United States Patent

Cherel

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[45] **June 27, 1972**

[54] APPARATUS AND METHOD FOR PROCESSING SPENT NUCLEAR FUEL ELEMENTS

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[21] Appl. No.: **738,336**

[30] **Foreign Application Priority Data**

June 19, 1967 France 67110858

[52] **U.S. Cl.** **83/35**, 83/39, 83/105, 83/165, 83/167, 83/201.01, 83/201.07, 83/201.11, 83/201.13, 83/280, 83/404, 83/417, 83/444, 83/461, 83/580, 83/639, 83/925

[51] **Int. Cl.** **B26d 1/08**, B26d 1/52, B26d 7/02

[58] **Field of Search** 83/35, 39, 42, 54, 104, 105, 83/280, 282, 460, 461, 580, 639, 417, 425, 427, 433, 444, 404, 165, 256, 167, 201.01, 201.11, 201.13, 201.07, 425, 516, 517

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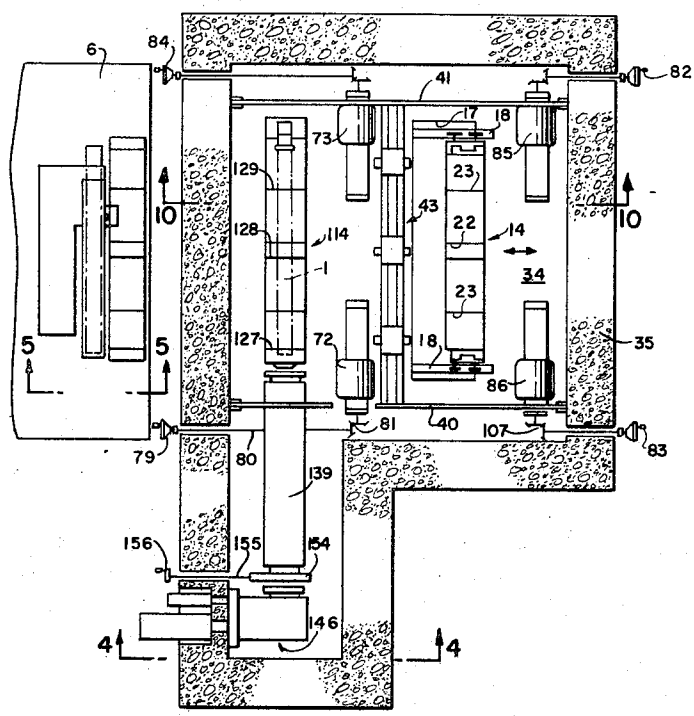
[57] **ABSTRACT**

Apparatus and method for the processing of spent nuclear elements preparatory to reconditioning the nuclear fuel thereof. Each element is, in turn, elevated on a truck moving along an inclined track, from a storage chamber to an enclosure wherein it is automatically transferred to a crane supported for movement horizontally in a direction normal to the length dimension of the element. Moving with the crane, the element is transported to and between two spaced sawing or abrasive cutting devices where its inert ends are cut off and collected. The element, sans ends, continues movement on and with the crane, to a table on which it is deposited. The crane returns to initial position. Mechanism incorporated in the table translates the element in the direction of its length to a shear wherein it is cut into fragments of relatively short length. The fragments are accumulated into batches and each batch is released in turn, for gravity drop into a tank of solvent for the nuclear fuel. A number of such tanks are provided and mechanism enables each batch to be directed, as desired, into a selected one of the tanks. All operating parts are completely shielded and controlled from remote stations exteriorly of the shielded enclosure. The invention eliminates a number of apparatuses, including panniers, necessary with prior art devices of like purpose.

29 Claims, 26 Drawing Figures



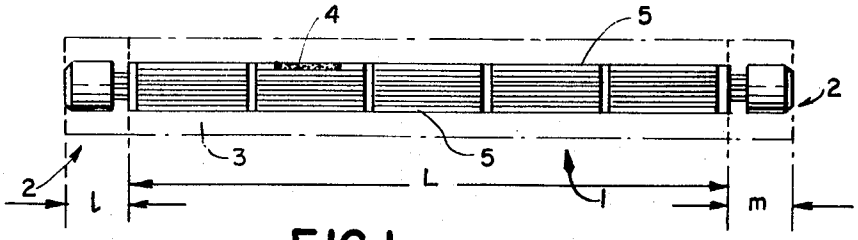


FIG.1.

FIG.2.

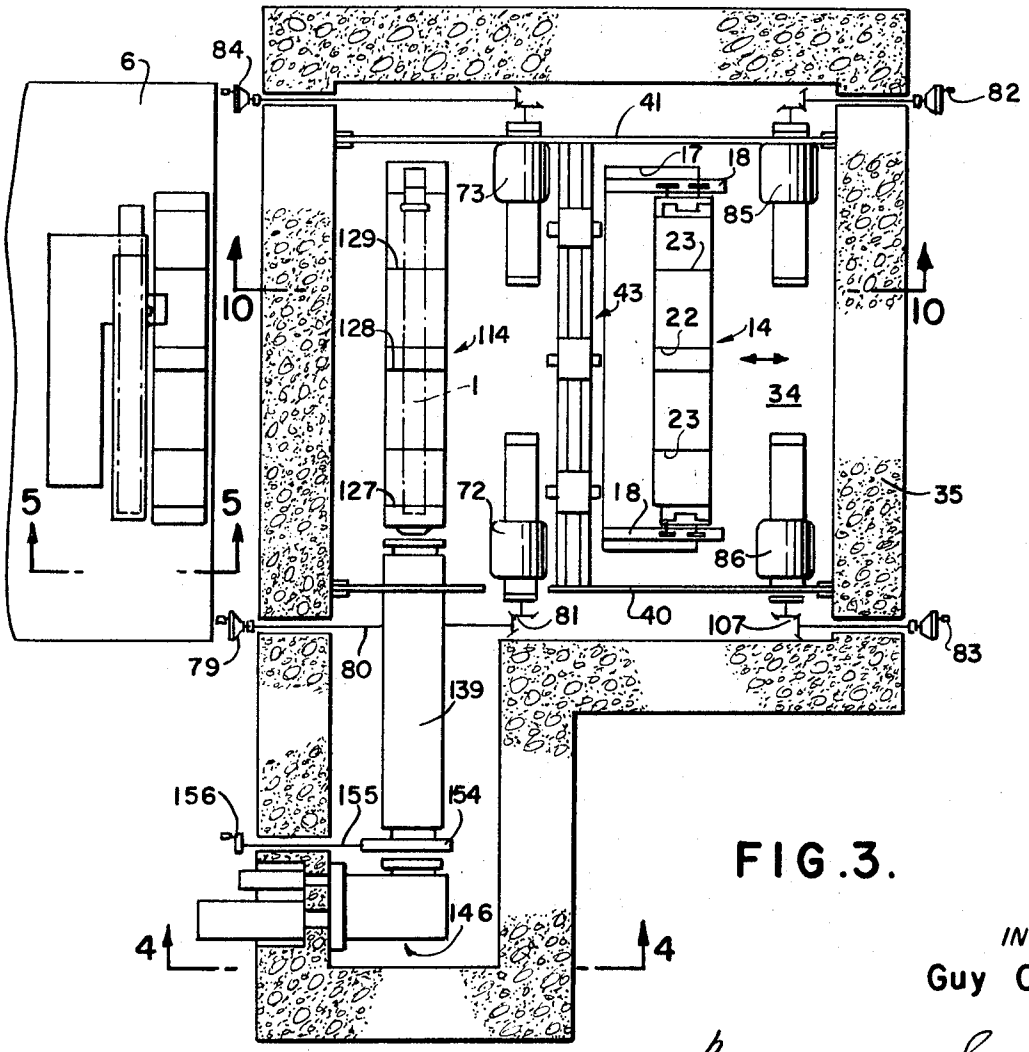


FIG.3.

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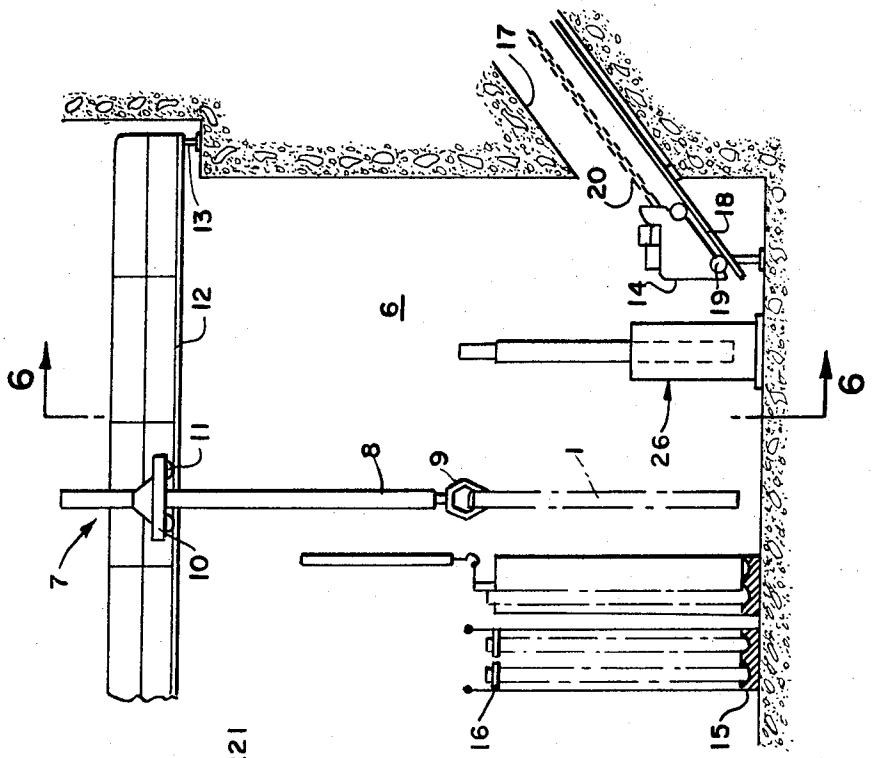

FIG.5.

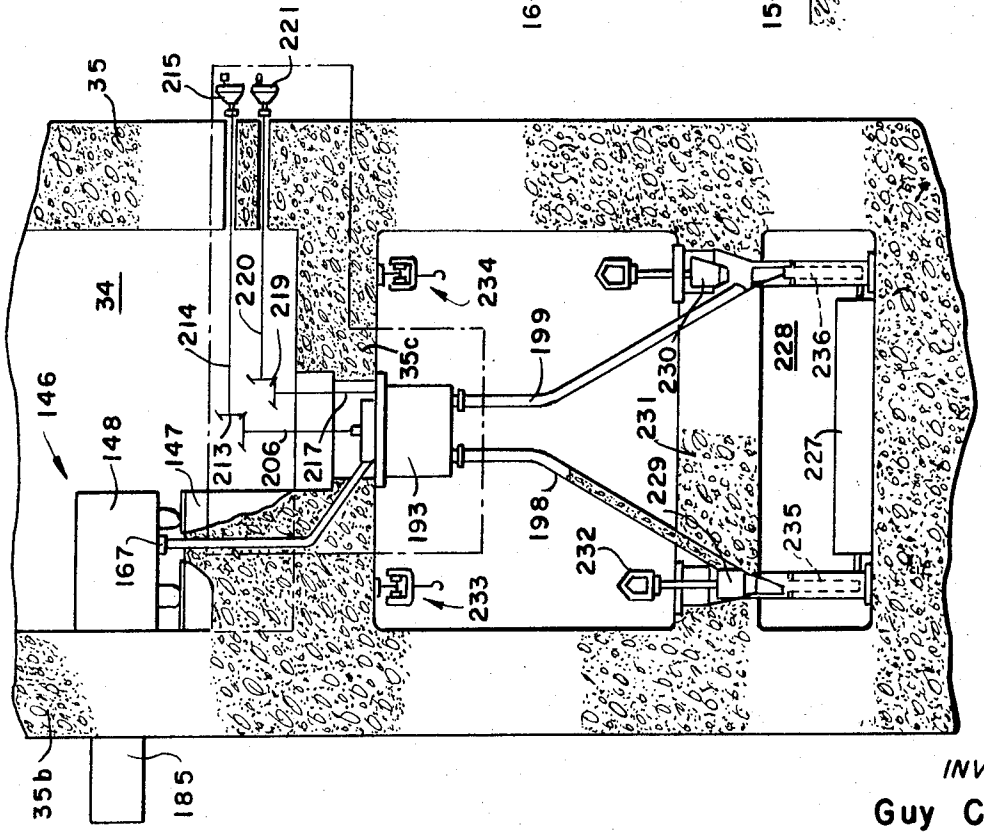

FIG.4.

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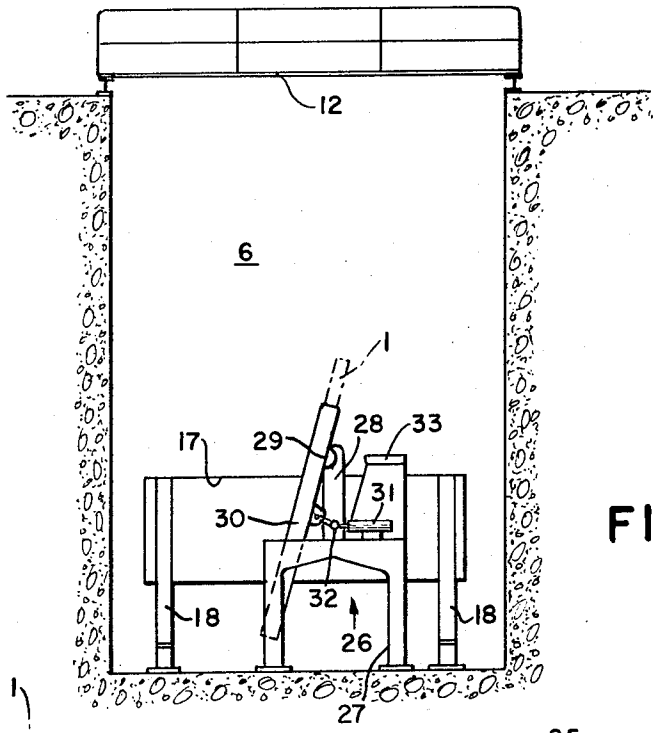
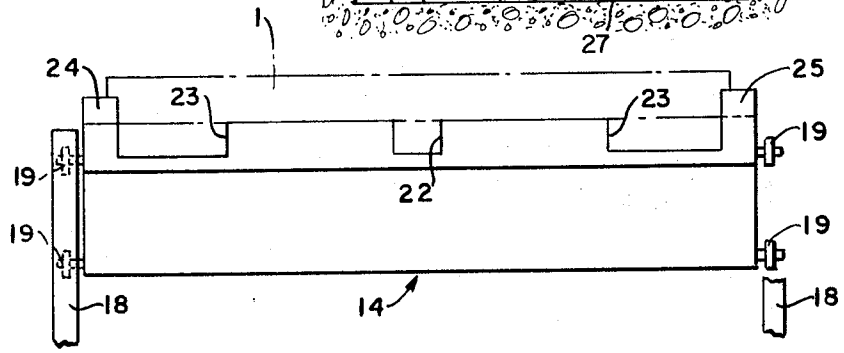


FIG. 6.



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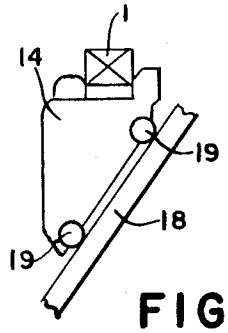

FIG. 9.

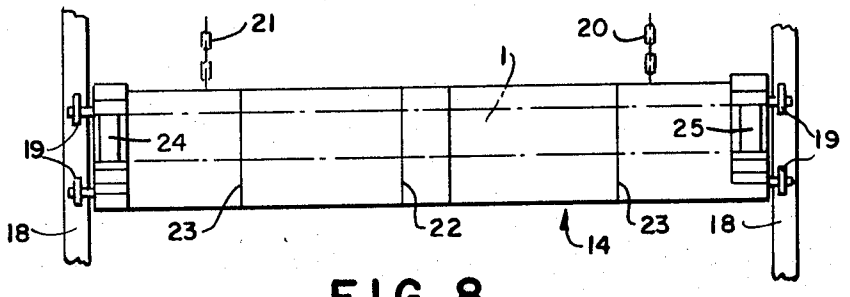

FIG. 8.

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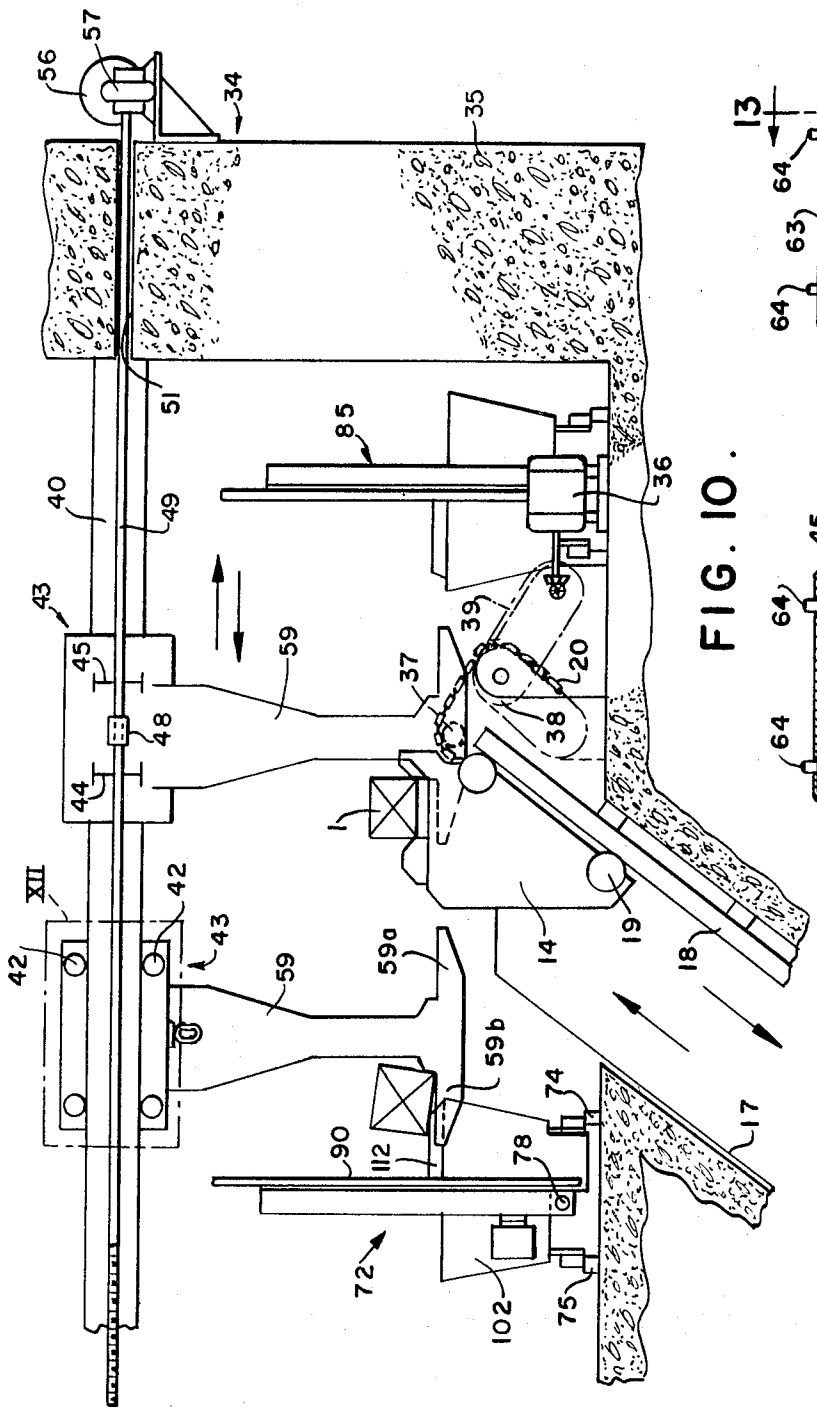

FIG. 10.

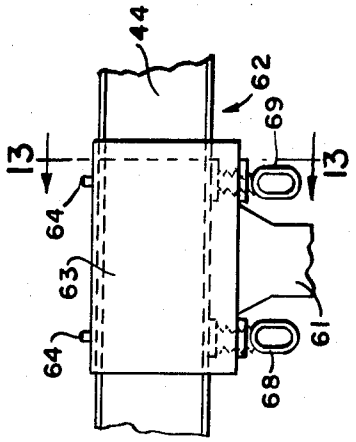

FIG. 12.

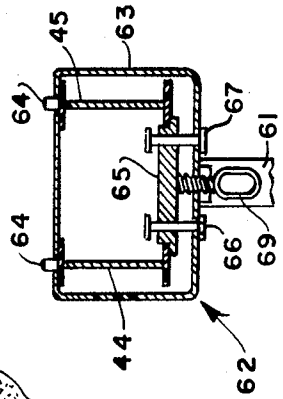

FIG. 13.

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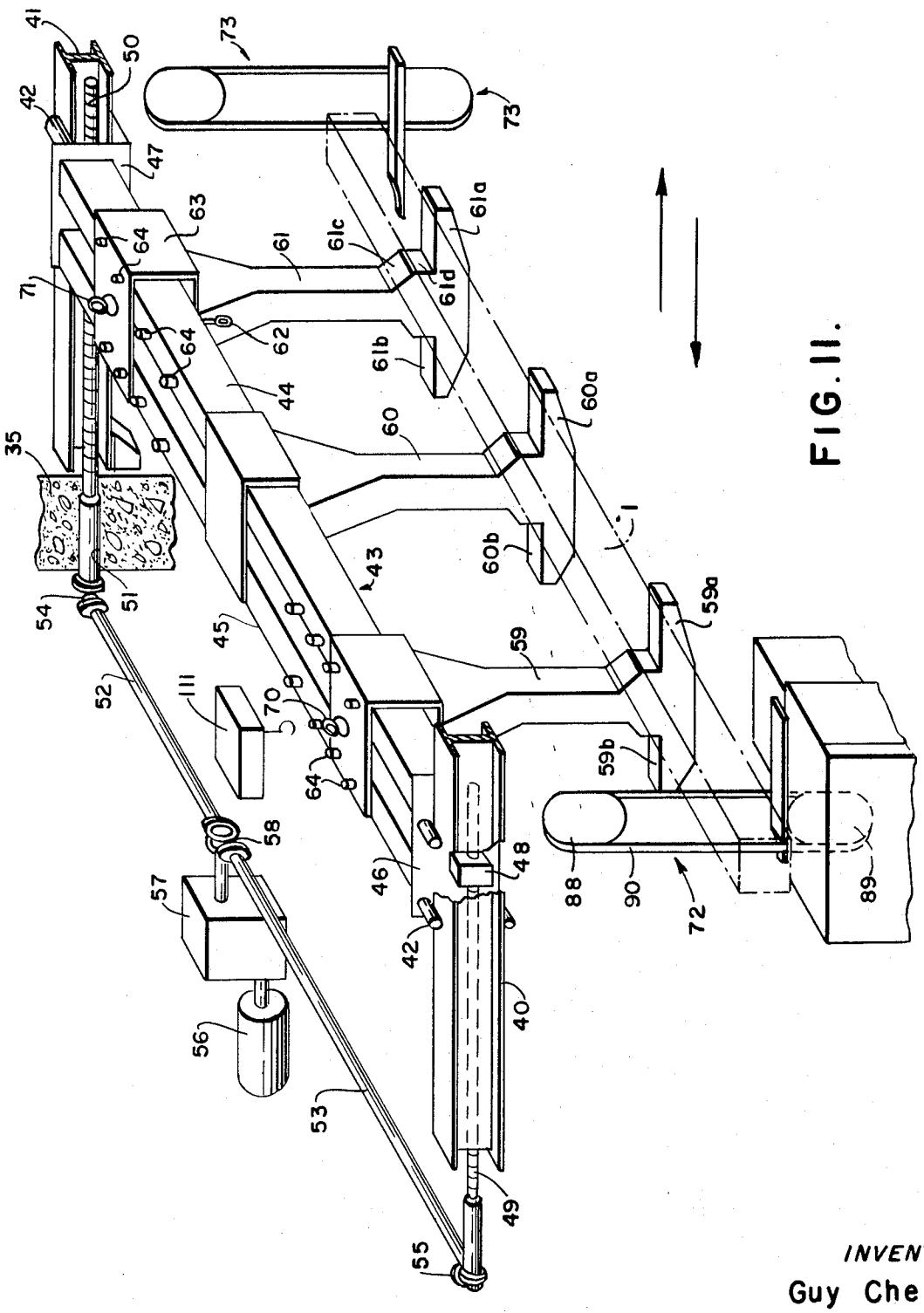

FIG. II.

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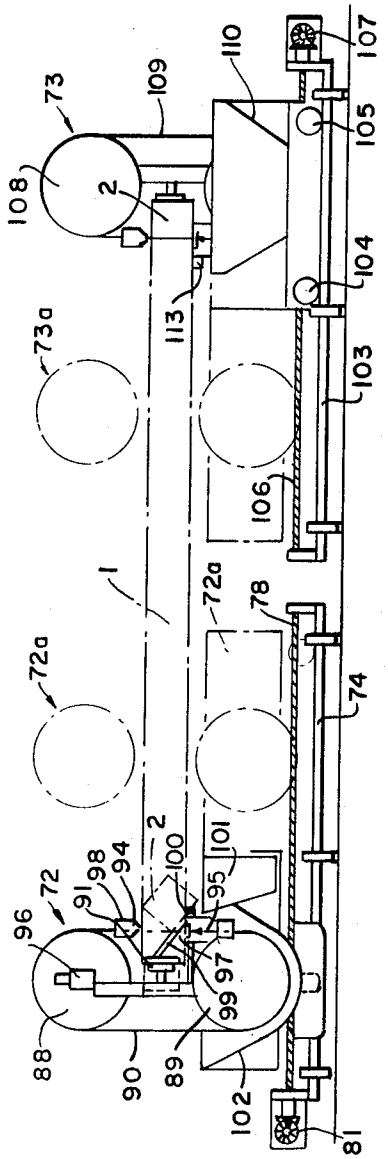
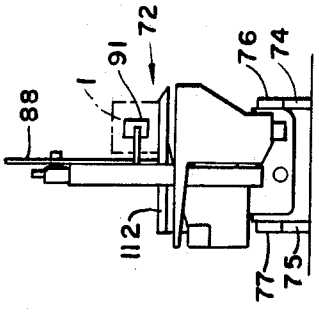


FIG. 14.

FIG. 17.



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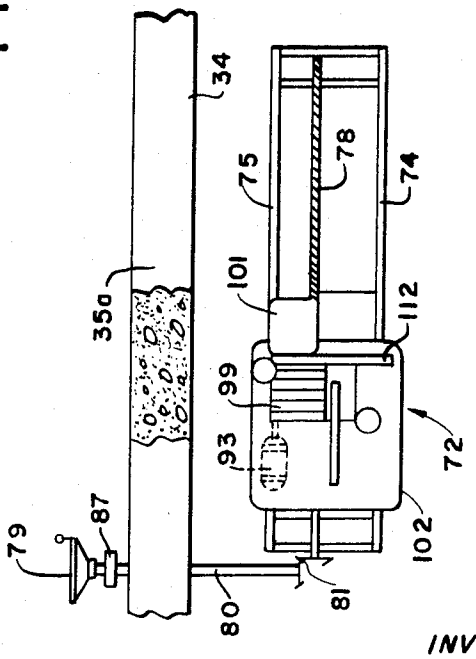

FIG. 15.

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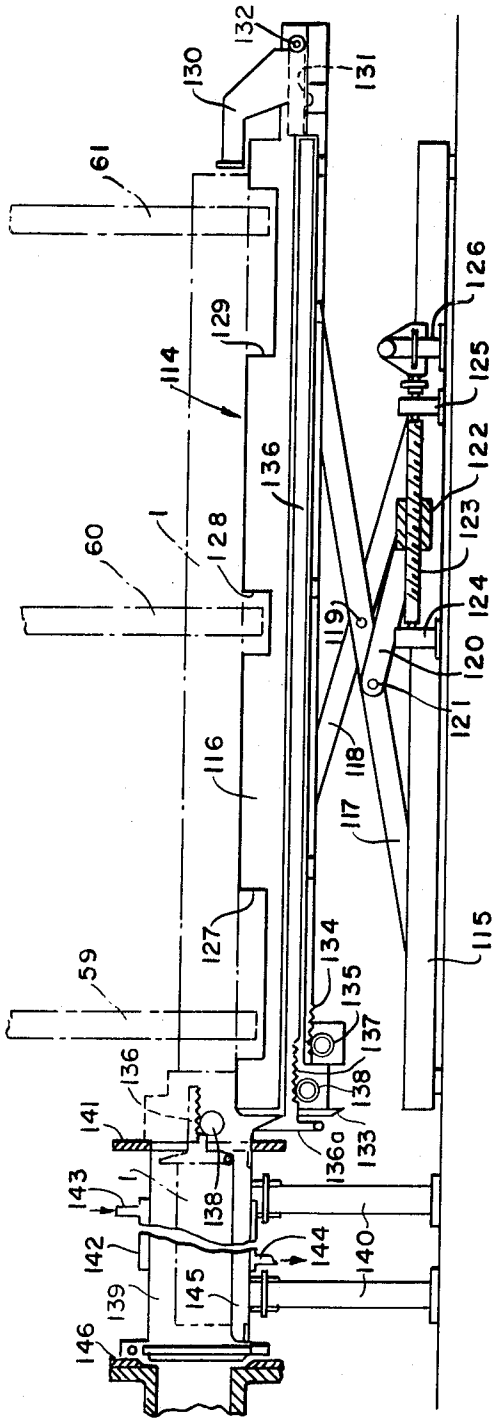

FIG. 18.

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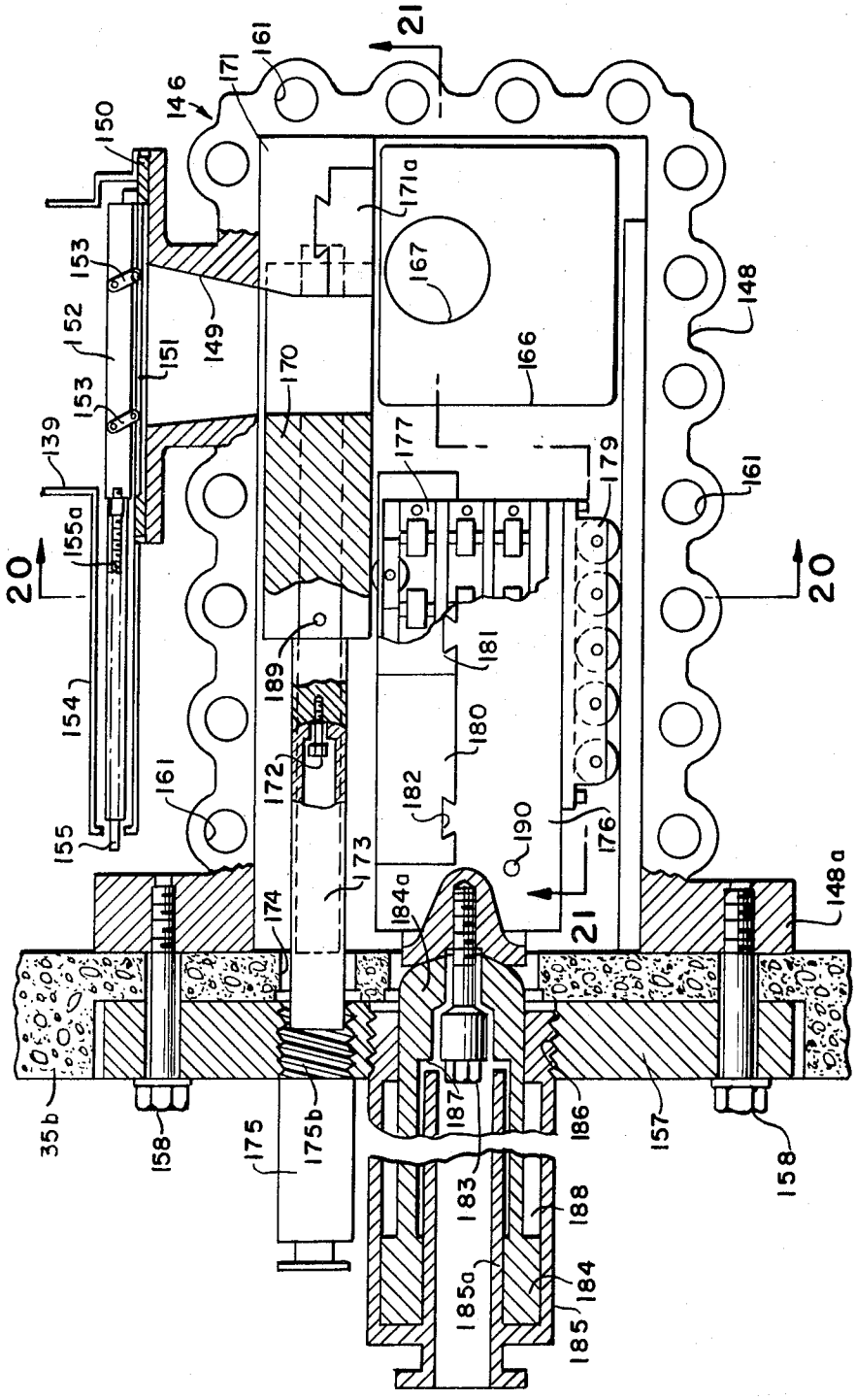

FIG. 19.

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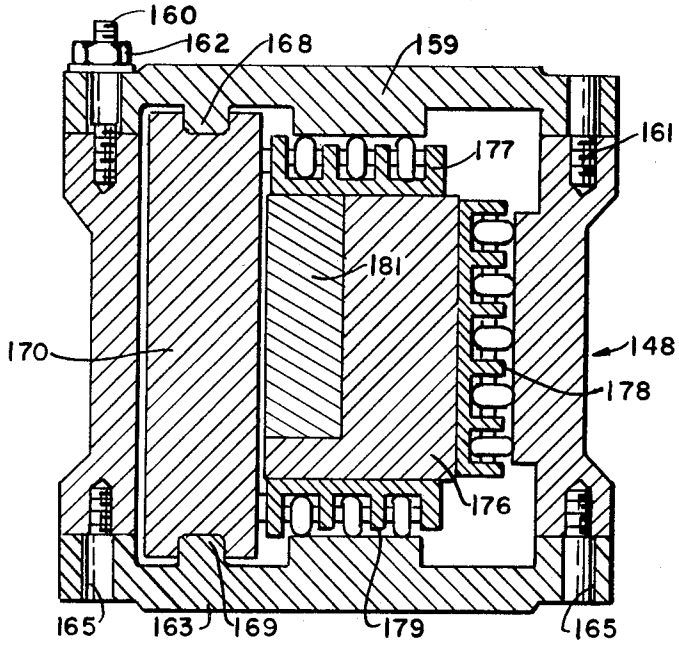

FIG. 20.

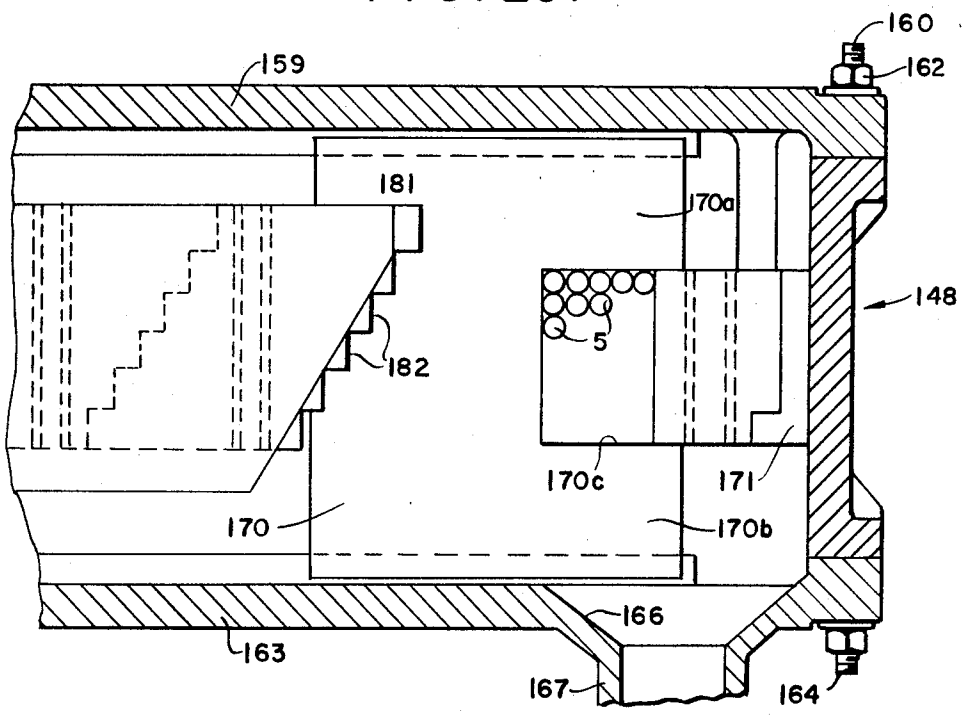

FIG. 21.

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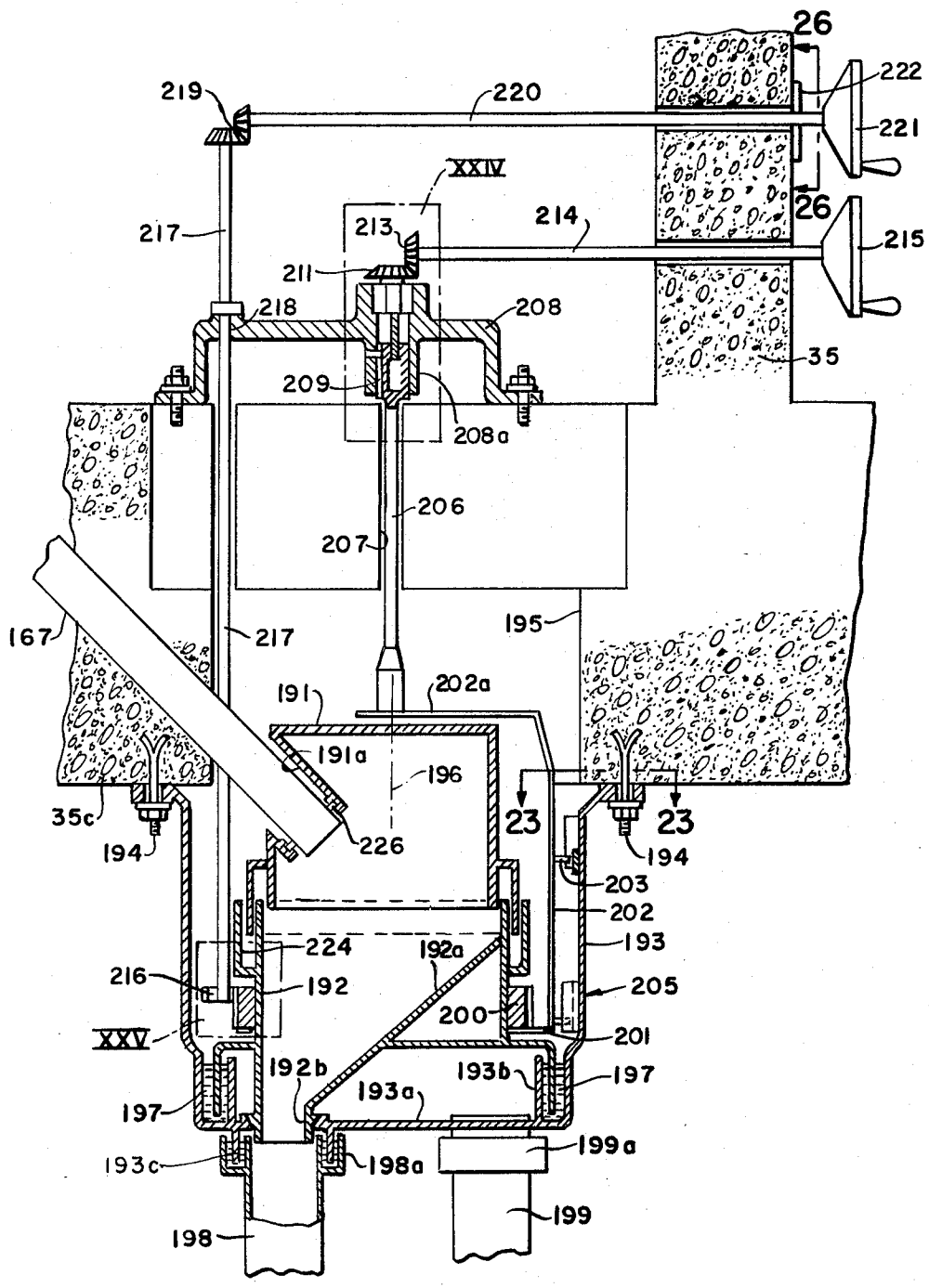

FIG. 22.

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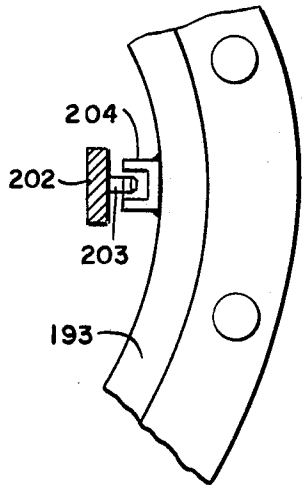

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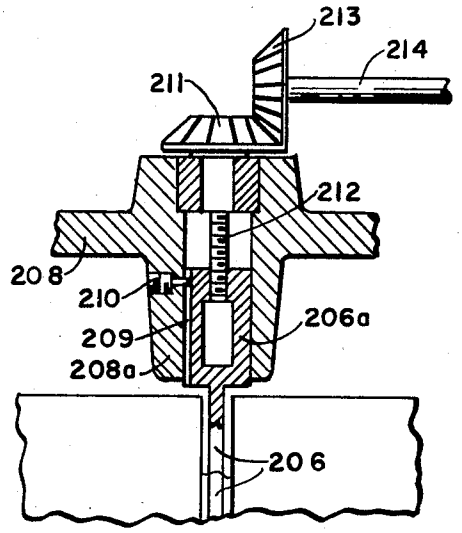

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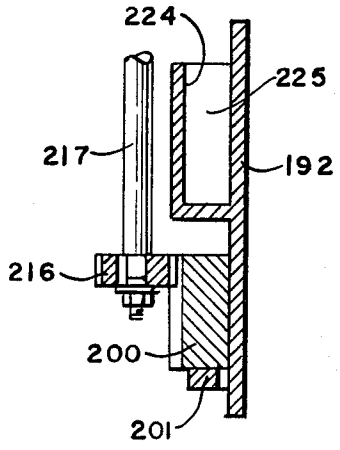

FIG. 25.

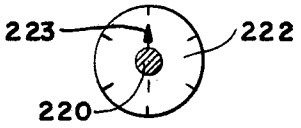

FIG. 26.

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APPARATUS AND METHOD FOR PROCESSING SPENT NUCLEAR FUEL ELEMENTS

This invention relates to apparatus and method for the processing of used or spent nuclear fuel elements preparatory to treatment of the combustible to restore it to predetermined degree of purity, for re-use.

Such elements are utilized in atomic piles and embody a central active portion containing the nuclear combustible, and two inert ends or extremities, all enclosed in a cartridge or sheath which may, for example, be of stainless steel or of an alloy of zirconium known as "Zircaloy." After a period of irradiation in the pile the combustible must be treated or processed for the purpose of restoring its purity to a predetermined value, by elimination or extraction therefrom of fission products so that it may be re-used.

The usual procedure called "chop and leach" consists in transporting each fuel element, by the aid of a suitable remotely controlled cradle, from a stockpile of elements, to a sawing apparatus or an abrasive wheel cutter where the aforesaid inert ends are cut off. The element, sans its ends, is then transported by a second remotely controlled means, to a shear where the cartridge is cut into fragments. These fragments are collected in perforated panniers each provided with a cover. When filled, each pannier is, in turn, transported to and immersed in a liquid bath capable of forming a solvate with the nuclear combustible.

As a result of the prior art procedure outlined in the preceding paragraph, it is necessary to provide remotely controlled apparatus to convey the combustible elements in sequence to the saw. Further, such apparatus must be operable to transport each element in the direction of its length in order to present the two ends thereof in succession, to the saw blade or abrasive wheel. Then a second remotely controlled apparatus is required to transfer the combustible element from the saw or end-severing means, to the shear, and to move it into operative relation therewith.

Moreover the perforated containers or panniers tend to overheat under the effect of disintegration of the nuclear combustible, and as a result should be stored after each use in a cooled compartment. This requires further remotely controlled apparatus. A further disadvantage of prior art procedure is that the apertures of the panniers become gradually clogged with accumulations and encrustations so that their effective size is progressively reduced. This retards free circulation of the solvent into and through the panniers and excessively prolongs the required time of immersion.

Another disadvantage is that the means for transporting the panniers from the shear to the chilled storage place, thence to the solvent bath, eventually become contaminated with radio-active dust.

The present invention relates to an apparatus and method for obviating the prior art drawbacks set forth in the preceding paragraphs.

It is the chief object to provide a method and remotely controlled apparatus for processing irradiated or spent nuclear combustible elements wherein each element is, in turn, transported from storage to a sawing device which simultaneously severs the aforesaid two inert ends of the element. The element is then moved in the direction of its length, into a shear where the cartridges containing the nuclear powder or fuel are fragmented and the fragments are diverted directly to a bath wherein the spent fuel is dissolved as a preliminary to its reconditioning for further use.

A further object is to eliminate remote control mechanism for raising the elements from the sawing machine, the cradle for the element required by such mechanism, the panniers, including their covers, and the storage and cooling means therefor. Elimination of the need for panniers also avoids the gradual slow-down otherwise resulting from the accumulations which inevitably collect thereon. As a corollary the invention results in an important saving of time required for the processing of each element. Furthermore, contamination of the parts by radio-active dust is reduced because the fragments of the cartridges are collected in a distributor and fall directly therefrom into the solvent bath.

A further object of the invention resides in the provision of apparatus for carrying out the method as previously outlined. Such apparatus is characterized by an assembly of means, remotely controlled, by which the elements are in succession, moved onto a support on which they pass directly to a sawing machine. In this machine both inert ends of the element are simultaneously removed and the element is passed directly to shearing mechanism. From thence the fragments and spent fuel of the element move directly to one of a battery of solvent baths, as selected by operating personnel.

Other objects and advantages of the invention will become clear to those skilled in the art, after a study of the following detailed description, in connection with the accompanying drawing.

In the drawing:

FIG. 1 is a side view of a combustible element of the type processed by the invention;

FIG. 2 is an end view of the element;

FIG. 3 is a plan view showing the general lay-out of the apparatus embodying the invention;

FIG. 4 is a sectional elevation taken in a plane identified by line 4 — 4, FIG. 3, showing the means for distribution of the fragments of the combustible elements;

FIG. 5 is a sectional elevation taken in a plane identified by line 5 — 5, FIG. 3, showing the chamber wherein spent nuclear elements are stored, retrieved, and loaded onto a truck for elevation and transport to shearing mechanism;

FIG. 6 is a sectional elevation taken in a plane identified by line 6 — 6, FIG. 5, and showing a nuclear element about to be pivoted into horizontal position and picked up by the truck;

FIG. 7 is a plan view of the truck which conveys each element from the storage chamber to the sawing and shearing apparatus;

FIG. 8 shows the truck in side elevation;

FIG. 9 is an end elevation to a reduced scale, of the truck and an element supported thereon;

FIG. 10 is a sectional elevation taken in a plane identified by line 10 — 10, FIG. 3, showing the truck elevated into the sawing chamber and carrying an element about to be picked up therefrom by the traveling crane;

FIG. 11 is a perspective view showing schematically the traveling crane, the supports thereof, and an element carried thereby about to be moved into contact with saws;

FIG. 12 is a detail view of the parts within the dot-dash rectangle XII of FIG. 10, namely one of the three support means for conjointly supporting a nuclear element being processed;

FIG. 13 is a section in a plane indicated by line 13 — 13, FIG. 12;

FIG. 14 is a side elevation of one pair of saws and an element about to be passed between them for severance of its ends;

FIG. 15 is a plan view of the saw appearing at the left of FIG. 14;

FIG. 16 is an end elevation of the machine shown at FIG. 15 as seen looking from the left, FIG. 14;

FIG. 17 is a detail view of an abutment element a respective one of which forms a part of each saw;

FIG. 18 is a side elevation showing the table on which each nuclear element is positioned after sawing, and which is equipped with means by which the element is translated from the table into the shearing mechanism;

FIG. 19 is a plan view of the shear with cover plate removed and parts broken away for greater clarity of description;

FIG. 20 is a section taken in a plane identified by line 20 — 20, FIG. 19;

FIG. 21 is a detail section in planes indicated by broken line 21 — 21, FIG. 19;

FIG. 22 is a central vertical section through the distributor and control means therefor;

FIG. 23 is a detail sectional view on line 23 — 23, FIG. 22;

FIG. 24 shows to an enlarged scale the mechanism within rectangle XXIV, FIG. 22;

FIG. 25 is an enlarged detail of the structure within rectangle XXV, FIG. 22; and

FIG. 26 is a sectional detail taken in a plane identified by line 26 — 26, FIG. 22.

Referring to FIG. 1 a combustible element 1 includes two inert extremities 2, of lengths l and m, respectively, and a body portion 3 of length L. The body portion comprises a bundle of tubes or cartridges 5 containing the nuclear powder of uranium oxide. FIG. 2 shows the element in end view.

The elements 1 are stores in a chamber 6, FIGS. 3, 5 and 6 and are movable therein from storage to loading positions by a crane device generally identified at 7 FIG. 5. This comprises a tube 8 carrying hook at its lower end and slidable vertically in and through a truck 10 mounted upon rollers or wheels 11 for guided translation on and along a track or bridge 12 horizontally spanning the chamber. Remotely-controlled power operated means not shown, are selectively energizable to (a) vertically translate the shaft in and with respect to truck 10; (b) move the truck on and along bridge 12; (c) translate bridge 12 on and along tracks 13. In this way hook 9 may be universally moved in three mutually normal directions, to pick up an element 1 from its base support 15 and translate it to the loading device. As shown at the left of FIG. 5 the elements are stored in vertical positions, each with its lower end resting in a recess in base 15 and having a yoke 16 releasably secured to its upper end.

A passageway 17 opens through one side wall of chamber 6 and extends outwardly and upwardly, FIG. 5, to open through the floor of enclosure 34, FIG. 3. Spaced parallel rails 18 extend along this passageway to support a carriage 14 rolling on flanged wheels 19. As shown upon FIGS. 7 and 8 the carriage is elongated and has chains or cables 20, 21 attached at spaced points along its length. Chain 20 also appears upon FIG. 5. These chains are connected at their other ends to windlass means subsequently described, by which the carriage loaded with an element 1 may be pulled upwardly out of chamber 6, in guided translation on and along tracks 18.

Reference to FIG. 9 shows that the carriage is so shaped as to present a generally horizontal upper surface as it moves along the rails. FIGS. 7 and 8 show that this upper surface is broken by a central channel 22 and end channels 23 spaced on either side thereof. These channels define between them a planar support for the element. At its ends the carriage is equipped with abutments or pockets 24, 25, FIG. 7, which receive the respective ends of the element and prevent it from shifting longitudinally and laterally with respect to the carriage when supported thereon. These abutments may be vertically by suitable jack means, not shown.

Referring to FIGS. 5 and 6, means generally identified at 26 are provided within chamber 6, for receiving an element 1 from hook 9 and tilting or pivoting it to the horizontal, in position to be picked up by carriage 14 and transported upwardly along rails 18. Such means includes a stand 27 having a column 28 rising from its top surface and mounting at 29, for pivoting about an axis normal to the plane of FIG. 6, a channeled support or cradle 30 having a closed or obstructed lower end. A jack 31 which may be of a mechanical or hydraulic type, is mounted on stand 27 and connected with support 30 by linkage 32 so that in response to energization or operation of the jack, support 30 is pivoted from the inclined position shown at FIG. 6, about mounting 29, to a horizontal position. This position is determined by engagement of support 30 with an abutment 33 fixed to the stand.

Reference to FIG. 5 shows how an element 1 is raised from its channel 15 and becomes tilted to about the same angle as that shown for support 30, FIG. 6. Thus the element is deposited in the support, by shaft 8, so that its lower end abuts against the closed end of the support and then released from hook 9 by suitable operation of shaft 8. When pivoted to the horizontal position on stand 27 the element is ready to be picked up by carriage 14.

FIG. 10 shows the top end of rails 18 passing through an opening in the floor of an enclosure generally indicated at 34 and defined by thick concrete walls 35. This figure also shows one of the chains or cables 20 from which it is noted that they pass about a roller 37, thence downwardly to and about coaxial sprockets one of which is shown at 38. From these sprockets the chains pass to a take-up reel, not shown. The sprocket is driven by a motor 36 connected therewith by a speed reducer generally identified at 39.

Two horizontal, horizontally spaced parallel beams 40, 41, FIGS. 10 and 11, span enclosure 34 and by means of rollers 42 support a carriage or crane 43 for guided translation in the directions indicated by the arrows, FIG. 10. Referring more particularly to FIG. 11, the crane comprises a pair of beams 44, 45, rigidly interconnected at their ends by plates 46, 47. Rollers 42 are journaled upon these plates.

Each plate carries an element such as 48 for plate 46, projecting horizontally and centrally therefrom. Each element has a threaded hole engaged by a respective one of two horizontal threaded shafts 49, 50. FIGS. 10 and 11 show that these shafts extend through openings such as 51 in wall 35 and are connected for rotation, externally of the enclosure 34, by shafts 52, 53 and bevel gearing 54, 55, each with a respective one of shafts 49, 50, and driven at equal speeds of rotation by motor 56, speed reducer 57 and gearing 58, in a way clear from FIG. 11. The connections are such that rotation of threaded shafts 49, 50 effects translation of carriage 43 on and along beams 40, 41.

Beams 44, 45 forming part of carriage or crane 43, mount supports 59, 60, 61 in fixedly spaced depending relation therealong. Central support 60 may be permanently fixed in predetermined position on the beams.

Referring to FIGS. 11, 12 and 13, support 61 includes at its top, a box-like sleeve 63 which fits about beams 44, 45. The top surfaces of these beams are provided with studs 64 fixed at equally spaced predetermined intervals therealong. Holes in the top of each sleeve, such as 63, are so located as to receive four of the pins, in a way clear from inspection of the figures identified, thus fixing each of the end sleeves in adjusted position on and along the beams. FIG. 13 shows a clamp plate 65 with side edges rabbeted to fit between and against the lower flanges of beams 44, 45. The plate is guided for positive vertical translation relatively to its sleeve, by pins 66, 67. Referring in particular to FIG. 12, set screws 68, 69 are threaded each through a nut welded to the bottom portion of sleeve 63 and, when turned up to the position shown, force plate 65 into contact with the beams and thus hold the sleeve in its location of adjustment therealong. When supports 59 and 61 are to be adjusted to a new position on and along the beams, the set screws such as 68, 69 are loosened. Then the corresponding sleeve may be raised sufficiently to clear pins 64, shifted to the new position, dropped over an appropriate set of pins. Set screws 68, 69 are then re-tightened to restore plate 65 to the operative clamping position shown. Eyebolts 70, 71, FIG. 11, attached to the top surfaces of sleeves 63 and 72, respectively, enable lifting and movement or adjustment, from a location exteriorly of the enclosure.

FIGS. 10 and 11 show that the lower ends of each of the supports 59, 60, 61, are formed with oppositely directed horizontal arms such as 61*a*, 61*b* for support 61. The upper surfaces of these arms are horizontally coplanar and the supports are so adjusted on and with respect to beams 44, 45 that when one arm of center support 60 is moved into the channel 22 of truck 14, as previously described in connection with FIGS. 7 and 8, each corresponding arm of end supports 59, 61 are located to enter a respective one of end channels 23 formed in the truck body.

By the construction described, when truck 14 has been elevated along tracks 18 to about the position shown upon FIG. 10, and supports 59, 60, 61 are located slightly to the right from the position shown adjacent the upper ends of tracks 18, energization of motor 56 moves the supports as a unit leftwardly and causes their arms to pass into the respective channels 22, 23, to a position wherein initiation of return movement of the truck downwardly along tracks 18, leaves nuclear element 1 supported solely by these arms. The truck may then continue downward movement into chamber 6 to pick up another element. It will be noted that since each of the

supports 59, 60, 61 has two oppositely directed arms such as 61*a*, 61*b*, FIG. 11, they may be moved by reversible motor 56 to pick up and transport a nuclear element in either of two opposite directions. Thus, for example, if support 61 is at the left of truck 14 when the latter rises along tracks 18 to the position shown at FIG. 10, the element thereon may be moved to the right. As subsequently explained, this makes it possible to provide a second cutting apparatus as indicated generally at 85, in case the first apparatus to be described, is out of order and needs servicing or repair.

When an element 1 has been thus been picked up by supports 59, 60, 61, it is precisely positioned relatively to the arms thereof, with respect to its longitudinal dimension and, by operation of motor 56 may be transported horizontally in either direction, into cutting relation with a respective one of two pairs of cutter blades. Thereby its two inert ends are severed as previously mentioned.

Since all of the cutter means are shown in the form of band saws and are alike and similarly mounted for adjustment, a description of one saw is sufficient. Still referring to FIG. 11, the saws of one pair are identified generally at 72 and 73 where they are shown so located in enclosure 34 as to operate upon the nuclear elements moved to the left as viewed upon FIG. 10. A second pair of such saws is, as previously noted, provided at 85, 86, FIG. 3, for operation upon elements 1 when moved to the right from the central position indicated, FIG. 10. Each arm like 61*a* is provided with a sloping surface such as 61*c*, followed by a vertical surface forming a shoulder with the horizontal surface of the respective arm. Thus, should an element 1 be not precisely aligned with the shoulders of the three supports, it is conjointly cammed by these sloping surfaces as truck 14 descends, until it drops into snug contact with all three vertical surfaces, like 61*d*.

The mounting for each of the band saws are shown in greater detail upon FIGS. 14, 15 and 16. FIG. 14 shows the two saws 72, 73 in elevation. FIG. 15 is a plan view of saw 72, and FIG. 16 is an end elevation thereof. A detailed description of saw 72 will be sufficient. A pair of parallel rails 74, 75 are fixed to the floor of the enclosure and extend horizontally at 90° to the direction of translation of element 1 as it moves with carriage 43. The base or frame of the saw has rollers such as 76, 77, FIG. 16, journaled thereon. These support the saw for guided translation on and along tracks 74, 75.

A threaded rod 78 extends in a vertical plane between and parallel with the tracks and is journaled at its ends in fixed bearings. The rod traverses a threaded hole in the frame of the saw so that by turning thereof the saw is precisely adjusted on and along its tracks. Reference to FIG. 15 shows that the rod may be turned by a handwheel 79 located exteriorly of wall 35*a*, mounted on one end of a shaft 80 passing through a hole in the wall and connected by bevel gears 81, with rod 78. A torque limiting device such as 87, FIG. 15, may be inserted in the drive between each handwheel and its shaft. From FIG. 3 it is seen that there are four handwheels 79, 82, 83, 84, and that each is rotatable in the manner just described for item 79, to adjust its respective saw.

Continuing detailed description of saw 72, FIGS. 14, 15 and 16, pulleys 88, 89 are journaled in superposed relation and guide a saw blade or band 90 in the manner conventional with ban saws. The frame of saw 72 includes an abutment 91 threaded onto a shaft 92, FIG. 17, so that it may be adjusted on and along the shaft for engagement with the corresponding end of element 1. The element is thereby accurately collocated with respect to blade 90, to assure that its cut is in the correct plane normal to the longitudinal axis of the element. Band saw pulley 89 is connected to be driven by a motor 93. There is one of these motors for each saw, located within enclosure 34, and each may protected by suitable sheathing of lead or like material, not shown.

In order to assure correct functioning of the saw it may be provided with upper and lower blade guides 94, 95. Also provided are (a) remotely controlled or telemetrically-operated means 96 for adjusting the tension of blade 90; (b) a brush or cleaner 97 for the blade; (c) a supply means 98 for liquid to decontaminate the blade; (d) a ramp or grill 99 pivoted on an axis 100 normal to the plane of FIG. 14, and effective to divert and guide the severed end 2 of element 1 into a receptacle 101; and (e) a receptacle 102 to catch detritus resulting from the cutting action of the blade.

FIG. 14 shows saw 72 in solid lines as adjusted substantially to its outward limiting position on and along tracks 74, 75. Its innermost position is indicated in dot-dash outline at 72*a*. Since saws 73, 85, and 86 may be like saw 72 just described, it is sufficient, still referring to FIG. 14, to identify saw 73, one of its two tracks 103, rollers such as 104, 105 mounting the saw for guided translation on and along the tracks, threaded adjusting rod 106, bevel gears 107, upper blade pulley 108, saw blade 109, and receptacle 110 for detritus. Saw 73 is shown in solid lines at about its outwardmost position of adjustment on and along tracks such as 103. This position corresponds to the one shown for saw 72. At 73*a* it is generally indicated in dot-dash lines, in its innermost position of adjustment. The other pair of saws 85, 86, previously mentioned are like those just described and are similarly mounted on and adjustable along tracks, not shown, like 74, 75.

The operation of the mechanism thus far described, for the purpose of safely transporting elements 1 in sequence from storage chamber 6, and eventually guiding each into engagement with the saws to sever the inert ends 2 thereof, will be generally clear from the foregoing paragraphs. The abutment of each saw such as that for saw 72, identified at 91, FIGS. 16 and 17, is adjusted with respect to the cutting blade thereof so that the distance between them is a little less than the distance l or m, FIG. 1. Each saw is initially adjusted along its tracks so that, referring to FIG. 14, it is in initial position which is retracted from its final or cutting position.

End supports 59, 61 are adjusted on and along beams 44, 45 by loosening set screws such as 68, 69, FIG. 12, lifting each sleeve such as 63 and its support, to clear studs 64, moving the sleeves to the proper locations along beams 44, 45 so that the studs enter a new set of holes, and turning the set screws home to lock each sleeve in the desired position. Ordinarily each end support will be the same distance on a respective side of center support 60. The remotely controlled means for lifting the supports by eyebolts 70, 71, FIG. 11, for shifting them to a new position of adjustment along the beams, are generally indicated at 111, but are not shown in detail since such means are known in the art.

After the aforesaid adjustments, crane means 7 is operated to pick up an element l, place it in cradle 30, from whence it is transferred to truck 14, after the cradle and element have been swung to horizontal position. It has been previously stated that abutments 24, 25 of truck 14 are vertically adjustable in unison by remotely controlled power means not shown. Referring to FIG. 5, when truck 14 is at its lowermost position on tracks 18, and abutments 24, 25 are fully lowered, these abutments lie slightly below an element on cradle 30. Thereafter the abutments are elevated and thus lift the element from the cradle. The truck now fully supporting the element is moved upwardly to a position free of stand 27, by energization of motor 36. After this the abutments are again lowered to fully depressed position so that the element rests upon the raised surfaces of the truck, defined between channels 22, 23. This may be done while motor 36 remains in operation and, by means of chains 20, 21, draws the truck upwardly along the tracks to the location about as shown at FIG. 10. In this position element l is a little above the horizontal plane conjointly defined by the upper surfaces of arms 59*a*, 60*a* and 61*a*. At this time, of course, beams 44, 45 and all parts carried thereby are to the right of the central position shown upon FIG. 10.

As soon as truck 14 has been elevated to the position shown, motor 56 is energized and supports 59, 60, 61 are thereby translated leftwardly until their arms enter within the respective channels 22, 23, and are thus beneath but slightly spaced from element 1. Truck 14 is then returned downwardly

along its tracks and thus leaves the element supported by the arms of the supports. The truck continues its downward movement to pick up another element.

Motor **56** is continued in operation until the element being moved thereby, rests upon the fixed supporting surfaces such as **112, 113**, FIG. **14**, with which all of the saws are provided. The motor is then stopped. Next, handwheels **79** and **84** are operated to move each saw **72, 73** along its tracks until each abutment like **91**, FIGS. **14** and **17**, is in contact with its respective end **2** of element **1**. The saw motors like **93**, of saws **72** and **73** are then energized and motor **56** is started in a direction which advances the element into the blades of the saw, to thereby cut off ends **2**.

It should be noted that carriage **43** and parts supported thereby appear twice in FIG. **10**. In the first position at the right the parts are in position to pick up an element **1** from the truck. In the second or leftward position as viewed upon the figure, the carriage is about to move the element onto the supports of the bandsaws, as indicated at **112, 113**.

After the ends of the element have been severed, the saws are retracted by operating handwheels **79** and **84**, while carriage **43** continues its movement to the left, FIG. **10**, until the element carried thereby, sans ends **2**, arrives over a table **114**, FIGS. **3** and **18**. Referring in detail to the latter figure, this table comprises a base **115** supporting a top **116**, by means of two pairs of crossed links. Each pair is a duplicate of the other. The one pair shown, namely, **117, 118** are interpivoted at **119**. Link **117** is also pivoted at its left end to base **115** while link **118** is pivoted at its left end to top **116**. The remaining ends of links **117, 118** are mounted for horizontal guided sliding movement on and with respect to top **116** and base **115**, respectively, in planes parallel with the plane of FIG. **18**. The second pair of links do not appear in the figure because each is parallel with and spaced directly behind a respective one of links **117, 118**. Pivot **119** may be a shaft or rod extending between and forming the pivotal connection of both pairs. An operating link **120** has one end pivoted at **121** to link **117** and its other end is connected to a nut **122** threaded upon screw shaft **123**. The shaft is journaled at its ends in bearings **124, 125**, and is rotated by reversible power means generally identified at **126** and remotely controlled from a location exteriorly of the enclosure. Nut **122** may also be connected by a second link, not shown, with the link of the second pair, parallel to link **117**.

Thus in a way clear from inspection of the figure, operation of means **126** in one direction or the other, is effective to elevate and lower top **116**.

Top **116** is provided with parallel transverse channels **127, 128, 129** which are so spaced therealong that each may receive an arm of a respective one of supports **59, 60, 61**, as indicated upon FIG. **18**. The vertical dimension or depth of the channels is such that when an element l is over the table, its top **116** may be raised to engage and fully support the element, free of arms **59a**, etc. Thus power means **126** may be operated or energized to slightly elevate an element l above the arms, after which motor **56** may be reversed to retract the supports and return them to about the central position depicted upon FIG. **10**, thus leaving the element **1** supported solely by the table.

Table top **116** is formed with a longitudinally extending guideway or channel below the level of the channels **127**, etc. A bar fits this guideway for guided horizontal movement in the direction of its length, that is, parallel to the plane of FIG. **18**, and at its right end carries an abutment **130** so shaped and disposed that its end normally lies slightly to the right of the adjacent end of an element l resting upon the table. A chain **131** passes about a first sprocket **132**, and a second one, not shown, located at the left end of the table. The bar integral with abutment **130** is connected with the upper run of the chain. The chain may be driven by a reversible motor, through reduction gearing not shown, so that in response to operation of the motor, the abutment may be controllably translated leftwardly to engage and move an element resting upon the table, in the direction of its length. It will be understood that the table incorporates suitable guides which confine each element thereon to translation in the direction of its length.

Table top **116** also embodies an obturator plate **133** which, for a purpose subsequently explained, includes an integral horizontal rack **134** operated by rotation of a pinion **135** in mesh therewith. The rack is formed in a tubular stem integral with plate **133**. A rod **136** is slidably mounted within the stem and is limited by pin and slot means, to translation only in the horizontal direction in the plane of the figure. The rod carries a pusher head **136*a***, and incorporates a rack **137** engaged by a pinion **138** journaled in the base of plate **133**. Selective and individual rotation of these pinions, as well as operation of chain **131**, is effected, for example, by motors controlled exteriorly of the enclosure **34**.

At the left of FIG. **18** is depicted a horizontal tube **139** mounted on supports **140**. Note also FIGS. **3** and **19**. The tube is sufficiently long to accomodate an element l and as shown upon FIG. **3**, it is in the same vertical plane as table **114** or, more particularly, an element l resting thereon.

At its right end, tube **139** has a closure plate **141** provided with an aperture having a beveled edge of which the correspondingly beveled edge of obturator plate **133** may seat, thus closing the end of the tube. The tube is also provided with a cooling jacket **142** extending about and along the greater part of its length, and supplied with inlet and exhaust couplings **143, 144** for circulation of coolant about the tube. Track or guide means **145** within the tube act to guide each element l in smooth and friction-reducing axial translation therealong. As subsequently described in connection with FIG. **19**, the left end of the tube is provided with a closure plate **146**, and means by which it may be positively shifted from a position obturating the contiguous end of the tube, to a position entirely free thereof.

When an element is deposited upon table **114**, as previously described, top **116** is below the axis of tube **139**, at about the level shown on FIG. **18**. In this position of the top, the element l is in axial alignment with the tube. Means **126** are then operated to raise top **116** just enough to lift the element off the arms of supports **59, 60, 61**. Carriage **43** being thus freed of the element, is retracted to a position ready to pick up another element coming up from storage on truck **14**.

Meanwhile, table top **116** is again lowered to the position shown so that when push bar **130** is operated leftwardly its full distance, by rotation of sprocket **132**, element l is thereby translated axially to position fully housed within tube **139**. Next, power-driven means **126** are operated to again elevate top **116** until obturator plate **133** is at the level of the opening in closure **141**, and pinion **135** is turned to force plate **133** onto its seat on the rim of the aperture. Head **136*a*** is now in registration with the contiguous end of element l and may, under operation by pinion **138** and its driving means, be moved leftwardly as desired, to thrust the element a short distance into the shear mechanism so that it may be advanced in sequential short steps and be severed into fragments.

FIG. **19** is a plan to an enlarged scale of the shear mechanism just referred to, and is generally indicated at **146**. From FIG. **3** it is seen that this shear device is located within enclosure **34**, in alignment with and adjacent to the delivery end of tube **139**. FIG. **4** shows it to be supported on a base or foundation **147**. Returning to FIG. **19**, the shear is enclosed within a casing **148** having a flanged opening **149** in its side wall. The delivery end of tube **139** is connected with this opening. A bezel **150** is connected with the flange of the opening and defines an aperture with beveled rim. A closure plate **151** having a complementarily beveled rim is shaped to fit the aperture in the bezel, as shown. A slide **152** is connected with plate **151** by four parallelogram links, two of which, **153**, appear upon the figure. The slide is mounted in any suitable way for guided translation in the direction of its length, parallel with the plane of the figure.

A housing **154**, fixed at the delivery end of tube **139**, journals a shaft **155**. From FIG. **3** it is noted that this shaft extends

leftwardly through an opening in the wall of the enclosure and at its free end is equipped with handwheel **156**. The inner end of the shaft is threaded at **155***a* and engages in an aperture in a lug fixed with slide **152**. Starting with plate **151** in the obturating position shown, operation of handwheel **156** in one direction of rotation, shifts slide **152** to the left, FIG. **19**. Through the action of links **153**, this movement first raises closure plate **151** from its obturating position and as soon as it has cleared bezel **150**, continued rotation of the shaft causes the slide and plate to retract as a unit into housing **154** where they finally leave opening **149** clear and unobstructed. On reversal of the direction of rotation of handwheel **156** the operation just described is reversed so that plate **151** re-seats in the obturating position shown. The delivery end of tube **139** may thus be opened and closed as desired.

Casing **148** has the flange **148***a* of its front wall, clamped to wall **35***b* of the enclosure by means of an external face plate **157** and cap screws **158** which pass freely through respective holes in the face plate and wall, and thread into apertures in the flange of the casing. FIG. **19** shows the shear with top cover removed. FIG. **20** shows this cover **159** secured in place by a plurality of stud bolts, as indicated at **160**, threaded into holes **161** in the housing wall and receiving nuts **162**.

The bottom wall of the housing is indicated at **163**, as secured to the housing wall by stud bolts **164** passing through holes **165**. See FIGS. **20** and **21**. Referring to FIG. **21**, this bottom wall has a funnel-shaped opening **166** merging into a downspout **167**. Within the housing, coplanar ridges **168**, **169** integral with the top and bottom parts **159**, **163**, respectively, fit within upper and lower channels formed in a clamp member **170**, and act to guide the member in translation. From FIG. **21** it is seen that this clamp member has upper and lower projecting portions **170***a*, **170***b*, defining between them a rectangular slot **170***c*. This slot is so dimensioned, and clamp member **170** is so positioned, that on movement of the clamp to the right from the position shown upon FIGS. **19** and **21**, the slot fits smoothly over an abutment **171** fixed with the housing. It is further noted that in the position shown at FIG. **21**, the top, bottom and vertical edges of the slot coincide or register with respective edges or surfaces of the opening **149** in the side wall of housing **146**. Therefore, when a group or bundle of cartridges **5** are advanced through this opening, as subsequently described, movement of clamp member **170** to the right, FIG. **19**, firmly clamps the tubes to abutment **171** and thus holds them ready for shearing.

FIG. **19** shows that clamp member **170** is connected by cap screw **172** with the end of a hollow or tubular rod **173** of a piston slidably fitting a cylinder **175**. This cylinder has its inner end threaded at **175***b* to engage the threads of an aperture in plate **157**. The construction is essentially like that subsequently described in connection with cylinder **185**, except that the stroke of the piston in cylinder **175** is less, and need only be sufficient to cause clamp member **170** to move from its position shown, rightwardly, into contact with abutment **171**. By connection not shown, pressure fluid may be introduced, under the control of suitable valves, into the outer end of cylinder **175**, to force the piston therein and member **170**, into cartridge-clamping position as previously mentioned. Likewise a second pressure fluid connection, not shown, enables the piston and member **170** to be retracted to the positions shown. Since rod **173** is hollow and open at its end exteriorly of the enclosure, screw **172** can be removed and replaced from the exterior of the apparatus. Thus the rod and member may be disconnected and reconnected when, for any reason, clamp member **170** must be removed for servicing, repair, or replacement. Part **171***a* is a functionally integral hardened portion of abutment **171**, held thereto by a dovetail joint and at times removable when the shearing edge thereof becomes dulled in use and the part must be resharpened or replaced.

The shear slide is generally indicated at **176**. This item is mounted for guided translation contiguous to and parallel with clamp member **170**. Groups of antifriction bearings **177**, **178**, **179**, top, side and bottom, respectively, FIG. **20**, include rollers which roll on inwardly-projecting inner surfaces of the top, side and bottom walls of housing **148**, and act to reduce the power required for shearing motion. Referring in particular to FIGS. **19** and **20**, shear **176** includes hardened shear inserts **180**, **181** detachable secured to the main portion of the shear by dovetail joint connections such as **182**, so that these parts can be replaced or reconditioned when they become worn or dulled in use. From FIG. **21** it is noted that the leading or shearing edge of bar **181** is stepped as indicated at **182**, to facilitate cutting of tubes **5**.

Sliding of shear **176** to effect cutting is effected by power operated means controlled exteriorly of the enclosure. For this purpose the shear **176** has a tapped hole engaged by the threaded end of a screw **183**. The screw passes freely through a hole in one end of a tubular piston rod **184***a* integral with piston **184**. This piston fits a cylinder **185** whose end is threaded at **186** into an aperture in plate **157**.

As clearly shown upon FIG. **19**, the cylinder has a central axial passageway defined by an integral internal sleeve **185***a*. Access to the hexagonal head of screw **183** to tighten or to disconnect it from shear **176**, is provided by this passageway. The parts are so dimensioned that the stroke permitted piston **184** is sufficient to force the cutting edge of shear **176**, past a group of cartridge tubes **5** held, as depicted upon FIG. **21**, within slot **170***c*, so that all tubes are sheared in a single stroke.

Operation of the shear in a cutting stroke may be produced in a number of different ways, but in the model shown, is effected by the introduction of pressure fluid into cylinder **185** between the head thereof and piston **184**, and the simultaneous exhaust of fluid from chamber **188**. Retraction of the piston and shear are effected by introduction of pressure fluid into chamber **188** and exhaust from the space between the piston and head of the cylinder. The pressure fluid connections and valves controlling flow thereof to and from the cylinder, are not shown. It is noted that the construction of cylinder **175** its piston and rod **173**, are essentially like those just described in connection with cylinder **185**. Also noted is the fact that when screws **172** and **183**, and cover **159** are removed, all operating parts, namely, clamp member **170** and shear **176** are exposed and may be lifted out for repair and/or replacement, by means such as **111**, FIG. **11**. Threaded holes **189**, **190**, FIG. **19**, in the member and shear, are provided for this purpose.

In operation, with closure plate removed from opening **149**, as previously explained, and with clamp **170** and shear **176** in the retracted positions shown upon FIG. **19**, pinion **138**, FIG. **18**, is rotated to thereby move an element **1** within and along tube **139** until the ends of tubes **5** have been advanced, say, **20** to **30** mm. past the cutting edge of shear **176**. Pressure fluid is then passed to cylinder **175** and acts to force clamp **170** to the right, FIGS. **19** and **21**, until the tubes or cartridges are rigidly clamped to abutment **171**. While so held, pressure fluid introduced into cylinder **185** ahead of the piston **184** therein, forces shear **176** to the right and cuts off the protruding ends of all cartridges **5**. The procedure is repeated by retraction of shear **176** and clamp member **170**, renewed operation of rack **136** to again advance the tubes **5** a distance of 20 to 30 mm., etc., until the tubes are completely fragmented.

Rack **136** and its head **136***a* are then retracted to the position of FIG. **18**, and table top **116** is lowered to the position shown ready for reception of another element **1**.

When shear **176** is thrust forwardly in a complete cutting stroke, the short sections of tubes **5** cut off, and the nuclear contents thereof, drop into downspout **167**, as is clear from FIG. **21**. Referring to FIGS. **4** and **22**, this spout extends downwardly and inwardly through floor **35***c*, to terminate within the top cover **191** of a rotary distributor casing **192**. It is contemplated that one distributor unit as about to be described, may receive detritus from more than one shear, described in connection with FIGS. **19**, **20**, **21**. In that event a corresponding number of spouts like **167** would lead into cover **191**, each through a respective opening therein.

A casing support **193**, FIG. **22**, has an upper flange secured by bolts **194** to floor **36***c*, coaxially of a hole **195** therein. The support is generally cylindrical with a closed lower or bottom wall **193***a*. This wall is provided with a number of circular openings which may be arranged equiangularly about the central vertical axis of symmetry **196** of the assembly. An inner vertical circular flange **193***b* extends upwardly from bottom **193***a* and provides an annular chamber for the retention of sealing liquid **197**. A number of pipes such as **198**, **199**, FIG. **22**, extend downwardly from support **193**. Each is in registration and communication with a respective one of openings in bottom wall **193***a*. For example, referring to pipe **198**, its upper end is outwardly and upwardly flanged at **198***a* to provide an annular chamber for sealing liquid. Each opening in wall **193***a* has a cylindrical flange such as **193***c*, which dips into the liquid and, in a way clear from FIG. **22**, effects a gas-tight seal between the parts. Pipe **199** is similarly sealed with wall **193***a*, as indicated at **199***a*.

Distributor casing **192** is generally cylindrical and symmetrical about axis **196**. It has a ring gear **200** fixed exteriorly about its lower end. A ring **201** surrounds the casing and engages the lower surface of gear **200**. This ring is supported by an integral extension **202** which rises along the wall of the casing, within support **193** and is guided for vertical translation only with respect to the support, by a pair of pins one of which is identified at **203**, FIGS. **22** and **23**, fixed with extension **202** in spaced relation therealong. Each pin rides in a vertical slot in a respective guide like **204**, FIG. **23**. The second such guide means is identified generally at **205**, FIG. **22**.

The top end of extension **202** is bent radially inwardly at **202***a*. A vertical shaft **206** extends upwardly along axis **196** and has its lower end fixed to end **202***a*. The shaft extends upwardly through a hole **207** in the floor and at its top end, referring to FIG. **24**, has an enlarged head **206***a*. The head fits smoothly within a bore in a hub **208***a* of a spider **208** which, as seen in FIG. **22**, has the ends of its three arms bolted to the floor. Head **206***a* is vertically slotted at **209** and a pin **210** threaded into a radial hole in the hub, fits the slot to thereby limit the shaft to vertical translation.

A bevel gear **211** is fixed with stub shaft **212**, journaled in a bearing carried within the top end of hub **208***a*. The shaft has a reduced extension **212** threaded into a central hole in the top of the hub. A gear **213** meshes with **211** and its shaft **214** extends to the right, FIG. **22**, through a hole in wall **35**. Thus, turning of a handwheel **215** affixed to the outer end of the shaft, effects limited vertical translation of shaft **206**, extension **202**, ring **201**, gear **200**, and distributor casing **192**. From FIG. **22** is is seen that this casing has a downwardly inclined surface **192***a*. The spout has an external frusto-conical flange adapted to seat in any selected one of the holes in bottom wall **193***a*. The purpose of the vertical adjustment effected by handwheel **215**, as just described, is therefore simply to temporarily raise the distributor casing a distance such that spout **192***b* will clear the hole in bottom wall **193***a* in which it has been seated, so that the distributor may be rotated about axis **196** to bring the spout into registration with another opening such, for example, as the one in communication with pipe **199**.

The aforesaid rotation of casing **192** is effected by a pinion **216**, FIGS. **22** and **25**, attached to the lower end of shaft **217** which passes upwardly through the floor and a bearing **218** in spider **208**. The shaft is rotated in a way clear from FIG. **22**, by bevel gears **219**, shaft **220** extending through wall **35**, and exteriorly thereof equipped with handwheel **221**. Referring to FIG. **26**, a dial **222** is fixed to the wall, coaxially about shaft **220** and cooperates with a pointer **223** fixed to the shaft. The dial is so graduated and the parts are so collocated and interconnected, that pointer **223** indicates precisely the position of spout **192***b* when it is in registration with a selected one of the holes in bottom wall **193***a* of casing support **193**.

FIGS. **22** and **25** show how casing **192** is provided with an outwardly and upwardly extending flange **224** forming with the casing wall, an annular reservoir **225** to contain sealing liquid. An outwardly and downwardly extending skirt fixed exteriorly to and about the wall of cover **191**, dips into this liquid in a way clear from inspection of FIG. **22**, and seals gas-tight the joint between the cover and casing. This figure also shows how the lower end of downspout **167** protrudes through an inwardly flanged opening **191***a*. A seal **226** is provided between the spout and opening.

Operation of the distributor will be generally clear from the foregoing description. Each of the pipes **198**, **199**, etc. leads downwardly to a respective valve, as subsequently explained in connection with FIG. **4**. When any one pipe is known to be filled with cut fragments of cartridges **5** and the nuclear contents thereof, handwheel **215** is rotated to elevate casing **192** until its funnel spout **192***b* is elevated above bottom wall **193***a*, clear of the hole in which it has been engaged. Gear **200** is of sufficient axial dimension so that it remains in mesh with pinion **216** when casing **192** has been elevated to the maximum required position. Further, the liquid seals at **197**, **198***a*, etc., remain unbroken by this maximum vertical movement of the casing. Then handwheel **221** is rotated until pointer **223** indicates on dial **222** that spout **192** is vertically above another selected pipe such as **199**. Handwheel **215** is then reversely rotated to lower casing **192** until spout **192***b* is fully seated on the rim of the selected opening in the bottom wall **193***a*. The apparatus is then in condition for further operation to fill the second pipe such as **199**, with sheared fragments and detritus.

Referring to FIG. **4**, a solvent tank **227** is located in a chamber **228**. The lower end of each pipe such as **198**, **199**, leads to a respective one of valves **229**, **230**, mounted in the ceiling **231** of the chamber. Valve **299**, for example, includes a closure element which is shown in the closed or obturating position and which may be raised to the open position by an eye **232** when engaged by the hook of an overhead traveling crane device generally identified at **233**. Likewise, valve **230**, shown in the open position, may be similarly actuated between its open and closed adjustments, by crane device **234**. In FIG. **4** the lower end of pipe **198** is shown partly filled with fragments and powder. In operation both valves like **229**, **230** are normally closed. When that one of the pipes such as **198** or **190**, presently in communication with spout **192***b*, has been substantially filled with fragments and detritus, distributor casing **192** is rotated to an unfilled pipe as previously explained. The valve of the pipe presently containing a charge of fragments is then opened and the contents gravitate into the corresponding one of perforated containers such as **235** for valve **229**, and **236** for valve **230**, where they may be treated with solvent and the solution passed to tank **227**.

It is of particular interest to note that the apparatus inhibits the spread of radio-active dust. For example, during the shearing of an element **1** within shear mechanism **146**, FIG. **19**, the end of tube **139** contiguous to table **114**, is completely obturated by plate **133**. A packing gland is provided in this plate, through which rod **136** slides. Hence dust resulting from shearing of the cartridge tubes **5** is prevented from passing out of tube **139** into enclosure **34** and all parts within the enclosure are protected from contamination.

In prior art procedure the panniers are in the form of perforated baskets each provided with a disposable or consumable lining of thin sheet steel about 0.01 inch in thickness. The liners are necessary to prevent radioactive dust and detritus from the sheared fragments of the nuclear fuel cartridges, from escaping through the interstices of the basket and thus creating a hazard in surrounding areas. On the other hand, each basket with its liner is deposited, full of fragments, into the usual bath such as nitric acid, so that before the acid can reach and act upon the spent fuel, it must first dissolve the liner. The baskets remain substantially unaffected by the acid.

But this has two principal disadvantages. Firstly, it prolongs the operation since substantial time is required for the acid to consume or dissolve the metal liner. Secondly, the metal of the liner which is dissolved by the acid, pollutes the bath, reduces its effective life, and complicates subsequent treatment in recovery of the reconditioned nuclear fuel.

As will be understood from the preceding description, the present invention eliminates the necessity for pannier or basket linings because the fragmented cartridges and dust and detritus therefrom are entirely enclosed from the time they are formed in the shear mechanism of FIGS. **19**, **20** and **21**, until the acculations thereof in pipe **198**, FIG. **4**, for example, are released by operation of valve **229**, for gravity flow into the perforate pannier or basket **235**, wherein they are directly and immediately contacted by acid, and dissolved.

Hence the present invention acts to speed up the dissolving of the nuclear fuel. It conserves material by confining dust and powder against escape to surrounding areas, and by eliminating the need for liners for the panniers; and it materially prolongs the useful like and effectiveness of the acid bath.

While I have disclosed the form of my invention presently preferred, the disclosure should be taken in an illustrative rather than in a limiting sense. Numerous changes in shape, size, disposition and relation of parts, substitution of equivalents, sequences of operations, and other alterations and modification, will readily occur to those skilled in the art, after a study of the foregoing description. It is therefore my desire and intention to reserve all changes within the scope of the subjoined claims.

Having fully disclosed the invention, what I claim and desire to secure by Letters Patent is:

1. The method of fragmenting spent nuclear fuel elements, each comprising a bundle of metallic tubes secured together in side by side relation and containing nuclear fuel, and including first and second inert end portions each attached to a respective end of the bundle of tubes thereof, said method comprising, advancing each element horizontally in the direction normal to the length of the tubes thereof, to and between spaced cutters, to simultaneously sever said inert end portions, and subsequently advancing each element step by step in the direction of the length of the tubes thereof, to project the ends of the tubes past a fixed plane normal to their lengths, and after each said step shearing off as a unit, in said plane, that portion of the tubes projecting past said plane, to form fragments.

2. The method of claim **1**, each said cutter being translatable in and along a line extending from one cutter to the other, separating the cutters along said line to freely receive an element between them, positioning an element between the cutters, moving the cutters toward each other along said line, to contact an abutment of each with a respective end of the element, and operating the cutters to sever the inert ends of the element.

3. The method of claim **2**, transferring the element, sans inert ends, to a table, and translating the element in the direction of the length of the tubes thereof, toward said plane.

4. In an apparatus for fragmenting spent nuclear fuel elements, each comprising a bundle of tubes secured together in side-by-side coextensive relation and containing nuclear fuel, a casing comprising top, bottom, side and end walls secured together along their meeting edges, there being an opening in and through one said side wall, a clamp member mounted in said casing for guided translation contiguous to said one side wall, from a first position obturating said opening, to a second position free of said opening, a shear, means mounting said shear in said casing for guided translation contiguous to said clamp member, to shear the ends of tubes of an element projecting through said opening and held by said clamp member when moved to its said first position, and power operated means for selectively and individually translating said clamp member and said shear.

5. The apparatus of claim **4**, a protective wall, means securing one end wall of said casing to said protective wall, said power operated means comprising first and second power cylinders fixed with and extending from said protective wall on the side thereof opposite to said casing, first and second pistons each slidably fitting a respective one of said cylinders, first and second tubular piston rods each fixed with a respective one of said pistons and projecting through said protective wall into said casing, and a detachable connection between the end of each said first and second piston rod within said casing, and said clamp member and shear, respectively.

6. The apparatus of claim **5**, the top wall of said casing being removable secured, said clamp member and said shear being liftable directly out of said casing as discrete units, when said top wall is removed and said connections are detached.

7. The apparatus of claim **5**, a mounting plate secured to said protective wall on the side thereof opposite said casing, each said cylinder having an end threaded into an opening in said mounting plate and comprising a central hollow sleeve open at its end remote from the plate, each said detachable connection comprising a headed machine screw extending through an opening in the end of its hollow piston rod and threadedly engaging said clamp member and shear, respectively, each said screw being removable and replaceable in and through the hollow sleeve of its cylinder, from the side of said protective wall opposite to said casing.

8. The apparatus of claim **4**, means for horizontally supporting an element exteriorly of said casing, and operable to advance an element thereon, step by step in the direction of the length of its tubes, through said opening and into said casing.

9. The apparatus of claim **8**, said last-named means including a support tube disposed horizontally with one end in registration with said opening, first and second obturator plates each movable between a first position obturating a respective end of said support tube, and a second position clear of the ends thereof, means connected with said plates and operable to selectively and individually move each between its said first and second positions, said first obturator plate having a central aperture therein, a push rod extending through said central aperture and slidable in the direction of its length and axially of and along said support tube when said first obturator plate is in first position, and means connected with said rod for axially sliding the same to engage an end thereof with a nuclear element in said support tube, and thereby advance the same in and along said support tube while said first obturator plate in its first and obturating position.

10. The apparatus of claim **9**, a table including a surface for supporting an element thereon, said first obturator plate and rod being mounted to said table surface for guided translation relatively thereto, and means connected with the surface of said table for vertically moving said obturator plate and push rod between the first and second positions of said first obturator plate.

11. The apparatus of claim **4**, there being an opening in said bottom wall through which fragments from said shear fall, a distributor mounted below the level of said casing, conduit means receiving fragments from said opening and conducting the same into said distributor, and a plurality of accumulation pipes extending downwardly from said distributor, said distributor comprising a casing rotatable to direct fragments flowing from said conduit means, to any selected one of said pipes.

12. The apparatus of claim **11**, said distributor casing being rotatable about a fixed vertical axis and translatable along said axis, and including a downspout radially offset from said axis, said downspout being insertable into the upper end of any selected one of said pipes, by and in response to translation and rotation of said distributor casing along and about said axis, first means operable to translate said distributor casing between a first position wherein said downspout is within the end of a selected one of said pipes, and a second position free of said pipes, and second means operable to rotate said distributor casing about said axis when the same is in its said second position of translation.

13. The apparatus of claim **12**, said second means comprising a ring gear fixed with said distributor casing, coaxially about said axis, and a pinion meshing with said gear, said first means comprising a shift element slidably contacting said gear, means supporting said shift element for guided vertical translation only, parallel with said axis and including a vertical shaft extending upwardly coincident with said axis, and means

remote from said distributor casing for selectively and individually rotating said pinion and translating said vertical shaft along said axis.

14. The apparatus of claim 13, said distributor casing having an open top, a cover member fixed over and closing said open top, said conduit means terminating at its lower end within a hole in said cover member, and liquid seal means between said cover member and distributor casing.

15. The apparatus of claim 13, a casing support comprising a fixed cylindrical shell extending about and enclosing said distributor casing, and including a bottom wall having perforations circumferentially spaced about said axis, the upper terminal of each said pipe being in registration with a respective one of said perforations, said downspout being engageable in any selected one of said perforations in response to rotation of said distributor casing, means fixed with said casing support and forming a container coaxially about said axis, sealing liquid in said container, and a skirt integral with said distributor casing and dipping into said liquid for all positions of vertical adjustment of said distributor casing.

16. In apparatus for the processing of spent nuclear fuel elements each comprising tubular means containing nuclear fuel, and first and second inert ends fixed with respective ends of the tubular means, support means for receiving and horizontally translating each said element in a first direction normal to its length, first and second band saws horizontally spaced in a plane normal to said first direction and in the path of movement of an element supported on and translated by said support means, each said saw having a blade movable in said plane, said band saws being constructed and arranged to sever the inert ends of an element, by and in response to translation thereof on and with said support means, means mounting each said saw for individual guided translation in the direction of length of an element on said support means, abutment means adjustably fixed with each said saw, for engagement with respective inert ends of an element on said support means, shielding walls forming a chamber enclosing said apparatus, and means operable externally of said walls for individually and selectively translating said saws toward and from each other.

17. In apparatus for the processing of spent nuclear fuel elements each comprising tubular means containing nuclear fuel, and first and second inert ends fixed with respective ends of the tubular means, a carriage for receiving and horizontally moving each said element in guided translation in a first direction normal to its length, first and second cutting devices horizontally spaced in a plane normal to said first direction and in the path of movement of an element supported on and translated by said carriage, said cutting devices being constructed and arranged to sever the inert ends of an element, by and in response to translation thereof on and with said carriage, said carriage including a plurality of depending supports spaced in a second direction normal to said first direction, each said support terminating in a horizontally directed arm, the coplanar upper surfaces of said arms extending in said first direction and conjointly supporting an element thereon, and shielding walls forming a chamber enclosing said apparatus.

18. The apparatus of claim 17, first reversible power means mounted exteriorly of said chamber, and operating connections between said first power means and said carriage to translate the same horizontally.

19. The apparatus of claim 17, said support means comprising first and second spaced parallel horizontal tracks extending in said first direction in said chamber, first and second parallel beams spanning the distance between said tracks, plate means interconnecting said beams at their ends and mounting the same on said tracks for rolling guided translation only therealong in said first direction, first and second threaded shafts each journaled for rotation contiguous to and parallel with a respective one of said tracks, each said shaft threadedly engaging a respective one of said plate means, a motor mounted exteriorly of said chamber, and a mechanical connection from said motor to each said threaded shaft to synchronously rotate said shafts.

20. The apparatus of claim 19, said support means also comprising first, second and third sleeves each surrounding said beams and spaced therealong in the order mentioned, at least said first and third sleeves being adjustable along said beams, each said sleeve having a respective one of said supports fixed therewith and depending therefrom, and means releasably fixing at least said first and third sleeves in a selected position of adjustment on and along said beams.

21. The apparatus of claim 20, each said sleeve being movable vertically for limited distance with respect to said beams, said last-named means comprising studs on one said beam, in spaced relation therealong, each said sleeve having an aperture positioned to seat over any selected one of a number of said studs, and means carried by each said sleeve and operable to releasably clamp the same to said beams with an aperture thereof fitting a selected one of said studs.

22. The apparatus of claim 17, there being a storage vault below said chamber, inclined track means extending in and upwardly along a passageway from said vault to and through an opening in the floor of said chamber, a truck mounted for translation on and along said track means in a vertical plane parallel with said first direction, from a first position within said vault, to a second position within said chamber, said truck having elevated portions defining horizontally coplanar upper surfaces for supporting an element thereon, said surfaces being spaced in a direction normal to said plane, said portiona defining transverse channels between them, spaced to receive a respective one of said horizontally directed arms when said truck is in its said second position, and said carriage is in an initial position remote from said cutting devices, a motor, and driving connections between said motor and truck to move the same on and along said track means from said first to said second position.

23. The apparatus of claim 22, a stand located in said vault contiguous to the terminal of said track means therein, a cradle adapted to receive and hold an element to be fragmented, means mounting said cradle on said stand for pivotal movement from an inclined position to a horizontal position, to correspondingly angularly move an element supported thereon, power means on said stand and operable to pivot said cradle between its said positions, and transfer means carried by said stand and vertically movable relatively thereto, to engage and elevate an element horizontally supported by said cradle, said truck being movable beneath an element so elevated, to support the same in response to lowering of said transfer means.

24. The apparatus of claim 23, and means in said vault to pick up an element vertically stored therein and to transport the same for deposit in said cradle.

25. In apparatus for the processing of spent nuclear fuel elements each comprising a plurality of tubes secured together in side-by-side relation and containing nuclear fuel, and first and second inert ends fixed with respective ends of the tubes, support means for receiving and horizontally translating each said element in a first direction normal to its length, first and second cutting devices horizontally spaced in a plane normal to said first direction and in the path of movement of an element supported thereon and translated thereby, said cutting devices being constructed and arranged to sever the inert ends of an element by and in response to translation thereof on and with said support means, shielding walls forming a chamber enclosing said apparatus, a horizontal table in said chamber and spaced in said first direction from said cutting devices, said support means in continued motion past said cutting devices being effective to deposit an element onto said table, a tube in said chamber having one end adjacent said table and disposed horizontally in a vertical plane through said table and normal to said first direction, shear means adjacent to the other end of said tube, and abutment means carried by said table and operable to advance an element thereon into said tube, and step by step from said tube into said shear means.

26. Apparatus for the fragmentation of spent nuclear fuel elements each comprising a plurality of tubes secured together in side-by-said relation and containing nuclear fuel, a table having a surface for supporting a nuclear element horizontally

thereon, means mounting said surface for controlled translation vertically between a first lowered position and a second elevated position, a tubular push bar mounted in said surface for longitudinal translation relatively thereto, to engage one end of an element supported on said table surface and to correspondingly translate the same in the direction of its length on and relatively to said surface, means connected with said table and operable to individually and selectively translate said surface vertically between first and second positions, and said push bar longitudinally on and along said surface, a tube horizontally mounted in the direction of longitudinal translation of said push bar, with one end adjacent said table and, when said surface is in its said second position, to receive an element from said table in response to translation of said push bar, an obturator plate having a central aperture, a push rod extending through said aperture, means mounting said plate and rod, below and parallel with said surface for individual translation in said direction, means operably connected with said obturator plate to translate the same when said table surface is in its said first position, from a position free of the contiguous end of said tube, to a position obturating said end, means connected with said plate and rod to positively, individually and selectively move said rod through said aperture and thereby advance an element in said tube step by step out of the end of said tube remote from said obturator plate, said obturator plate and rod being below the level of said tube when said surface is in its said first position, a casing connected with and in communication with the end of said tube remote from said obturator plate, and into which an element in said tube may be advanced by selective operation of said rod, a shear, means mounting said shear in said casing for movement to sever an end of an element projecting from said tube into said casing, and first power means connected with said shear and operable to move the same in shearing motion.

27. The apparatus of claim **26**, clamp means in said casing, between said shear and tube, and operable to clamp to said casing the end of an element projecting thereinto, and second power means to move the clamp means between a first position free of the end of an element projecting from said tube into said casing, and a second position clamping said element to said casing.

28. The apparatus of claim **27**, said shear and said clamp means being translatable in said casing in side-by-side parallelism, a protective wall, a support plate, means securing said casing and support plate as a unit to respectively opposite sides of said wall, said first power means comprising a first cylinder threaded into an aperture in said support plate, exteriorly of said wall, a piston slidably fitting said first cylinder, a rod attached at its ends to said piston and shear, respectively, said piston and rod having a central longitudinal passageway and said cylinder having a central axial sleeve fixed therewith and extending into and along said passageway, and screw-threaded means connecting said piston and shear, and removable and replaceable through said sleeve from the exterior side of said wall.

29. The method of fragmenting spent nuclear fuel elements comprising tube means containing nuclear fuel, and first and second inert end portions each attached to a respective end of the tube means, said method comprising advancing the tube means in the direction normal to its length to and between spaced cutters to simultaneously sever said inert end portions, subsequently advancing said tube means step by step in the direction of its length to project an end thereof past a fixed plane normal to its length, and after each said step shearing off as a unit, in said plane, that portion of the tube means projecting past said plane, to form fragments.

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