 is telescoped within the sleeve 17, an open end portion 31 of the control rod guide tube 12 abutting and bearing against a flange or shoulder 32 that is formed within the inner surface of the sleeve 17. The shoulder 32 in the sleeve 17 transfers compression loads directly to the guide tube 12 in a manner described subsequently in more complete detail.

Throughout the portions of the lengths of the control rod guide tube 12 and the sleeve 17 that are coextensive, protrusions or "dimples" 33 are swaged or otherwise suitably formed in the control rod guide tube 12 and the sleeve 17 in order to hold the sleeve and the guide tube together and form a tight joint. Immediately below the grill 14, circumscribing a portion of the sleeve 17 and bearing against a transverse surface of the grill 14, is a ring shaped collar 34. As shown, the collar 34 and the encircled portions of the sleeve 17 and the control rod guide tube 12 are also provided with protrusions or dimples 35, 36 that have been swaged or otherwise formed in the materials in order to position the collar 34 properly relative to the balance of the fuel assembly 10 and to permit the collar to sustain loads imposed in the direction of the longitudinal axis 37 of the control rod guide tube 12 and to transfer these loads between the grill 14 and the combination of the sleeve 17 and control rod guide tube 12.

A washer 40 rests upon the transverse surface of the grill 14 that is opposite to the transverse grill surface that engages the collar 34. The coil spring 22 encloses a portion of the sleeve 17 that protrudes above the grill 14. The longitudinal axis of the coil spring 22 generally coincides with the longitudinal axis 37 in order to press against a further washer.

Illustratively, the washer 41 is in engagement with the cellular spider 20. As shown, the sleeve 17 is received within a cellular recess 42 in the spider 20 with sufficient clearance between the sleeve and the walls of the spider recess 42 to permit the spider and the sleeve to move relative to each other in the direction of the longitudinal axis 37.

A terminal portion 43 of the sleeve 17 protrudes above the spider 20 in order to engage the lock 21. To engage the lock 21, the outer surface of the portion 43 is provided with a circumferential groove 44 that forms a protruding shoulder 45 which serves to engage edges of the lock 21. Possibly, as best shown in Figure 3, the lock 21 can be assembled from an array of resilient parallel plates 46, 47 that are meshed and interlock with similarly resilient plates 50, 51 that are generally perpendicular to the plates 46, 47 at the respective lines of intersection to form a cellular grid structure. As shown, the separation between the parallel plates 46, 47 is less than the maximum outside diameter of the groove 44 that is formed in the portion 43.

The plate 50 has a generally arcuate shape that conforms to and bears against a segment of the grooved surface of the terminal sleeve portion 43. The companion plate 51, however, has a planar profile that permits part of an edge of this plate to engage the shoulder 45 (Figure 2). In this manner, all of the control rod guide tubes 12 that are shown in Figure 1 are locked together as a single unit.

As is best shown in Figures 2 and 3, the terminal sleeve portion 43 is provided with four longitudinal slots 52, 53, 54 and 55 that are parallel to the longitudinal axis 37. The slots 52, 53, 54 and 55 are each spaced from the next adjacent slots by about 90° and penetrate the portion 43 to a depth that is at least equal to the combined longitudinal depth of the shoulder 45 and the width of the plates 50, 51.

A grapple 56 is shown in Figure 4. The grapple 56 is operative to release the lock 21 from the control rod guide tube sleeves 17 and also provides a means for installing or removing as one entire unit the complete assembly that comprises the lock 21, the sleeves 17 with the associated control rod guide tubes 12 (not illustrated in Figure 4), the spider 20, the coil springs 22 and the grill 14. To accomplish these results, the grapple 56 is provided with a member 57 that is movable vertically in the direction of a longitudinal axis 60. A transversely disposed linkage 61 is secured through a crosspiece 62 (Figure 5) to the vertically movable member 57. End portions of the linkage 61 have slots 63, 64 (Figure 4) which receive respective pins 65, 66. The pins 65, 66 are transversely movable within the respective slots 63, 64 in order to enable two jaws 67, 70 that are pivotally connected to a transversely disposed tool frame 71 to move in a scissors-like manner. A pivot 72 joins the jaw 70 to the tool frame 71.

As shown in Figure 4, the jaw 70 is provided at its extreme end with a clamp 73 that engages a longitudinal edge of the grill. In a similar manner, the extreme end of the jaw 67 is provided with a clamp 74 that is oppositely disposed from the clamp 73 on the jaw 70.

As is perhaps best shown in Figure 5, a linkage 75 with pinned and pivoted jaws 76, 77 is joined by means of the crosspiece 62 to the longitudinally movable member 57 to form a companion structure that matches and balances the structural arrangement comprising the linkage 61 and the jaws 67, 70.

The transversely disposed tool frame 71 is provided with an array of longitudinally aligned apertures 80 that each accommodate one of a group of tools 81. As illustrated in Figure 4, the tools 81 are formed from generally cylindrical rods that are longitudinally aligned with the axis 60. Each of the tools 81 has a generally conical lower end portion 82. The mid-section of the tool 81 has four fins 83, of which only three are shown in the plane of the drawing. As illustrated, each of the fins 83 is spaced about 90° from the next adjacent fins. Each of the fins 83 has a tapered slope 84 of which the narrow edge is oriented toward the end portion 82. The tapered slope 84 ends in a generally flat surface 85. The width of each of the fins 83 is slightly less than the transverse width of the individual slots 52, 53, 54, 55 (Figures 2 and 3) in the terminal portion 43. However, the transverse depth of each of the fins 83, between the flat surface 85 (Figure 4) and the adjacent surface of the tool 81, is greater than the corresponding wall thickness of the terminal sleeve portion 43 as shown in Figures 2 and 3.

An annular collar 86 is secured to the tool 81 and spaced longitudinally from the flat surfaces 85 on the fins 83 a sufficient distance to enable the fins when aligned with the respective slots 52, 53, 54, 55 in the terminal sleeve portion 43 to bear against the terminal portion and prevent the flat surfaces 85 of the fins 83 from penetrating the sleeve 17 to a depth greater than the longitudinal protrusion of the slots in the terminal sleeve portion 43 (Figure 2) above the spider 20.

As illustrated in Figure 4, each tool 81 is threaded at the end 87 thereof opposite to the end portion 82 to enable nuts 90, 91 to secure the tool 81 to a transversely disposed plate 92 that is movable in longitudianl directions as indicated by means of arrows 93, 94 under the control of spring biased pneumatic cylinders 95, 96. Thus, depending on the relative activation of the pneumatic cylinders 95, 96, the tools 81, when aligned with respective terminal sleeve portions 43, are driven into the sleeves 17 to a sufficient depth to permit the flat surfaces 85 on the fins 83 to bear against the plates 46, 47, 50, 51 (Figures 2 and 3). The flat surfaces 83 press these plates in a radially outward direction relative to the longitudinal axis 37 through a distance that is sufficient to permit all of the plates to clear the shoulder 45 that is formed in the terminal sleeve portion 43. In this manner, the entire cellular lock 21 is released from its engagement with the sleeves 17 and fixes itself temporarily to the tools 81 in the array of tools.

In operation, and, as perhaps best understood through an examination of Figure 6, the grapple 56 is aligned with the end fitting to permit the clamp 73 on the jaw 70 (as well as the clamp 74 on the jaws 67, and the clamps on the jaws 76, 77 that are not shown in Figure 6) to be spaced outwardly of the grill 14, but within the same transverse plane as the grill.

During this phase of the operation of the grapple 56, springs associated with spring-loaded pins 97 are compressed through activation of the pneumatic cylinders 95 which moves the plate 92 in the direction of the arrow 93.

As illustrated in Figure 7, the clamps 73, 74 on the jaws 70, 67, respectively, (as well as the clamps on the companion pair of jaws 76, 77) swing inwardly in the directions indicated by arrows 101, 102, in order to grasp firmly peripheral portions of the grill 14. This inward swinging movement of the clamps 73, 74 is achieved through longitudinal movement of the member 57 in the direction of an arrow 103. This movement of the member 57 causes the pins 65, 66 to ride within the respective slots 63, 64 toward the longitudinal axis 60. The motion of the pins 65, 66 within the slots 63, 64 compels the jaws 67, 70 to pivot anticlockwise and clockwise, respectively, about the pivot 72 (for the jaw 70) and a similar pivot (not shown in Figure 7) for the jaw 67.

The next illustrative step in the technique for dismounting the end fitting from the balance of the fuel assembly is shown in Figure 8. Thus, the pneumatic cylinders 96 are activated to drive piston rods 104 in the longitudinal direction indicated by an arrow 105. The exposed ends of the piston rods 104 bear against the adjacent transverse surface of the spider 20. The force applied by the piston rods 104 to the spider 20 overcomes the oppositely directed forces established by means of the coil springs that are received on the sleeves, of which the coil spring 22 and the sleeve 17 in Figure 8 are illustrative. In response to this new balance of forces the spider 20 also moves in the longitudinal direction of the arrow 105 in order to provide a longitudinal clearance 106 between the spider 20 and the lock 21 to relieve the force that the spider 20 applies to the lock 21.

In a typical embodiment of the invention, the next step in the technique involves movement of the grapple 56 that is best illustrated in Figure 9. Recall for a moment that the cellular structure of the lock 21 is so designed that the groove 44 (Figure 2) and the shoulder 45 that is formed in the terminal sleeve portion 43 engage the plates 46, 47, 50, 51 (Figure 3) that comprise the structure of the cells in the lock 21.

Turning now once more to Figure 9, the pneumatic cylinders 95 are deactivated to enable the coiled springs on the spring-loaded pins 97 to release and press the plate 92 in a longitudinal direction as indicated by an arrow 107. Because the recess and shoulders on the sleeves 17 restrain the lock 21 from engaging in any longitudinal movement in the direction of the arrow 107, the tools that are fastened to the plate 92, of which the tools 81 are typical, are pressed through the individual cells in the locks 21 into the respective sleeves 17. The fins 83 that protrude radially from the tools 81 are driven into mating slots 52, 53, 54, 55 (Figures 2 and 3). This longitudinal movement of the tools 81 permits the tapered slope 84 of the pins 83 (Figure 9) to press the plates 46, 47, 50, 51 on the lock 21 in a radially outward direction in order to disengage these plates from the nested engagement within the annular groove 44 (Figures 2 and 3) that is formed in the terminal sleeve portion 43.

In those circumstances, further longitudinal movement of the tools 81 (Figure 9) in the direction of the arrow 107 under the force of the released springs on the pins 97 is limited only by the braking action of the collars 86 on each of the tools. The collars 86 are so spaced relative to the lock 21 that the plates which form each of the cells in the lock 21 are forced on to the corresponding flat surface 85 of the fins 83. The effect of this engagement between the plates that form the cells on the lock 21 and the flat surfaces 85 of the fins 83 is to press the plates out of engagement with the respective annular grooves 44 (Figures 2 and 3) and shoulders 45.

In the next illustrative disassembly step, the entire grapple 56 is moved longitudinally in the direction of an arrow 108. The grapple, withdrawn from the balance of the fuel assembly in the foregoing manner, takes with it most of the end fitting components in their proper relative position. Typically, the lock 21, the spider 20, and the grill 14 remain with the grapple 56. The coil springs 22 with their associated washers 40, 41 (Figure 2) are also drawn away with the grapple 56 (Figure 9). In this instance, the tools 81 serve as temporary spring guides or keepers for the coil springs 22 and the washers 40, 41. The springs 22, moreover, serve to keep an approximately proper longitudinal separation between the grill 14 and the spider 20. Note in this respect that the sleeves 17 remain with the balance of the fuel assembly 10.

To reassemble the end fitting components on the main portion of the fuel assembly 10, the end portions 82 of the tools 81 on the grapple 56 are longitudinally aligned with their respective sleeves. The grapple 56 is then moved longitudinally in the direction of the arrow 107 until each of the tools 81 are fully seated in the respective sleeves 17. One or more clamps (not shown in the drawing) hold the lock 21 in suitable position relative to the grooves 44 (Figures 2 and 3) and the shoulders 45 on the terminal sleeve portions 43. In this condition, the pneumatic cylinders 95 (Figure 9) are activated to compress the springs on the spring loaded pins 97, thereby extracting the pins 83 from engagement with the plates that form the cells in the lock 21. The disengagement of the tools 81 and the lock 21 permits the plates that form each of the lock's cells to snap back into the annular recesses 44 (Figures 2 and 3) and shoulders 45 in the terminal sleeve portions 43.

The spider 20 (Figure 9) bears against the adjacent surface of the lock 21 under the action of the coil springs 22. The member 57, moreover, is moved longitudinally in the direction of the arrow 107 to permit the jaws 67, 70 to pivot in clockwise and anti-clockwise directions, respectively. This pivoting movement of the jaws 67, 70 releases the grip that the clamps 73, 74 had on the grill 14. The further clamps (not shown in the drawings) that engage the lock 21 are also removed.

The entire end fitting is now reassembled on the balance of the fuel assembly in a manner that clearly avoids the prior art requirement for tedious detailed, piece-by-piece disassembly and reassembly. This technique also avoids the hazards that might attend the loss of one of these small end fitting components, and the like.

CLAIMS

1. A control rod guide tube assembly comprising a control rod guide tube having at least one open end, a cylindrical sleeve telescoped over a portion of said guide tube and having a flange formed on the inner surface thereof to engage said control rod guide tube, an annular groove formed in the outer surface of said sleeve, said sleeve having an end portion having at least one longitudinally arranged slot that extends through said annular groove, and a collar circumscribing a portion of said telescoped guide tube and sleeve, said collar and circumscribed guide tube and sleeve portion being joined together to form an integral control rod guide tube assembly.

2. A fuel assembly incorporating a control rod guide tube assembly according to claim 1.

3. An end fitting for a nuclear reactor fuel assembly, the end fitting comprising a plurality of control rod guide tubes in parallel longitudinal alignment, a plurality of cylindrical sleeves, each said sleeve having a flange formed in the interior thereof and each said sleeve being telescoped over a portion of a respective one of said guide tubes in order to engage said flanges with said guide tubes, a cellular grill transversely disposed relative to said guide tubes and said sleeves, at least some of the cells in said grill engaging adjacent surfaces of respective said sleeves lodged therein in the plane of said telescoped engagement, a plurality of collars each circumscribing a respective one of said sleeves adjacent to said transversely disposed grill, a spider spaced longitudinally from said grill, said spider being transverse to said sleeves and having a plurality of cells formed therein, each of said cells receiving a respective one of said sleeves to enable an end portion of each of said sleeves to protrude in a longitudinal direction beyond said spider, a lock engaging each of the protruding sleeve end portions to restrict the movement of said spider between said lock and said grill, and at least one spring interposed between said grill and said spider to permit said end fitting to absorb longitudinal forces.

4. An end fitting according to claim 3, wherein said spring comprises a coil spring, the longitudinal axis of said coil spring being in general alignment with the longitudinal axis of one of said control rod guide tubes.

5. An end fitting according to claim 3 or claim 4, wherein said lock further comprises a cellular lattice, the lattice sides of at least some of the cells engaging adjacent surfaces of the protruding sleeve end portions.

6. An end fitting according to claim 5, wherein said protruding sleeve end portions each have an annular groove formed in the outer surfaces thereof to permit said adjacent lattice sides to be received within said grooves, thereby releasably engaging said lock with said sleeves.

7. An end fitting according to claim 6, wherein said protruding sleeve end portions each have at least one longitudinally oriented slot formed therein, said slot permitting said lock to be selectively engaged with and disengaged from said annular grooves.

8. A fuel assembly incorporating an end fitting according to any one of claims 3 to 7.

9. A fuel assembly substantially as herein described with reference to Figures 1 to 3 of the accompanying drawings.

10. A grapple for manipulating an end fitting for a fuel assembly that includes control

rod guide tubes, the grapple comprising a longitudinally movable member, a transversely disposed crosspiece coupled to said member for movement therewith in a longitudinal direction, a transversely disposed linkage secured to said crosspiece and having transversely oriented slots formed therein, two jaws each slidably pinned to a respective one of said slots of said transversely oriented linkage, a tool frame transversely disposed relative to said member, said jaws being pivotally connected to said tool frame, and a respective clamp formed on each of said jaws to selectively grasp the fuel assembly end fitting, the arrangement being such that said clamps on said jaws swing into engagement with the end fitting as said member, crosspiece and linkage are moved in a longitudinal direction.

11. A grapple according to claim 10, wherein said transversely disposed tool frame further comprises a plurality of longitudinally aligned tools secured to said frame for selectively releasing the control rod guide tubes from the fuel assembly end fitting.

12. A grapple substantially as herein described with reference to Figures 4 to 9 of the accompanying drawings.

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