PATENT SPECIFICATION

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(54) SYSTEM FOR ASSEMBLING NUCLEAR FUEL ELEMENTS

(71) We, WESTINGHOUSE ELECTRIC CORPORATION, of Westinghouse Building, Gateway Center, Pittsburgh, Pennsylvania, United States of America, a company organised and existing under the laws of the Commonwealth of Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the assembly of nuclear fuel elements and particularly to the automatic assembly of nuclear fuel elements employing mixed oxide fuels.

In many designs of nuclear reactors, the reactor vessel has an inlet and an outlet for circulation of a coolant in heat transfer relationship with a core contained therein that produces heat. The core comprises an array or arrays of fuel assemblies which contain fuel elements. The fuel element is generally a cylindrical metallic sheath sealed at both ends containing nuclear fuel. The nuclear fuel which may be, for example, ceramic fuel pellets of a uranium compound is stacked in the fuel elements. During reactor operation, the nuclear fuel pellets decompose releasing fission products such as fission gas while generating heat in a manner well known in the art. The reactor coolant absorbs the heat while circulating through the core thereby cooling the fuel elements of the core and heating the coolant. Of course, the heated coolant may then be used to produce power in a conventional manner.

There are several methods known in the art for loading uranium fuel pellets into the cylindrical metallic sheath for use in a light water reactor. One such method comprises simply placing the fuel pellets in the metallic sheath by hand. This method is possible because non-irradiated uranium fuel does not pose serious radiological problems to working personnel. However, when the nuclear fuel utilized is of a more toxic nature such as plutonium or a reprocessed uranium compound, then increased safeguards must be employed to prevent releasing radioactive contaminants to the atmosphere and to prevent overexposing working personnel. When such toxic fuel is employed, it is known in the art to use glove box handling techniques to load the fuel pellets into the metallic sheath.

Typical glove box handling procedure first requires transferring the nuclear fuel pellets in a sealed container into the glove box and then firmly sealing the glove box. Once placed in the glove box, the sealed container may then be opened by manual gloved manipulation. The fuel pellets may then be loaded into a metallic sheath either totally enclosed within the glove box, or with its open end sealed into a glove box through a plastic membrane. When the metallic sheath has thus been filled to the proper level with fuel pellets, the fuel element must then be placed in a sealed container or its contaminated open end sealed off in order to be moved to the next glove box where the next procedure can be performed such as welding the end plug on the metallic sheath. The process of transferring the material and components from one glove box to the next can be quite time consuming and thus renders such procedures unacceptable from a mass production standpoint.

An example of an arrangement for transferring nuclear fuel elements into a glove box enclosure is described in U.S. Patent No. 3,711,993 to J. Liesch et al, issued January 23, 1973. The Liesch patent discloses a cylindrical chamber disposed in an isolation wall between a contaminated and an uncontaminated area for providing a passageway therebetween. The chamber is enclosed between a pair of shutters with variable apertures that allow the passage of a nuclear fuel element therethrough. The chamber may be flushed or purged with a gas so as to entrain contaminated particles in the gas which may then be conducted through a filter located remote from the chamber thereby trapping the contaminated particles in the filter. The patent to Liesch indicates that such a filter may be of the electrostatic or activated carbon type. While the Liesch patent describes a particular arrangement for transferring a nuclear fuel element into or out of a glove box type enclosure, it along with the other prior art does not solve the problem of automatically transferring nuclear fuel elements between assembly stations on a mass production basis without releasing contaminants into the atmosphere.

It is therefore the principal object of this invention to provide a system for automated assembly of nuclear fuel elements, which system includes a mechanism which permits movement during assembly of a fuel element along the assembly stations without excessive release of contaminants.

With this object in view, the present invention resides in a system for assembling nuclear fuel elements in which nuclear fuel element sheaths open at one of their ends pass from assembly station to assembly station comprising at least a fuel pellet load station containing fuel pellet loading apparatus for loading fuel pellets into the open ends of said fuel element sheaths, a plug insertion station arranged near said fuel pellet load station and containing end plugs for inserting said end plugs into the open ends of said fuel element sheaths, welding apparatus for welding said plugs into said fuel element sheaths to seal said fuel pellets in said fuel element sheaths thereby forming said fuel elements, sealing means associated with said assembly stations for sealing off said fuel element sheaths while they extend into said assembly stations, and transport means for transporting said fuel element sheaths from assembly station to assembly station, characterized in that said assembly stations are interconnected by an elongated seal housing having an opening along one side for receiving one end of each of the fuel element sheaths and permitting movement of said fuel element sheaths from one to the next assembly station with their one to the next assembly station with their one ends remaining within seal housing, said seal housing having seals arranged at said opening which seals are deformable to extend around any fuel element sheaths inserted into said opening for closing said opening so as to limit release of radioactive contaminants from within said assembly stations.

The invention will become more readily apparent from the following description of a preferred embodiment thereof shown, by way of example only, in the accompanying drawings, wherein:

Figure 1 is a plan view of the automated system;

Figure 2 is a view in perspective of the assembly portion of the system;

Figure 3 is a view in perspective of the entry portion of the system;

Figure 4 is a cross-sectional view of the sealing mechanism;

Figure 5 is a partial view in perspective of the sealing mechanism; and

Figure 6 is an end view in elevation of the assembly.

Referring to Figures 1, 2 and 3, a load station 10, decontamination station 12, plug station 14, first check station 16, weld station 18, and second check station 20 are arranged along a long horizontal sealing mechanism 22 such that the open end of each station may be connected to sealing mechanism 22 in a fluid-tight fashion. A transport mechanism 24 is arranged adjacent to sealing mechanism 22 so that fuel element sheaths 26 may be supported thereon in a horizontal attitude with the open ends of fuel element sheaths 26 extending through sealing mechanism 22 and into the several assembly stations such as load station 10. Transport mechanism 24 is capable of automatically advancing fuel element sheath 26 from load station 10 to second check station 20 while the fuel element sheaths 26 remain in a horizontal position so that the internals may be placed in fuel element sheaths 26.

Referring now to Figures 4 and 5, sealing mechanism 22 includes a housing 28 which is attached to the walls of the various assembly stations such as load station 10. A series of end plates 30 are attached to the end of housing 28 near transport mechanism 24 while the other end of housing 28, that extends into the assembly station, is formed in a slot configuration 32. Slot configuration 32 establishes a small cross-sectional area with respect to the assembly station and thereby limits the outward flow of particles from the assembly station. Two elongated inflatable seals 34 are attached to housing 28 in slot configuration 32 so as to oppose each other and extend the length of sealing mechanism 22. Pressurised gas supply means 36 are connected to inflatable seals 34 so that inflatable seals 34 may be inflated and expanded into close contact with each other thereby closing the entrance to housing 28 and thus limiting the escape of particles from within the assembly station. Inflatable seals 34 are chosen from suitable material such that when a fuel element sheath 26 extends between the inflated seals, the inflated seals substantially conform to the curvature of fuel element sheath 26 thereby closing the entrance to housing 28. In addition, the pressure inside the assembly stations such as load station 10 is maintained lower than the pressure in the room that contains transport mechanism 24 so that any flow of air through sealing mechanism 22 will be inwardly toward the assembly stations. This positive inflow of air further limits any containing particles from migrating out from within the assembly stations.

Still referring to Figures 4 and 5, an electrostatic seal 38 is disposed in housing 28 at the end opposite inflatable seals 34 and extends the length of sealing mechanism 22. Electrostatic seal 38 comprises arays of individual electrostatic precipitator cells 40 which may be manufactured of aluminum located above and below an open slot 42 through which fuel element sheath 26 extends. Precipitator cells 40 are in the form of rectangular metal boxes having dimensions of approximately 2.5 cm x 2.5 cm x 15 cm. The side 44 of each precipitator cell 40 facing open slot 42 is open so that air can freely move into and out of precipitator cell 40. A series of 3.2 mm diameter metal rods 46 are spaced apart and arranged transverse to precipitator cells 40 thereby forming a protective shield which will prevent large objects from açcidentally falling into precipitator cells 40 while allowing air to move freely thereacross. End plates 30 which may be manufactured from an insulating material serve as insulating supports for electrodes 48 which are attached thereto by common means. Common electrical leads (not shown) may be attached to electrodes 48 to apply a voltage to electrodes 48. Electrodes 48 are cylindrical high voltage electrodes that support a one inch long tungsten wire 50 on the end thereof opposite end plates 30. When a high d.c. voltage, typically 6—10 kV, is applied to electrodes 48 a corona discharge is produced around the tip of tungsten wire 50. As a result of the corona discharge, a region of high electrostatic space charge is produced at the end of precipitator cell 40 near tungsten wire 50. Any airborne particulate matter that flows through this region becomes electrostatically charged and is attracted to the metal walls of the precipitator cells 40 or to rods 46 and is thereby deposited out of the air stream. While the bulk air stream is maintained inwardly through open slot 42 and into the assembly stations due to pressure differences, back stream diffusion of particles opposite to this bulk flow may occur due to differences in concentration of particles in the assembly stations and in the area outside sealing mechanism 22. Thus, if particulates such as nuclear fuel dust, tend to flow in reverse direction to the bulk air flow, the particulates have a high probability of entering the precipitator cells 40 and becoming captured therein or on rods 46. Tests conducted on a small precipitator arrangement similar to the one described herein indicated that the probabilities of capture for particles in the size range 0.3 to 1.0 microns and 1.0 to greater than 10.0 microns are approximately 98.5% and 99.8% respectively, for flow velocities up to approximately 150 ft/min. Once the open end of a fuel element sheath 26 has been positioned in an assembly station such as load station 10, the inflatable seals 34 may be inflated thereby closing the end of slot configuration 32. Should the inflatable seals 34 not close perfectly around the fuel element sheath 26, the constant inward flow of air will limit leakage through any gaps between the seals and fuel element sheaths. Furthermore, should any particulate contamination diffuse in a reverse manner to the bulk air flow, the electrostatic seal 38 will further limit escape of such contaminants. When the process is completed, the inflatable seals 34 are deflated and the transport mechanism 24 advances the fuel element sheath 26 to the next assembly station while the open end of the fuel element remains within sealing mechanism 22. During such movement of the fuel element sheath 26 when the inflatable seals 34 are deflated, the inflow of air together with the electrostatic seal 38 and slot configuration 32 sufficiently limit the escape of contaminants.

The transport mechanism 24 includes structural members 52 for its support. Pneumatic holding members 54 having grooves 56 conforming to the curvature of a fuel element sheath are disposed at several loctions in line with load station 10 for holding several fuel element sheaths 26 such that the open end of fuel element sheath 26 extends through sealing mechanism 22 while the remainder of the fuel element including the sealed end is supported by pneumatic holding members 54. The open end of an uncontaminated fuel element sheath 26 may be inserted through opening 58 of sealing mechanism 22 while the fuel element sheath rests on pneumatic holding members 54. A vacuum pump (not shown) is connected to each pneumatic holding member 54 by vacuum line 60. Vacuum line 60 extends through pneumatic holding member 54 to the underside of grooves 56 so that when fuel element sheaths are placed in grooves 56 the vacuum pump may be activated thereby creating a suction in grooves 56 and thus holding the fuel element sheaths firmly in place. Roller chain members 62 which may consist of attachments for the fuel element sheaths that are attached to a roller driven chain are disposed between pneumatic holding members 54 so as to further support the fuel element sheaths and, when activated, are capable of advancing the fuel element sheaths. Roller chain member

62 has a first end 64 and a second end 68 that rest on a horizontal bar 66 with both ends being movably connected to structural members 52. Horizontal bar 66 is supported thereunder by lifting mechanisms 70 which may be a mechanical-pneumatic piston arrangement. When the vacuum pump (not shown) is deactivated which thereby enables the fuel element sheath to be released from grooves 56, then lifting mechanism 70 may be activated which raises horizontal bar 66 which in turn raises roller chain members 62. This action causes roller chain members 62 to be raised slightly higher than pneumatic holding members 54 which causes the fuel elements thereon to be lifted out of grooves 56. Roller chain members 62 may then be activated which moves each fuel element sheath toward second end 68 and onto first ramps 72. Several fuel element sheaths may be collected on first ramps 72.

A conveyor 74 is supported by structural members 52 and arranged adjacent to first ramps 72 to carry fuel element sheaths 26 from first ramps 72 to second ramps 76 located near the end of the assembly station line. Conveyor 74 has holders 78 disposed thereon that are capable of holding a fuel element sheath during transport on conveyor 74. As conveyor 74 operates, holders 78 grasp the lowermost fuel element sheath 26 on first ramps 72 and carry the fuel element sheath until the conveyor 74 is stopped. A control mechanism (not shown) may be chosen from those well known in the art that is capable of stopping conveyor 74 at appropriate locations so that the fuel element sheath becomes aligned with the proper assembly station. Several grapple mechanisms 80 are located at locations corresponding to the assembly stations that are capable of firmly grasping a fuel element sheath so that an assembly process may be performed. Grapple mechanisms 80 may have articulated arms 82 that are capable of being retracted below the plane of conveyor 74 so that the fuel element sheath may pass above it. However, when conveyor 74 has stopped a fuel element sheath at the proper location, the articulated arems 82 can be extended so as to firmly grasp the fuel element sheath. In addition, grapple mechanism 80 may be equipped to be able to advance the fuel element sheath toward the assembly station thereby increasing the length of fuel element sheath disposed within the assembly station. When the fuel element sheath has been transported to the end of the process, conveyor 74 allows the fuel element sheath to roll down second ramps 76.

OPERATION

Several uncontaminated empty fuel element sheaths 26 are inserted through opening 58 and onto pneumatic holding members 54 by hand. The fuel element sheaths generally may be cylindrical tubes with the top end open and the bottom end sealed. The top end which is open is the end inserted through opening 58 and through sealing mechanism 22 into load station 10. At this point the inflatable seals 34 are deflated so that the fuel element sheaths may be easily inserted through electrostatic seal 38 and between the deflated inflatable seals 34. In this position, the open ends of the fuel element sheaths 26 extend between the deflated inflatable seals 34 and into load station 10. During this part of the process, the electrostatic seals 38 are activated while a flow of air is maintained inwardly, as previously described. At this point, the inflatable seals 34 are inflated thereby tightly contacting the fuel element sheaths 26 and sealing the slot configuration 32. At the same time, the vacuum pump is activated which causes the fuel element sheaths to be held firmly in grooves 56 by a suction action. Load station 10 contains automatic equipment chosen from those well known in the art that is capable of loading nuclear fuel pellets through the open end of the fuel element sheath and stacking the fuel pellets in the fuel element sheath. Because load station 10 contains nuclear fuel pellets which may contain plutonium, it is important that the assembly station be tightly sealed so that contaminants do not leak out into the area of transport mechanism 24 where personnel may become exposed. Load station 10 along with the other stations has glove ports 84 that provide working personnel with access to the inside of the stations. Glove ports 84 may be utilized to repair or arrange the equipment therein. Once the fuel element sheaths have been loaded with fuel pellets, inflatable seals 34 are deflated and the vacuum pump is deactivated. Lifting mechanisms 70 may then be activated which raise horizontal bar 66 and in turn raise roller chain members 62. This action causes roller chain members 62 to be raised slightly higher than pneumatic holding members 54 which causes the fuel element sheaths thereon to be lifted out of grooves 56. Roller chain members 62 may then be activated which causes the fuel element sheaths to be advanced toward second end 68 and onto first ramps 72. The fuel element sheaths are thus collected on first ramps 72 while additional fuel element sheaths are loaded into load station 10 as described above. Since the open ends of the fuel element sheaths were exposed to contaminants while inside the load station 10, it is necessary to maintain those ends within sealing mechanism 22. Between assembly stations, sealing mechanism 22 has a closed back end opposite the end through which the fuel element sheaths extend which thereby maintains the open ends of the fuel element sheaths within a sealed compartment between assembly stations. While the open ends of the fuel element sheaths remain within sealing mechanism 22 and while the remainder of the fuel element sheaths remain on first ramps 72, holders 78 on conveyor 74 engage the fuel element sheath nearest the bottom of first ramps 72 and carry the fuel element sheath to decontamination station 12. At this point, conveyor 74 is stopped and articulated arms 82 are extended thereby firmly grasping the fuel element sheath. Grapple mechanism 80 may then advance the fuel element sheath further into decontamination station 12 so that a greater portion of the fuel element sheath is within decontamination station 12 than was exposed in load station 10. The inflatable seals 34 are then inflated further sealing the decontamination station 12. Automated machinery located in decontamination station 12 and chosen from those well known in the art may then be utilized to clean the portion of the fuel element sheath that is within the station thereby removing contaminants. The inflatable seals 34 are then deflated while grapple mechanism 80 releases the fuel element sheath. Conveyor 74 may then move the fuel element sheath to another location within the same station or move it to the next station which may be plug station 14.

Once properly located within plug station 14, the inflatable seals 34 are inflated and grapple mechanism 80 activated. Following this positioning, the process of plug station 14 may then be performed. The process of plug station 14 may include loading a spring into the fuel element sheath along with other components and tightly fitting a plug into the end of the fuel element sheath. Following the same procedure as described above the fuel element sheath may then be moved to first check station 16 where a contamination check such as an alpha check may be performed on the end of the fuel element sheath using state of the art equipment. The fuel element sheath may then proceed to weld station 18 where the end plug may be welded onto the fuel element sheath. When the end plug has thus been welded on the fuel element sheath, the fuel element may then be removed from sealing mechanism 22 without risking exposure to personnel because the nuclear fuel is tightly sealed in the fuel element. From weld station 18, conveyor 74 moves the fuel element to the end of conveyor 74 and discharges the fuel element onto second ramps 76 where the fuel element rolls down the ramps onto support apparatus 86. Support apparatus 86 serves to position the fuel element and provide a base for second check station 20. Second check station 20 may consist of an automatic alpha check mechanism such as an alpha scintillation counter that may move along the length of the fuel element while being supported by support apparatus 86. During such movement of the alpha check mechanism, support apparatus 86 may rotate the fuel element thereon so that a full length alpha check of the fuel element may be made. Should the full length alpha check prove negative, the support apparatus 86 will release the fuel element thereby allowing the fuel element to roll down the remainder of second ramps 76 into a collection rack 88. When a sufficient number of fuel elements have been collected in collection rack 88, a person may then remove the fuel elements by hand without exposing himself to radiation danger. Of course, the above-described processes are performed concurrently on different fuel elements in the system so as to produce an automated system. The invention, therefore, provides an automated system for assembling nuclear fuel elements having a sealing mechanism whereby a fuel element may be automatically advanced without releasing excessive contaminants.

WHAT WE CLAIM IS:—

1. A system for assembling nuclear fuel elements in which nuclear fuel element sheaths open at one of their ends pass from assembly station to assembly station comprising at least a fuel pellet load station containing fuel pellet loading apparatus for loading fuel pellets into the open ends of said fuel element sheaths, a plug insertion station arranged near said fuel pellet load station and containing end plugs for inserting said end plugs into the open ends of said fuel element sheaths, welding apparatus for welding said plugs into said fuel element sheaths to seal said fuel pellets in said fuel element sheaths thereby forming said fuel elements, sealing means associated with said assembly stations for sealing off said fuel element sheaths while they extend into said assembly stations, and transport means for transporting said fuel element sheaths from assembly station to assembly station, characterized in that said assembly stations are interconnected by an elongated seal housing having an opening along one side for receiving one end of each of the fuel element sheaths and permitting movement of said fuel element sheaths from one to the next assembly station with their one ends remaining within said seal housing, said seal housing having seals arranged at said opening which seals are deformable to extend around any fuel element sheaths

inserted into said opening for closing said opening so as to limit release of radioactive contaminants from within said assembly stations.

2 A system as claimed in claim 1, characterized in that said seals comprise elongated first and second inflatable seal strips attached to the said housing at opposite sides of said opening and extending the length of said housing, said first and second inflatable seal strips being inflatable so as to contact each other for thereby closing said opening, also in that an electrostatic filter structure is disposed in said housing in series with said inflatable seal strips for trapping any particles by electrostatic precipitation.

3. A system as claimed in claim 2, characterized in that said electrostatic filter structure comprises electrostatic precipitator cells and electrodes located along the walls of said housing and protective rods arranged in alignment with said opening defining a passageway for receiving said fuel element sheaths and preventing damage to said electrodes.

4. A system as claimed in claim 1, 2 or 3, characterized in that said transport means comprises a conveyor mechanism arranged adjacent to said seal housing for laterally transporting said fuel elements, holding apparatus disposed on said conveyor mechanism for securing said fuel element sheaths during said transport and grapple mechanisms, arranged near said assembly stations for firmly grasping said fuel element sheaths during an assembly process and for advancing said fuel element sheaths toward said assembly stations thereby adjusting the length of said fuel element sheaths contained within said assembly stations.

5. A system for assembling nuclear fuel elements substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

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FIG.1.

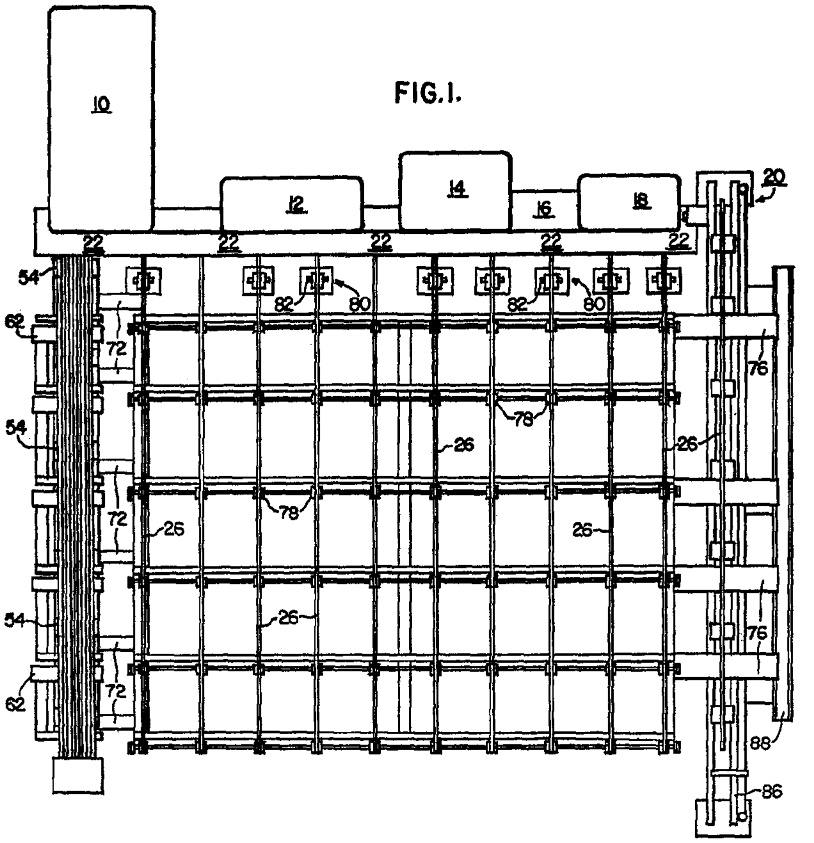
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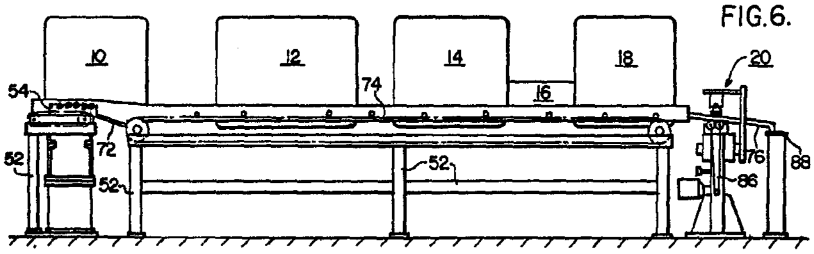
FIG.6.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1567109 COMPLETE SPECIFICATION

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Sheet 2

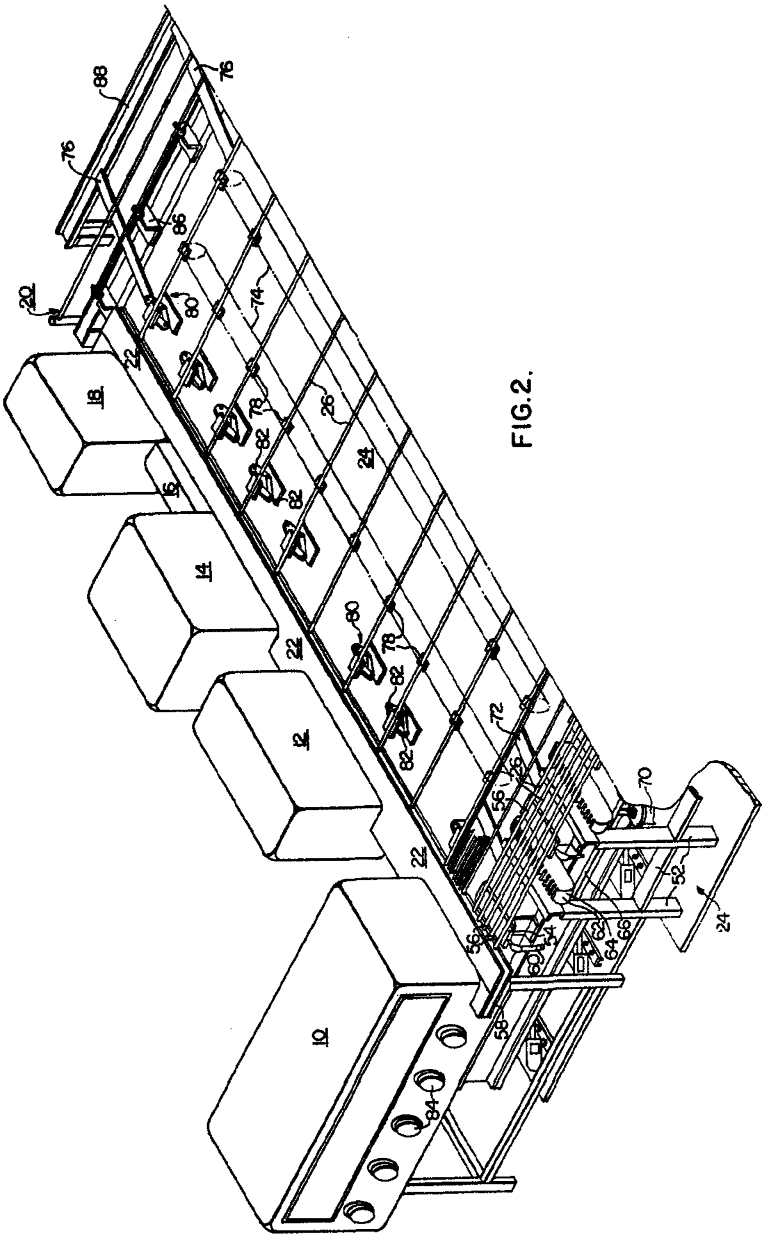

FIG.2.

1567109 COMPLETE SPECIFICATION

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Sheet 3

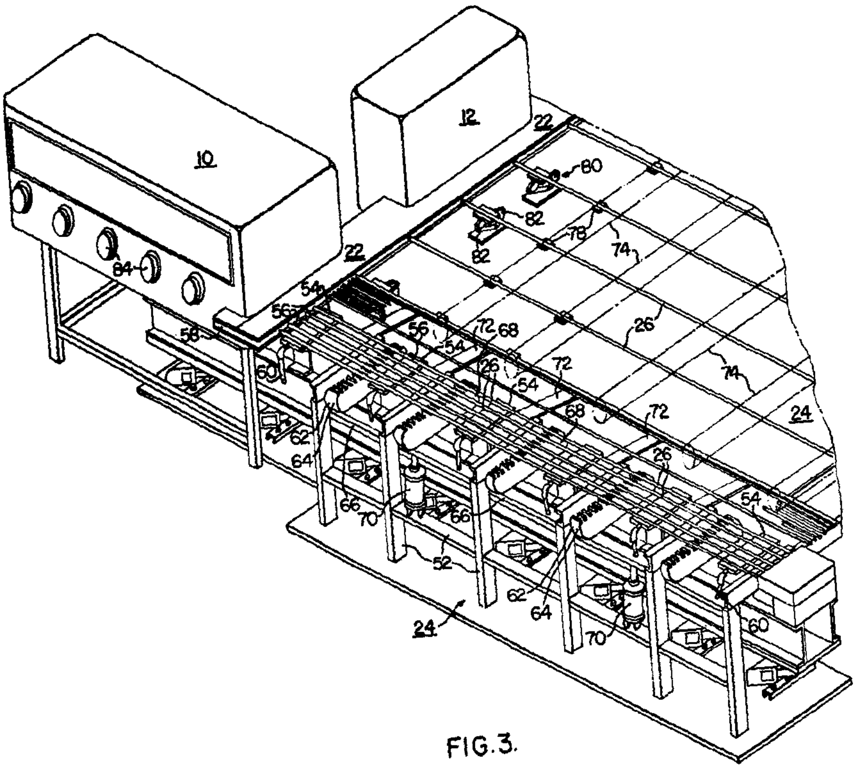

FIG.3.

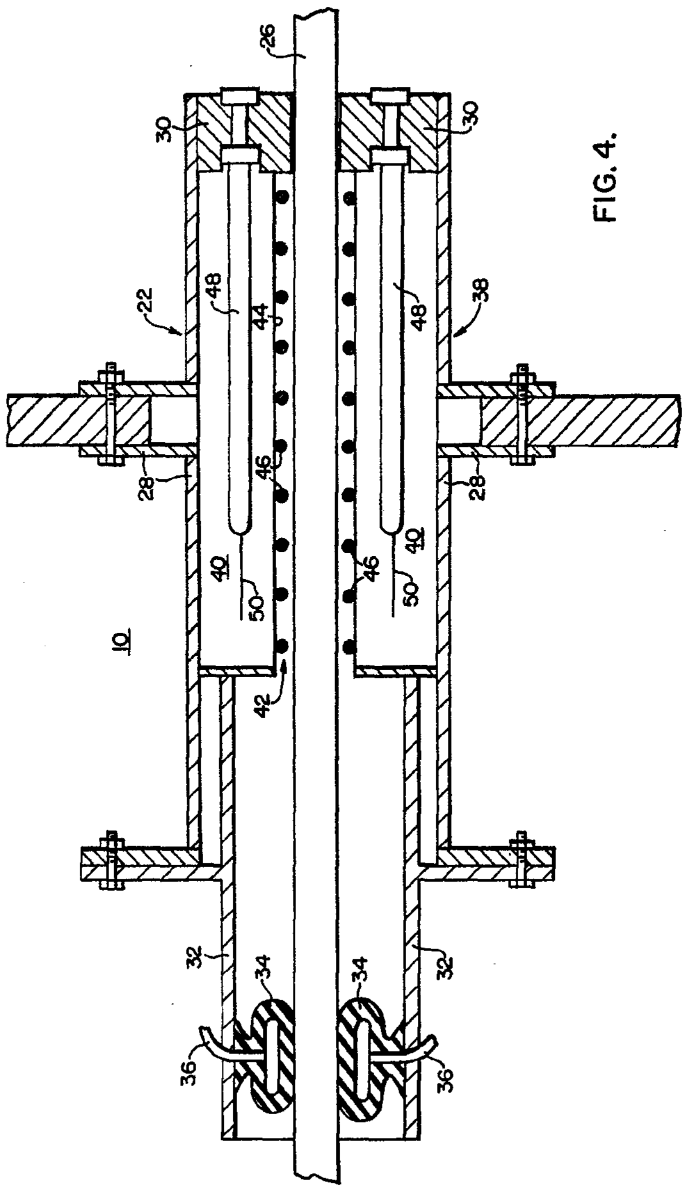

FIG. 4.

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Sheet 5

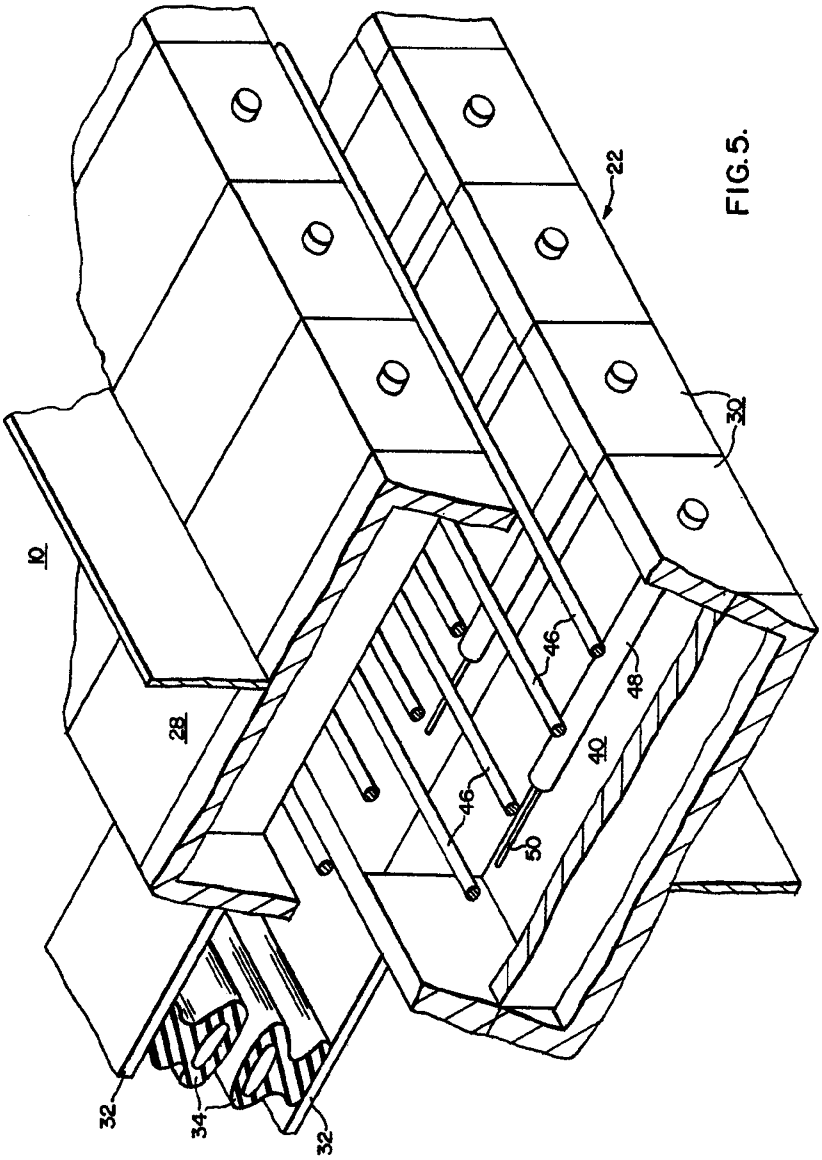

FIG.5.