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(54) **System for ultrasonically cleaning tubes for nuclear fuel rods or similar rods.**

(57) The system comprises a tank (42) containing liquid (44) and ultrasonic transducers (46), oppositely inclined ramps (66, 68, 88) for guiding the tubes (23) into and through the liquid (44) in single-file fashion and along a switchback path, and endless conveyor means (102) for picking up the cleaned tubes (23), one at a time, and conveying them to a tube discharge location (104) outside the tank. The transducers (46) are spaced apart, in substantial alignment with each other, in the longitudinal direction of the tubes (23) being guided through the liquid in the tank.

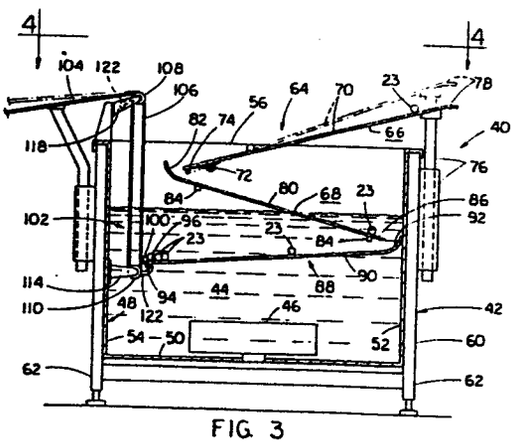

FIG. 3

EP 0 225 114 A1

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SYSTEM FOR ULTRASONICALLY CLEANING TUBES FOR NUCLEAR FUEL RODS OR SIMILAR RODS

The present invention relates generally to fuel assemblies for nuclear reactors and, more particularly, to a system for ultrasonically cleaning tubes used in the manufacture of fuel rods, control rods, and the like.

In most nuclear reactors, the reactor core is composed of a large number of elongate fuel assemblies each including a multiplicity of fuel rods which are held in an organized array by grids spaced along the fuel assembly. The grids are attached to control-rod guide thimbles, and top and bottom nozzles are secured to guide-thimble end portions extending above and below the opposite ends of the fuel rods.

The fuel rods contain fissile material and are grouped together in an array which is organized such as to provide sufficient neutron flux in the core to support a high rate of nuclear fission and, thus, the release of a large amount of energy in the form of heat. All materials present in the reactor core will be irradiated by the fissile material in the fuel rods and, in turn, will interact with it. In order to produce the desired neutron flux in the core, the nuclear interaction and, thus, the chemical composition of all components introduced into the reactor core must be known and taken into consideration. Therefore, the materials composing all such components are carefully selected in order to obtain the desired interaction with the neutron flux.

In order to control what materials are introduced into the core, extensive measures and steps are taken to maintain a clean environment not only in the reactor facility itself but also in the facilities where the components are manufactured. One part of this overall effort toward achieving a high standard of cleanliness is the cleaning of component parts during fabrication to remove foreign matter therefrom. In the case of tubes used for fuel rods or the like, one of the final steps in their fabrication is a thorough cleaning of the interior and exterior of each tube.

The conventional cleaning technique employed involves bundling a large number of tubes, for example three hundred, submerging the bundle in a tank of cleaning solution for a predetermined time, and then submerging the bundle into a rinse tank to flush impurities from the tube surfaces. This conventional technique has certain drawbacks insofar as the tube cleaning solution typically used is methylene chloride toluene which is environmentally undesirable, and as the steps of gathering and bundling the tubes are inherently inefficient and cumbersome and the manipulation of the large bundles of tubes requires the use of a crane and operator.

It is the principal object of the invention to provide a better way of cleaning tubes, one which does not have these drawbacks.

The invention accordingly resides in a system for cleaning tubes, characterized by the combination comprising (a) a cleaning tank holding a quantity of liquid; (b) means for generating ultrasonic cavitational energy within the liquid in the tank; (c) means for delivering the tubes into the liquid within said tank in single-file fashion and oriented substantially in parallel with respect to each other; (d) means for moving the tubes, within said liquid, across the tank along a path causing each tube to pass through and be cleaned by the cavitation energy in the

liquid; and (e) means for removing the cleaned tubes from said liquid and from said tank.

The tube moving means comprises a ramp disposed below the tube delivering means in tube-receiving relationship with respect thereto and defining said path, which latter is substantially linear and slightly inclined, preferably just sufficiently to cause the tubes to gravitate therealong.

The tube delivering means comprises oppositely inclined upper and intermediate ramps which define a switchback path for the tubes to gravitate individually therealong and onto the above-mentioned ramp therebelow. The upper and intermediate ramps are supported from the tank, the upper ramp in a manner allowing the degree of its inclination to be varied. Each of the upper, intermediate, and lower ramps preferably consists of a plurality of tracks extending in substantially parallel spaced relationship with respect to one another.

The tube moving means includes means for holding the tubes, at the end of their travel down the lower ramp, in readiness for removal of the tubes by the tube removing means. The latter comprises an endless conveyor operable to move between a tube pickup location adjacent said end of tube travel and a tube discharge location outside the tank, and the conveyor includes tube pickup members which are effective, during operation of the conveyor, to pick up tubes at the tube pickup location and unload the tubes at the tube discharge location. The tube pickup members are adapted to pick up one tube at a time, and are arranged on the conveyor such as to unload one tube at the tube discharge location before picking up the next tube at the tube pickup position. Preferably, the conveyor comprises a plurality of endless conveyor elements having respective ones of said tube pickup members disposed thereon, and the endless conveyor elements are supported in substantially parallel spaced relationship with respect to one another, each having its tube pickup members aligned substantially

horizontally with the corresponding tube pickup members on the other endless conveyor elements. The endless conveyor elements have associated therewith drive means for driving the endless conveyor elements generally at the same speed, relative to one another, so as to maintain each tube conveyed thereon substantially level, the drive means preferably being controlled to momentarily change the relative speeds of the conveyor elements once each time a tube is being conveyed from the pickup location toward the tube discharge location, in a manner such as to momentarily tilt the tube so as to drain therefrom any liquid introduced during its travel through the tank.

The means for generating ultrasonic cavitational energy comprises a plurality of elongate transducers mounted on the bottom wall of the tank and spaced apart, substantially in alignment with each other, in the longitudinal direction of the tubes moving through the tank.

It will be appreciated that, unlike the previously used batch-type operation wherein the tubes were moved about and cleaned in bundles, the ultrasonic cleaning system embodying the invention utilizes a technique of processing the tubes individually on a first-in, first-out basis yet in a relatively continuous operation which, moreover, lends itself readily to being automated. Furthermore, the ultrasonic energy transmitted from the transducers aligned with each other along the bottom of the liquid-containing tank produces cleaner tubes, and the liquid employed in the tank as an energy transmitting and cleaning agent may be plain water containing a biodegradeable detergent; thus, the need to use an environmentally undesirable methylene chloride toluene cleaning solution, such as typically utilized before, is obviated.

A preferred embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 is an elevational view, partly in section, of a nuclear fuel assembly illustrated in vertically foreshortened form and with parts broken away for clarity;

from which fuel or similar rods are made for use in a fuel assembly such as shown in Fig. 1;

Fig. 3 is an end elevational view of the tube cleaning system embodying the invention;

Fig. 4 is a top plan view of the cleaning system, as seen when viewed in the direction of the arrows on line 4-4 in Fig. 3;

Fig. 5 is a sectional side elevational view of the tube removal apparatus forming part of the tube cleaning system, as taken along line 5-5 in Fig. 4; and

Fig. 6 is an enlarged detail view of a fragmentary portion of the tube removal apparatus of Fig. 5, as taken along line 6-6 in Fig. 4.

In the following description, like reference characters designate like or corresponding parts through the several views of the drawings, and terms such as "forward", "rearward", "left", "right", "upwards", downwards" and the like are employed as words of convenience not to be construed as limiting terms.

Referring now to the drawings, and particularly to Fig. 1 thereof, the fuel assembly illustrated therein and generally designated with reference numeral 10 is of the type used in pressurized water reactors (PWR). Basically, it comprises a lower end structure or bottom nozzle 12 for supporting the assembly on the lower core plate (not shown) in the core region of a nuclear reactor (not shown), longitudinally extending guide tubes or thimbles 14 projecting upwards from the bottom nozzle 12, transverse grids 16 axially spaced along the guide thimbles 14, an organized array of elongate fuel rods 18 transversely spaced and supported by the grids 16, an instrumentation tube 20 located in the center of the fuel assembly, and an upper end structure or top nozzle 22

attached to upper end portions of the guide thimbles 14. The fuel assembly 10 forms an integral unit capable of being conventionally handled without damage to its component parts.

Each of the fuel rods 18 includes an elongate cladding tube 23 which contains nuclear fuel pellets 24 and is hermetically sealed at its opposite ends by means of end plugs 26,28. Typically, a plenum spring 30 is disposed in the tube 23 between the upper end plug 26 and the stack of pellets 24 to keep the latter firmly stacked. The fuel pellets 24, composed of fissile material, are responsible for creating the reactive power in the reactor. During operation of the latter, liquid moderator/coolant, such as water or water containing boron, is pumped upwards through the fuel assemblies in the reactor core so as to extract therefrom heat for use thereof in producing useful work.

The fission process is controlled by means of control rods 32 extending into guide thimbles 14 at predetermined locations within the fuel assembly and reciprocally movable therein by means of a rod-cluster control mechanism 34 associated with the top nozzle 22. The rod-cluster control mechanism 34 includes a hollow-cylindrical, internally threaded member 36 with radially extending flukes or arms 38 each of which has at least one of the control rods 32 connected thereto, all as well known in the art.

Tube Cleaning System

Turning now to Figs. 3 to 6, there is shown an ultrasonic cleaning system, generally designated with reference numeral 40 and embodying the invention, for thoroughly cleaning fuel rod tubes, such as the tube 23 of Fig. 2, inside and outside during manufacture of the tube. The cleaning system 40 basically includes a cleaning tank 42 holding a quantity of liquid 44, such as water containing a suitable biodegradable detergent, and means in the form of a series of transducers 46 mounted in the tank 42

for generating ultrasonic cavitational energy within the tank water.

More particularly, the elongate cleaning tank 42 comprises a receptacle 48 having a bottom wall 50 and upright spaced-apart opposite side walls 52, 54 and end walls 56, 58 which are connected together and to the bottom wall. The receptacle 48 has a long, relatively narrow, rectangular configuration adapting it to accommodate long fuel rod tubes 23, typically about 4 inches in length. The receptacle 48 which holds the detergent-laden water 44 is removably mounted in an outer support shell 60 of the tank 42 having a plurality of support legs 62. The series of transducers 46 are mounted in spaced relation on the bottom wall 50 of the tank 42 and arranged in a generally linear pattern which extends between the opposite tank end walls 56, 58 and generally parallel to the opposite tank side walls 52, 54. The ultrasonic transducers 46 are known devices which convert electrical energy into mechanical energy. When the transducers 46 are attached to a radiating surface, i.e., the bottom wall 50 of the cleaning tank receptacle 48, the mechanical energy is converted into ultrasonic cavitational energy which produces the cleaning effect. The detergent is used in the water 44 to augment or promote the cleaning action primarily carried out by the ultrasonic energy.

In addition, the cleaning system 40 includes means, generally designated 64, for delivering tubes 23 individually into the liquid 44 within the tank 42. The tube delivery means 64 is composed of an upper tube entry ramp 66 and a middle or intermediate tube transfer ramp 68.

The upper ramp 66 includes a plurality of elongate inclined tracks 70 for guiding and delivering tubes 23 into the tank 42 in single-file fashion, i.e., oriented substantially in parallel with respect to each other. The tracks 70, preferably four in number, extend generally parallel to one another, are inclined downwardly from above the one side wall 52 toward the opposite side

wall 54 of the tank receptacle 48, and are laterally spaced apart between the opposite end walls 56, 58 thereof. An elongate shaft 72 mounted on and extending between the opposite end walls 56, 58 of the tank receptacle 48 pivotally supports the tracks 70 adjacent to tube discharge ends 74 thereof. Adjacent their tube receiving ends 78, the tracks 70 are connected to upright support members 76 which are mounted on the tank support shell 60 at locations adjacent the tank-receptacle side wall 52, and which support the tube receiving ends 78 of the tracks 70 at a level above the receptacle side wall 52 and higher than that at which the tube discharge ends 74 of the tracks 70 are supported by the shaft 72. The support members 76 are adjustable vertically (as indicated in phantom outline in Fig. 3) to permit adjustment of the elevation of the tube receiving ends 78 of the tracks 70 and, hence, of the inclination or downward slope of the tracks 70.

The middle ramp 68 comprises a plurality of elongate, inclined tracks 80 for receiving tubes 23 from the discharge ends 74 of the upper ramp tracks 70 and for guiding and delivering them in single-file fashion into the water 44 within the tank 42. The tracks 80 (only one is shown in Fig. 3), preferably four in number, extend generally parallel to one another, are inclined downwardly from tube-entry ends 82 thereof, spaced below the discharge ends 74 of the upper ramp tracks 70, and toward the side wall 52 of the tank receptacle 48, and are laterally spaced apart between the opposite end walls 56, 58 thereof. Two spaced elongate members 84 mounted on and extending between the opposite end walls 56, 58 of the tank receptacle 48 support the middle ramp tracks 80 at a fixed inclined position and with their tube entry ends 82 at a substantially higher elevation than their tube exit ends 86.

Furthermore, the cleaning system 40 includes means 88 for moving or transferring the tubes 23 across the tank 42 within the liquid 44 therein, such that each tube

will pass through and be cleaned by the ultrasonic cavitation energy in the liquid. The tube moving or transferring means 88 is in the form of a lower or tube soak ramp comprising a plurality of elongate inclined tracks 90 for receiving tubes from the exit ends 86 of the middle ramp tracks 80 and guiding the tubes in single-file fashion along a linear path across the tank 42, within the water 44 and above the transducers 46 mounted in the tank. The tracks 90, preferably four in number, extend generally parallel to one another, are slightly inclined downwardly from their tube receiving ends 92 below the exit ends 86 of the middle ramp tracks 80 adjacent the one side wall 52 and toward the opposite side wall 54 of the tank receptacle 48, and are laterally spaced apart between the opposite end walls 56, 58 thereof. An elongate member 94 mounted on and extending between the opposite end walls 56, 58 of the tank receptacle 48 supports the lower ramp tracks 90 adjacent tube accumulating ends 96 thereof such that the tube receiving ends 92 of the tracks 90 are positioned against the side wall 52 of the tank receptacle 48 at an elevation slightly higher than that of the tube accumulating ends 96 of the tracks. Triangular end stops 100 are attached to the tracks 90 at their tube accumulating ends 96 for holding the tubes 23 in readiness for removal thereof from the tank 42, the end stops 100 being placed at positions along the tracks ends 96 calculated to ensure that only one tube 23 at a time will be removed from the tracks 90, as described more fully hereinbelow.

Finally, the cleaning system 40 includes means 102 for removing tubes, one at a time, from the liquid 44 within the tank 42 and transporting them to a tube discharge location 104, such as the surface of an outlet table. The tube removing means 102 takes the form of a conveyor which is supported in a generally vertical disposition from the side wall 54 of the tank receptacle 48. The conveyor is operable to move between a tube pickup position adjacent the accumulating ends 96 of the lower

ramp tracks 90 and the discharge location 104 outside the tank 42, so as to pick up one tube 23 at a time at the accumulating ends 96 of the lower ramp tracks 90 and to lift the tube from the water 44 and to the discharge location 104 above the tank 42, the tube thus being removed from the tank before another tube is picked up by the conveyor 102.

More particularly, the conveyor 102 includes a plurality of endless conveyor elements in the form of flexible drive chains 106, preferably three in number, each of which is trained about an upper drive sprocket 108 and a lower follower sprocket 110. The follower sprockets 110 are rotatably mounted on a shaft 112 supported by and extending between lower brackets 114 secured to the tank-receptacle side wall 54 at a level below the surface of the liquid 44 in the tank 42. Each of the drive sprockets 108 is secured to a shaft 116 which is rotatably supported by a pair of upper brackets 118 secured to the receptacle side wall 54 at a level above the water surface, and is driven by a drive unit 120 associated therewith. The arrangements of chains 106 and sprockets 108, 110 extend generally parallel to one another and are laterally spaced apart between the opposite end walls 56, 58 of the tank receptacle 48.

Each of the drive chains 106 has a pair of tube cradles 122 attached thereto at positions spaced apart approximately one-half the length of the drive chain. The drive chains 106 define generally parallel endless paths extending between the tube accumulating ends 96 of the lower ramp tracks 90 and the tube discharge location 104 above the tank 42. Due to the distance or spacing between the tube cradles 122 on each drive chain 106, the operation will be such that when one set of laterally or axially aligned ones of the cradles on the several drive chains is disposed in a tube-unloading or upper position adjacent the tube discharge location 104, as seen in Fig. 3, the other set of laterally or axially aligned cradles on the chains

is disposed in a tube loading position just below the end stops 100 at the tube accumulating ends 96 of the lower ramp tracks 90, as seen in Figs. 3 and 6. In this manner, the corresponding cradles 122 in the pairs thereof will pick up only one tube 23 at a time, and lift it to the discharge location 104, before another tube is picked up.

The cleaning system 40 also includes a pump/filtration arrangement (not shown) for circulating and filtering the water in the tank to remove therefrom foreign matter which has been cleaned from the tubes.

From the foregoing description, it will be understood that tubes 23 will be gravity-fed into the tank through a switchback path defined by the upper and middle ramp tracks 70, 80, and then move along a generally linear path, defined by the lower ramp tracks 90, through the water to the end stops 100. Preferably, sensors (not shown) strategically placed along the tracks 70, 80, 90 and along the drive chains 106 will monitor the passage of each tube through the tank. Signals from these sensors are fed to a controller (not shown) which will track the movement of each tube and initiate the removal of each tube by starting the drive units 120 for the chains at the appropriate time. In such manner, every tube will soak in the ultrasonic cavitation energy for the same predetermined amount of time. Moreover, the tubes are removed from the tank 42 on a first-in/first-out basis.

In order to drain liquid from the inside of each tube 23, the drive units 120 preferably are controlled in a manner such that one of the drive chains 106 will momentarily slow down or stop while the other chains continue to move, whereafter opposite changes in the relative speeds of the drive chains 106 are effected so as to re-level the tube. After such re-leveling, the tube is moved to the apex of the upper drive sprockets 108, at which moment the drive units 120 are momentarily stopped, thereby causing the tube to roll onto the discharge surface 104.

CLAIMS

1. A system (40) for cleaning tubes (23), characterized by the combination comprising:

(a) a cleaning tank (42) holding a quantity of liquid (44);

(b) means (46) for generating ultrasonic cavitational energy within the liquid in the tank;

(c) means (64) for delivering the tubes (23) into the liquid within said tank in single-file fashion and oriented substantially in parallel with respect to each other;

(d) means (88) for moving the tubes (23), within said liquid (44), across the tank (42) along a path causing each tube to pass through and be cleaned by the cavitation energy in the liquid; and

(e) means (102) for removing the cleaned tubes (23) from said liquid (44) and from said tank (42).

2. A system according to claim 1, characterized in that the tube moving means (88) comprises a ramp disposed below the tube delivering means (64) in tube-receiving relationship with respect thereto and defining said path.

3. A system according to claim 2, characterized in that said path is substantially linear and slightly inclined.

4. A system according to claim 2 or 3, characterized in that said ramp (88) comprises a plurality of

tracks (90) extending in substantially parallel spaced relationship with respect to one another.

5. A system according to claim 1, 2, 3 or 4, characterized in that the tube delivering means (64) comprises oppositely inclined upper and intermediate ramps (66,68) which define a switchback path for the tubes (23) to gravitate individually therealong.

6. A system according to claim 5, characterized by means (72,76) supporting the upper ramp (66) from said tank (42).

7. A system according to claim 6, characterized in that the supporting means (72,76) is adjustable in a manner varying the degree of inclination of said upper ramp (66).

8. A system according to claim 5, 6 or 7, characterized by means (84) supporting the intermediate ramp (68) from said tank (42).

9. A system according to claim 8, characterized in that the supporting means (84) associated with the intermediate ramp (68) support the latter in a fixed inclined disposition thereof.

10. A system according to claim 5, 6, 7, 8 or 9, characterized in that said upper and intermediate ramps (66,68) each comprises a plurality of tracks (70, 80) extending in substantially parallel spaced relationship with respect to one another.

11. A system according to any one of the preceding claims, characterized in that the tube moving means (88) includes means (100) for holding the tubes (23) at the end of said path in readiness for removal of the tubes by the tube removing means (102), said tube removing means (102) comprising an endless conveyor operable to move between a tube pickup location adjacent said end of said path and a tube discharge location (104) outside said tank (42), said conveyor (102) including tube pickup members (122) effective, during operation of the conveyor, to pick

up tubes at the tube pickup location and unload the tubes at said tube discharge location (104).

12. A system according to claim 11, characterized in that said tube pickup members (122) are cradles adapted to pick up one tube (23) at a time.

13. A system according to claim 11 or 12, characterized in that said tube pickup members (122) are arranged on the conveyor (102) such as to unload one tube (23) at said tube discharge location (104) before picking up the next tube (23) at said tube pickup location.

14. A system according to claim 11, 12 or 13, characterized in that said conveyor (102) comprises a plurality of endless conveyor elements (106) having respective ones of said tube pickup members (122) disposed thereon, said endless conveyor elements (106) being supported in substantially parallel spaced relationship with respect to one another and each having its tube pickup members (122) aligned substantially horizontally with the corresponding tube pickup members (122) on the other endless conveyor elements (106).

15. A system according to claim 14, characterized in that said endless conveyor elements (106) are supported from a wall (54) of said tank (42).

16. A system according to claim 14 or 15, characterized in that said endless conveyor elements (106) have associated therewith drive means (120) for driving the endless conveyor elements generally at the same speed, relative to one another, so as to maintain each tube conveyed thereon substantially level, said drive means (128) being controlled to momentarily change the relative speeds of the drive means once each time a tube (23) is being conveyed from said pickup location toward said tube discharge location (104) and in a manner such as to momentarily tilt the tube (23) sufficiently to drain liquid therefrom.

17. A system according to any one of the preceding claims, characterized in that said means (46) for

generating ultrasonic cevitational energy comprises a plurality of transducers (46) mounted on a bottom wall (50) of said tank (42) and spaced apart, substantially in alignment with each other, in the longitudinal direction of the tubes (23) moving through the liquid in the tank (42).

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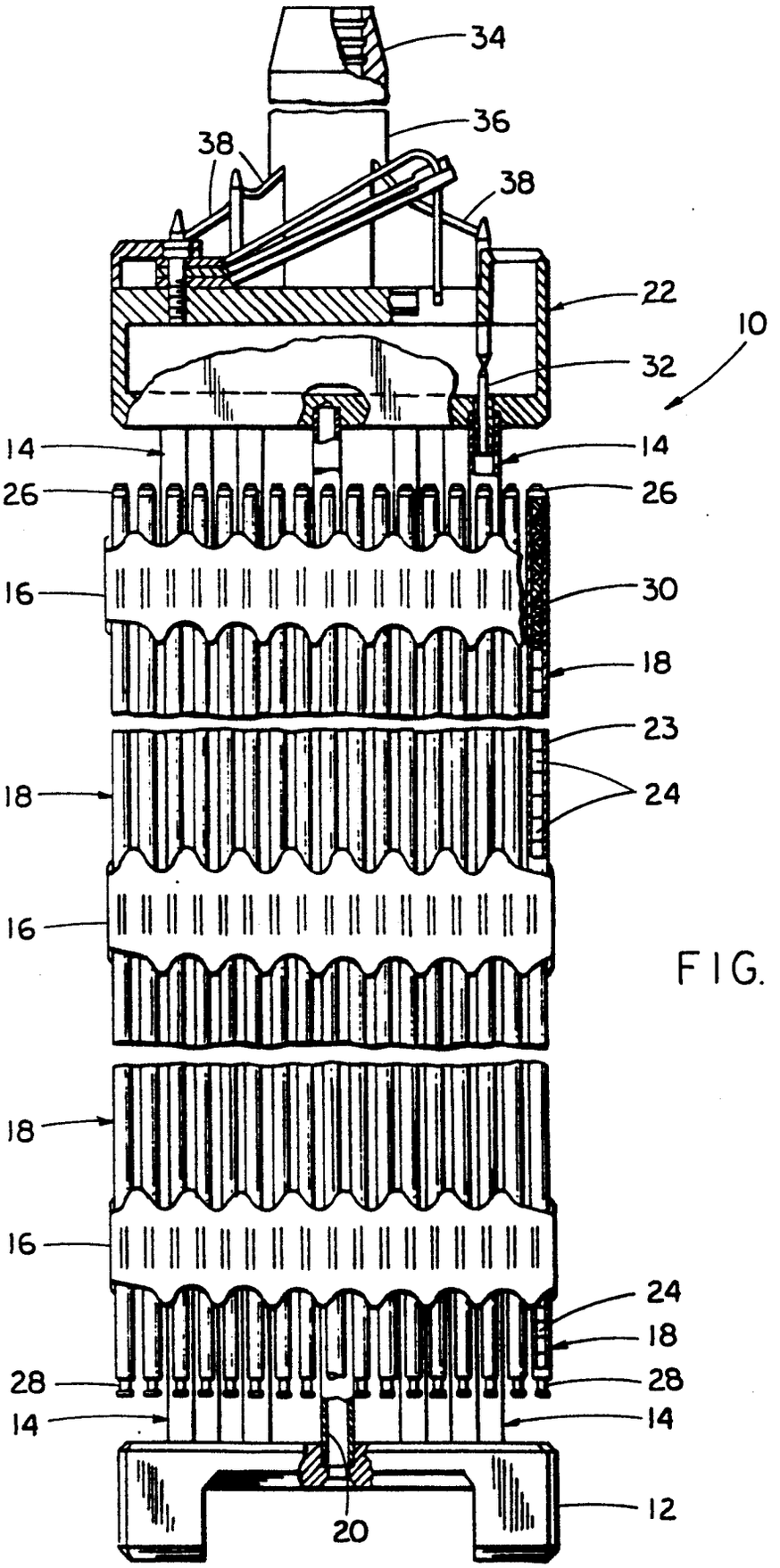

FIG. 1

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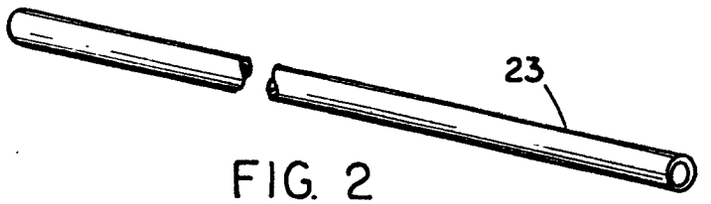

FIG. 2

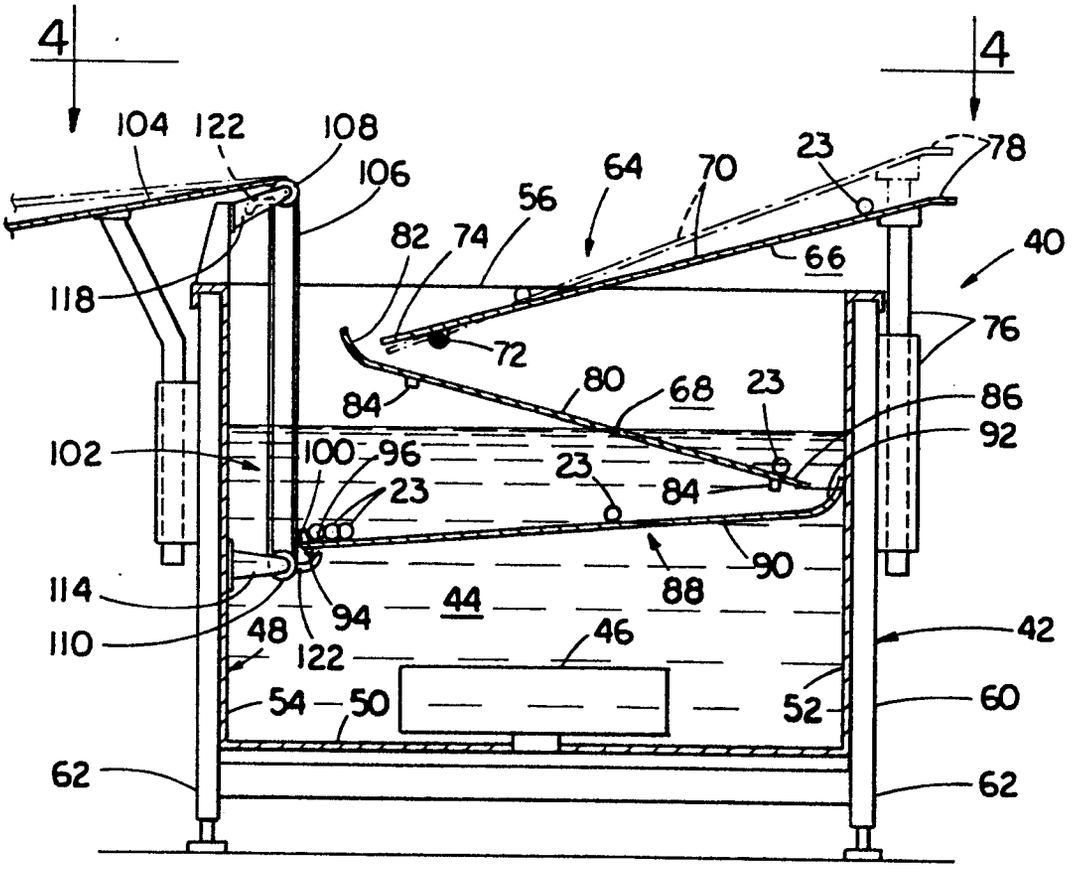

FIG. 3

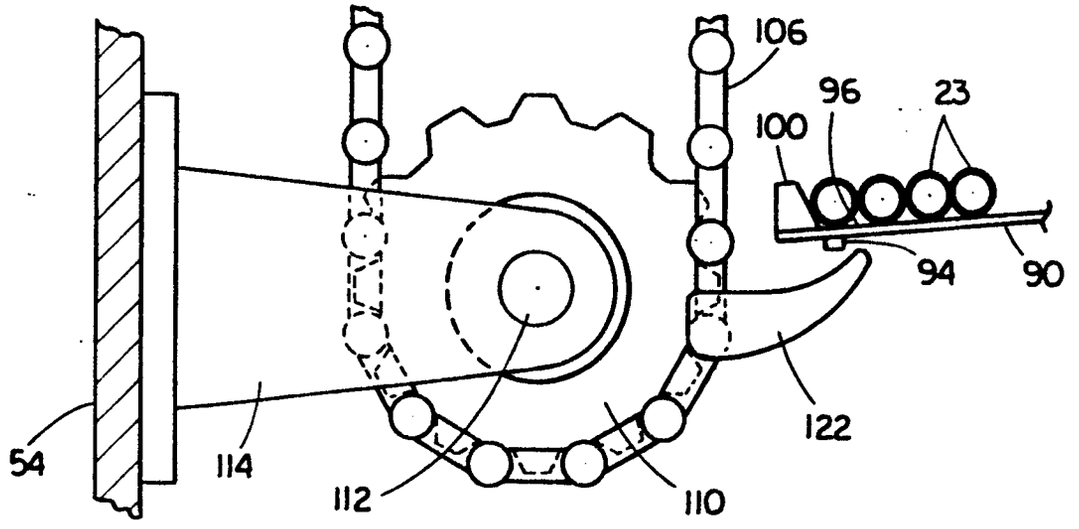

FIG. 6

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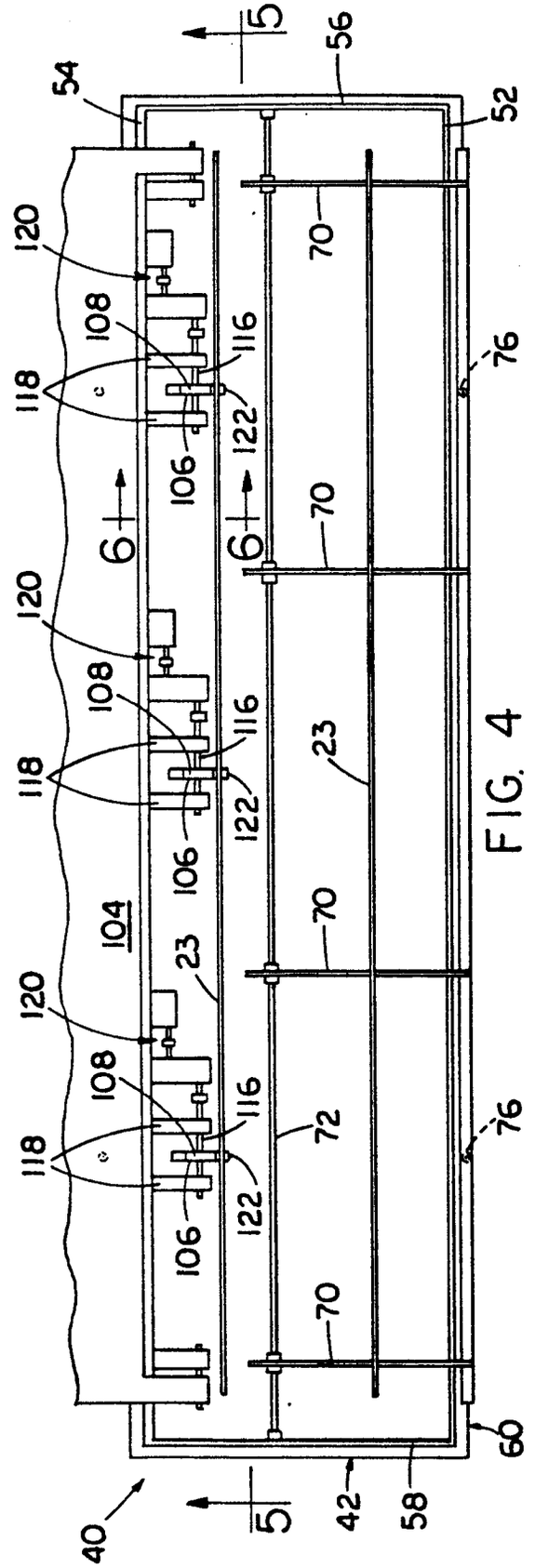

FIG. 4

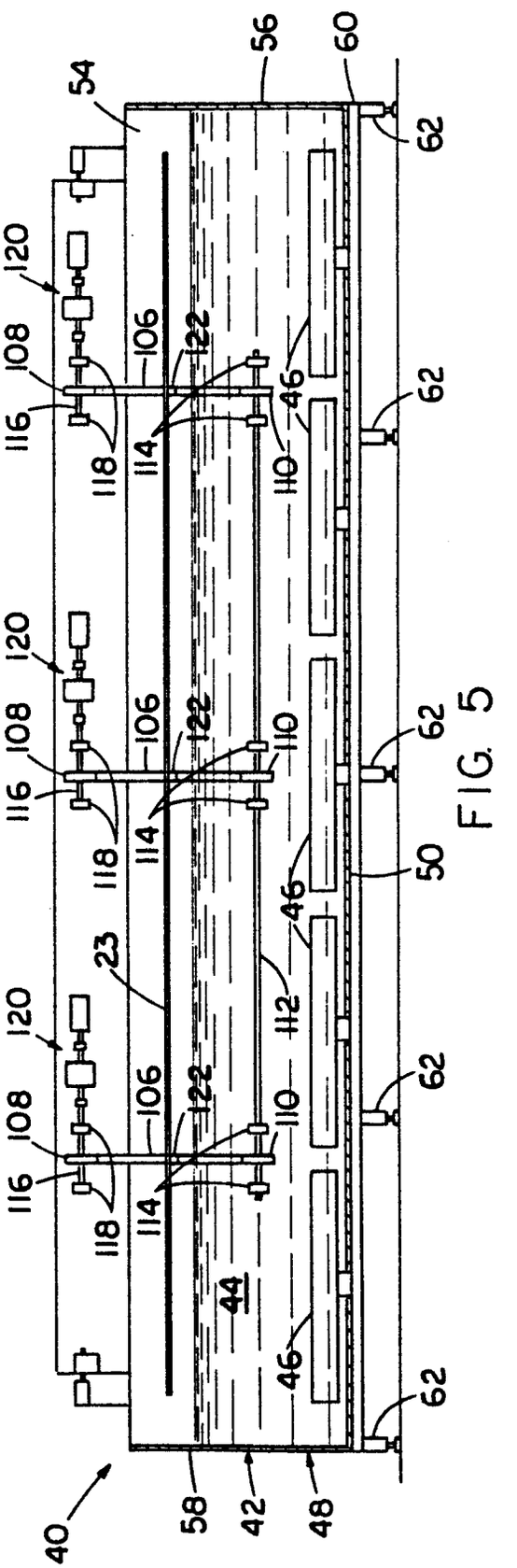

FIG. 5

European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 86 30 9012

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	US-A-4 194 922 (GRASEL) * Column 2, line 61 - column 7, line 9; figures 1-9 *	1-3,5-9,11-14,17	B 08 B 3/12 B 08 B 9/02
Y	US-A-3 210 788 (HOLLIDAY) * Column 3, line 68 - column 5, line 10; figures 4-6 *	1-3,6,7,11-14,17	
Y	DE-B-1 052 776 (SIEMENS-SCHUCKERTWERKE AG) * Column 2, line 43 - column 4, line 18; figure *	5,8,9	
A		1-3	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

B 08 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	24-02-1987	VOLLERING J.P.G.

CATEGORY OF CITED DOCUMENTS

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