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(54) IMPROVEMENTS IN OR RELATING TO NUCLEAR REACTORS

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The present invention relates to nuclear reactor complexes and more particularly to refuelling installations for recharging the reactor vessels of such complexes with new fuel assemblies and for removing spent fuel assemblies from the reactor vessel.

According to the present invention there is provided in a nuclear reactor complex, a refuelling installation for recharging the reactor vessel with new fuel assemblies from a first container and for removing spent fuel assemblies from the reactor vessel into a second container, said installation comprising an hemetically sealable chamber communicating through respective sealable openings in its bottom with the reactor vessel, the first container and the second container, a recharging machine comprising a movable platform upon which is mounted a manipulator tube movable vertically relative to the platform, and a grip arranged within and capable of axial movement with respect to the manipulator tube, drive means for moving the movable platform, e manipulator tube and the grip independently of each other whereby movement of the platform, the manipulator tube and the grip in the appropriate sequences is effective to transfer fuel assemblies between said containers and the reactor vessel and movable tank means positionable below the movable platform during its travel between the openings to the nuclear reactor vessel and the second container, such that during the transfer of a spent fuel assembly from the reactor vessel to the second container any liquid reactive coolant running off the spent assembly is collected in said tank means, a sealed hatch being provided in the sealed chamber for the entry and removal of the tank means.

The invention will now be particularly described by way of example with reference to the accompanying diagrammatic drawings, wherein:

Figure 1 is a side elevation of a portion of a nuclear reactor complex including a refuelling installation;

Figure 2 is a section on line II-II of Figure 1;

Figure 3 is a view of Section A of Figure 1 to an enlarged scale, showing hingedly coupled cars;

Figure 4 is a section on line IV-IV of Figure 3;

Figure 5 is a view from below of a hingedly coupled car shown in Figure 3;

Figure 6 is a view similar to that of part of Figure 3 showing a modification of the hingedly coupled cars;

Figure 7 is a side view of the hingedly coupled cars showing a modification of the coupling;

Figure 8 is a side elevation of a portion of the refuelling installation showing the withdrawal of one embodiment of the hingedly coupled cars;

Figure 9 is a view similar to Figure 8 showing a different embodiment of the hingedly coupled cars;

Figure 10 is a cross section through a container holding the hingedly coupled cars after their withdrawal from the nuclear reactor;

Figure 11 is a side elevation similar to Figure 1 showing a different arrangement of the parts; and

Figure 12 is a side elevation similar to a portion of Figures 1 and 11 showing a further arrangement of the parts.

The illustrated refuelling installation of a nuclear reactor complex comprises a hermetically sealed chamber 1 (Figure 1) of a material which provides a biological shield to protect personnel from radiation. On the bottom 2 of the chamber 1 is a recharging machine 3 having a movable platform 4 on wheels 5 which run along rails 6 placed on the bottom 2. The platform 4 is driven by a drive shaft 7 which is coupled through a sealed gear 8 to a driving mechanism 9 located outside the hermetically sealed chamber 1. Channels 10, 11 and 12 are provided opening through the bottom 2 of the hermetically sealed chamber 1. These channels 10, 11 and 12 connect the chamber 1 with an intermediate distribution chamber 13 of a reactor vessel 14, a container 15 for storing spent fuel assemblies 16, and a container 17 for storing new fuel assemblies 18, respectively.

Rigidly mounted on the movable platform 4 is a first reduction gear 19 which serves to support and vertically move a manipulator tube 20 provided at its lower end with a grip 21 for holding new fuel assemblies 18 or spent fuel assemblies 16. The first reduction gear 19 is coupled through a drive shaft 22 and the sealed gear 8 to the driving mechanism 9. This kinematic connection allows the manipulator tube 20 to be moved in the vertical direction by the first reduction gear 19 along guide rollers 23. The grip 21 is movable within the manipulator tube 20 and can be driven in the vertical direction with respect to the manipulator tube 20 by means of a second reduction gear 24, a drive shaft 25, and the sealed gear 8. The hermetically sealed chamber 1 is provided with a lid 26 having holes covered by sealing jackets 27 under which are installed sealing plugs 28 for sealing off the channels 10, 11 and 12. The sealing plugs 28 are manufactured from a material which protects personnel from radiation, and are suspended with the aid of cables 29 from winches 30 housed under the sealed jackets 27.

On the bottom 2 of the hermetically sealed chamber 1 are tanks in the form of cars 32 which are hingedly coupled to one another and can run on wheels 31. The cars 32 are manufactued from a material which is resistant to the effects of high temperatures and the reactor coolant which is a liquid metal. Arranged between the facing end walls of each pair of adjoining cars 12 are overhead covers 33, each constructed, for example as shown in Figure 3, as a bent sheet of a material similar to that of the cars 32, which may be metal. Each overhead cover 33 is mounted (welded, for example) on one of the end walls of each car 32 and spans the gap 34 between adjoining cars 32.

The height of the cars 32 is less than the distance between the bottom 2 and the base of the platform 4, so the cars 32 can pass freely under the platform 4, between its wheels 5. It is possible to position the cars 32 between the channels 10 and 11 and introduce the cars 32 into or withdraw them from the hermetically sealed chamber 1, using very simple means, for example, a hook (not shown in Figure 1). The cars 32 can be introduced or withdrawn from the chamber 1 through a sealable hatch 35 provided in a wall 36 of the chamber 1.

Figure 2 shows the cars 32 positioned between the channel 10 (Figure 1) leading to the intermediate distribution chamber 13 and the channel 11 (Figure 2) leading to the container 15 for storing spent fuel assemblies 16. A third reduction gear 37 is mounted on one side of the movable platform 4 and is arranged to transmit rotary motion from the drive shaft 7 to the third reduction gear 37 to move the platform 4 (Figure 2) along the rails 6.

The train of cars 32 is placed over a guide member 38 formed as an upstanding element extending in the direction indicated by the arrow 39, in which the recharging machine 3 moves between the channels 10 (Figure 1) and 11.

Figure 3 illustrates one embodiment of the coupling between cars 32 in the train, this embodiment comprising a hinge unit 40. Overhead covers 33 span the gap 34 between adjoining cars 32. Under each car 32 between the wheels 31, is fixed (for example by welding) a channel member 41 which acts as a guide means by receiving the guide member 38 upstanding from the bottom 2 of the hermetically sealed chamber 1 (Figure 1). The wheels 31 (Figure 4) of the cars 32 are in fact bearings rotatably mounted on axles 42 which are rigidly secured to the undersides of the cars 32. The wheels 31 run directly on the chamber bottom 2. The lateral positionings of the cars 32 in the train is determined by the upstanding guide member 38, which is aligned with the path (indicated by arrow 39, Figure 2) followed by the recharging machine 3.

Each hinge unit 40 comprises a hool 43 inserted through an eyebar 44 (Figure 5). Hinged coupling of the cars 32 to one another means that the train of cars 32 can

assume any shape and thus follows the path of the recharging machine irrespective of the meanderings of this path. Figure 6 shows a modification of the overhead covers 33 spanning the gap 34 between the cars 32, in which the overhead covers 33 are constructed as arched braces and are attached to two facing end walls of adjacent cars 32.

Figure 7 shows another way in which the cars 32 can be combined into a train. Two pulleys, an upper pulley 46 and a lower pulley 47, are rotatably mounted on axles 45 on each side wall of each car 32. The like pulleys of adjacent cars 32 are coupled by flexible cables 48, all of equal length and having a loop 49 at each end.

For a train of cars 32 connected in the manner shown in Figure 7, the hatch 35 through which the cars 32 can be withdrawn from the hermetically sealed chamber 1, can be provided in the lid 26 of the hermetically sealed chamber 1 (Figure 8). In this case, hoisting hooks 51 are rigidly fixed to a carrier car 50 provided at an end of the train, and cables 52 of a hoisting means (not shown in Figure 8) are attached to these hooks 51.

Figure 9 also shows a train of cars 32, as it is being withdrawn from the hermetically sealed chamber 1 through the hatch 35 in the chamber lid 26. According to this embodiment, the hoisting hooks 51 are mounted on a carrier car 50 in the middle of the train of cars 32. The length of this carrier car 50 is at least double that of the cars 32. The carrier car 50 is provided with two pairs of upper pulleys 46 and lower pulleys 47 from which the cars 32 are suspended on flexible cables made, for example, of steel.

Figure 10 is a view of a container 53 arranged to house a train of cars 32 with an elongate carrier car 50 in a compact arrangement. The container 53 had a lid 54 and provides a biological shield against radiation.

The described refuelling installation operate as follows.

At the beginning of a recharging operation, the recharging machine 3 (Figure 11) is in an intermediate position, for example, between the channels 11 and 10 inside the hermitically sealed chamber 1, and the channels 10, 11 and 12 are sealed by the sealing plugs 28. First, the sealing plugs 28 are hauled up by the winches 30 and cables 29 and withdrawn into the sealed jackets 27, whereby the channels 10, 11 and 12 are accessible to the recharging machine 3 (Figure 1). The driving mechanism 9 is then actuated to move the platform 4 of the recharging machine 3 along inside the hermetically sealed chamber 1 by means of the drive shaft 7 and the third reduction gear 37 (Figure 2). The platform 4 (Figure 12) moves along the rails 6 until the axis of the manipulator tube 20, mounted on the platform 4, aligned with the axis of the channel 12 of the container 17 for storing new fuel assemblies 18. At this point, the grip 21 is in its extreme upper position inside said manipulator tube 20. The driving mechanism 9 then moves the grip 21 vertically downwards via the drive shaft 25 and the second reduction gear 24 until it is in its extreme lower position within the manipulator tube 20 (Figure 12).

Next, the driving mechanism 9 lowers the manipulator tube 20 via the drive shaft 22 and the first reduction gear 19 (not shown in Figure 12) until the manipulator tube 20 is inside the channel 12 and the grip 21 is able to take hold of a new fuel assembly 18. The driving mechanism 9 then moves the grip 21 vertically upwards within the manipulator tube 20 via the drive shaft 25 and the second reduction gear 24, so that the grip 21 and the new fuel assembly 18 are drawn into the manipulator tube 20. The tube 20 is next raised to its extreme upper position, thereby leaving the channel 12. The platform 4 is then moved along the rails 6 through the hermetically sealed chamber 1 until the manipulator tube 20 becomes coaxial with the channel 10 (Figure 1) leading to the reactor vessel 14. The manipulator tube 20 and grip 21 are then lowered, and the new fuel assembly 18 is installed in the intermediate distribution chamber 13. The manipulator tube 20 and grip 21 are once again raised in succession into their extreme upper positions. In known manner the fuel assemblies within the chamber 13 are moved until the manipulator tube 20 with the grip 21 are coaxial with a spent fuel assembly 16. By moving the grip 21, the manipulator tube 20 and the movable platform 4, in succession, the spent fuel assembly 16 is transported from the intermediate distribution chamber 13 to the container 15 for storing spent fuel assemblies 16. As the movable platform 4 and the manipulator tube 20 with the spent fuel assembly 16 inside it move along the path 39 (Figure 2) between the channels 10 and 11, any coolant (i.e. molten metal) retained on the spent fuel assembly 16 trickles off into the cars 32 on the bottom 2 of the hermetically sealed chamber 1. Some of the coolant will drop on the overhead covers 33 and will run down the covers 33 into the cars 32.

The remaining spent fuel assemblies 16 are replaced by the new fuel assemblies 18 in a similar manner.

On completion of a recharging operation, the recharging machine 3 (Figure 11) assumes its intermediary position between the channels 10 and 11 inside the hermetically sealed chamber 1, and the plugs 28 are lowered, thus sealing the channels 10, 11 and 12. The sealed hatch 35 in the wall 36 of

the hermetically sealed chamber 1 is then opened, to allow the train of the cars 32 now containing coolant, to be withdrawn from the hermetically sealed chamber 1 using, for example, a hook which engages with the eyebar of the end car 32. The cars 32 are then cleaned and repositioned below the path along which the spent fuel assemblies 16 are transported, by re-introducing the cars 32 into the hermetically sealed chamber 1 through the hatch 35 and directing them along the upstanding guide member 38. At this stage, personnel can enter the chamber 1 to carry out periodic checks or maintenance of the refuelling installation.

If the cars 32 are coupled by means of the flexible cables 48 (Figure 7), the train of the cars 32 is withdrawn from the chamber 1 through the hatch 35 which is provided in the lid 26 of the chamber 1. Figure 8 illustrates the withdrawal process for when the carrier car 50 having the hoisting hooks 51 is the end car in the train. The cables 52 of the hoisting means (not shown) are lowered through the hatch 35 into the chamber 1 and attached to the hoisting hooks 51 of the carrier car 50. The hoisting means then hauls up the carrier car 50. Since carrier car 50 is connected by means of the flexible cables 48 to the adjoining car 32, this car 32 will first be pulled along the bottom 2 of the chamber 1 guided by the guide member 38 into the position previously occupied by the carrier car 50, and will then be hauled up after the carrier car 50, suspended from its flexible cables 48. As all the following cars 32 are also interconnected by flexible cables 48, they are all hauled up and suspended on the cables 48 (as is shown in Figure 8) is a similar manner, thus forming a chain of cars suspended one below another. All the flexible cables 48 are of equal length, and therefore each car 32 is suspended in an exactly horizontal orientation, which prevents escape of the coolant.

Figure 9 illustrates the case where the carrier car 50 is found in the middle of the train and is at least twice as long as any of the cars 32. The length of the chain of the suspended cars 32 and the carrier car 50 formed is only half the length of the above described case.

When such a train of cars 32 has been withdrawn from the chamber 1, it is installed in a container 53 (Figure 10) whose lid 54 has been previously removed. The flexible cables 48 are slackened and the cars 32 take up a compact arrangement one above another. The carrier car 50 is situated at the top of the compact arrangement. The cables 52 are then removed from the hooks 51 of said carrier car 50. The container 53 is covered with the lid 54 and transported to a cleaning area. The cars 32 and 50 are emptied of coolant and re-installed in the hermetically sealed chamber 1 (Figure 1).

When this latter embodiment is used the height of the container 53 (Figure 10) need only be one half of the height of a container required if the carrier car 50 is at the end of the chain and the cars are withdrawn as illustrated in Figure 8. However, the width of the hatch 35 and the container 53 needs to be greater.

The particular embodiment selected in any particular instance will depend upon any specific requirements imposed upon the arrangement of the recharging mechanism and the layout of the auxiliary services for these mechanisms.

The described installation is advantageous in that it prevents coolant retained on spent fuel assemblies removed from the nuclear reactor vessel from trickling onto the bottom of the hermitically sealed chamber. In addition, it allows the rapid and remote controlled removal of coolant from the hermetically sealed chamber. The installation is further advantageous in that it provides reliable protection from radiation for personnel during operation and maintenance of the mechanism for the recharging system, which mechanisms are nevertheless readily accessible.

The described installation is particularly applicable to the refuelling of liquid metal cooled fast breeder reactors.

WHAT WE CLAIM IS:

1. In a nuclear reactor complex, a refuelling installation for recharging the reactor vessel with new fuel assemblies from the reactor vessel into a second container, said installation comprising an hermetically sealable chamber communicating through respective sealable openings in its bottom with the reactor vessel, the first container and the second container, a recharging machine comprising a movable platform upon which is mounted a manipulator tube movable vertically relative to the platform, and a grip arranged within and capable of axial movement with respect to the manipulator tube, drive means for moving the movable platform, the manipulator tube and the grip independently of each other whereby movement of the platform, the manipulator tube and the grip in the appropriate sequences is effective to transfer fuel assemblies between said containers and the reactor vessel, and movable tank means positionable below the movable platform during its travel between the openings to the nuclear reactor vessel and the second container such that during the transfer of a spent fuel assembly from the reactor vessel to the second container any liquid reactor coolant running off the spent assembly is collected in said tank means, a sealed hatch being provided in the sealed chamber for the entry and removal of the tank means.

2. An installation according to claim 1, wherein the tank means comprises a series of movably interconnected cars each having guide means arranged to engage an upstanding guide member extending over the chamber bottom along the path traversed by the recharging machine between the reactor vessel opening and the second container opening, the gap between the facing end walls of adjacent cars being spanned by an overhead cover.

3. An installation according to claim 2, wherein the cars are coupled together by means of a hook secured to one of the end walls of a car, which hook is engageable with an eyebar attached to the facing end wall of the adjacent car.

4. An installation according to claim 2, wherein the cars are coupled together by means of flexible cables fitted with the aid of end loops over pulleys mounted on the side walls of each car.

5. An installation for refuelling reactors, substantially as hereinbefore described with reference to the accompanying drawings.

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1559436 COMPLETE SPECIFICATION

6 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

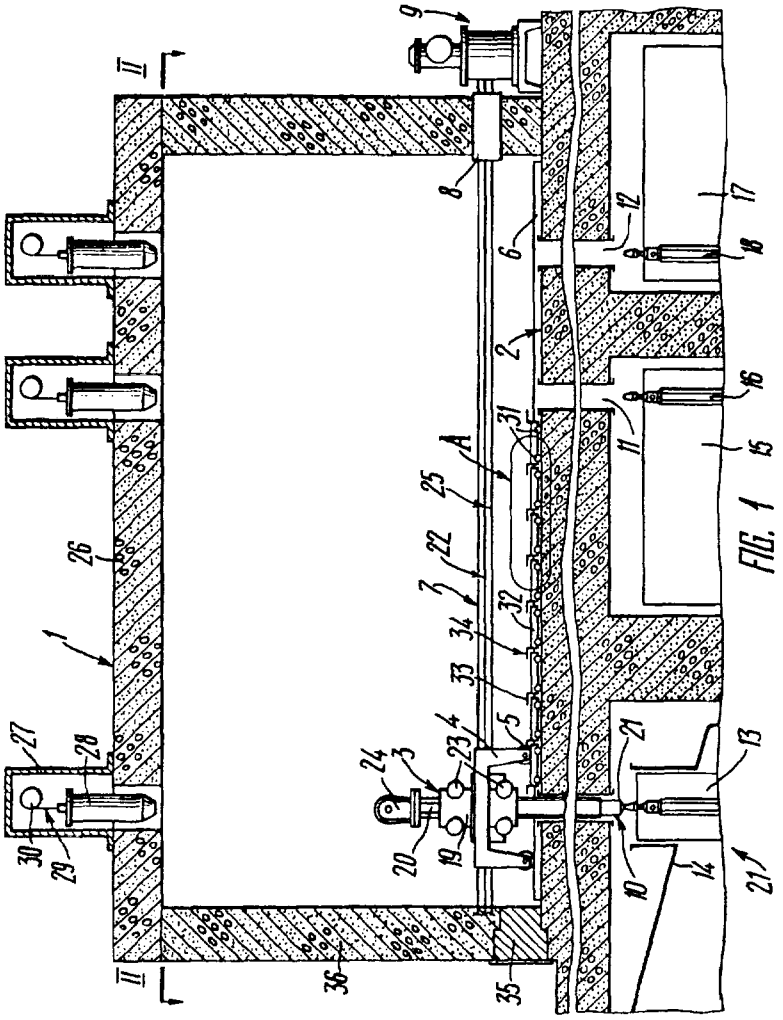

FIG. 1

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Sheet 2

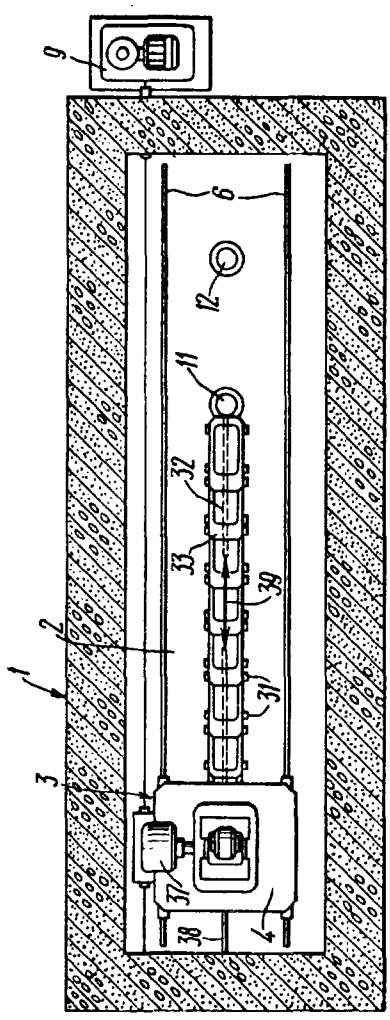

FIG. 2

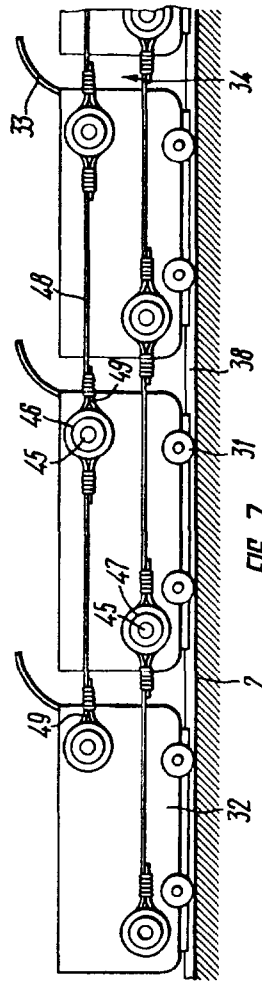

FIG. 7

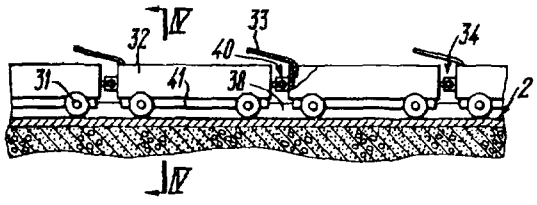

FIG. 3

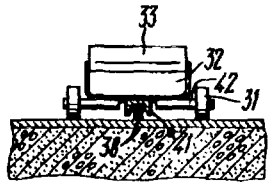

FIG. 4

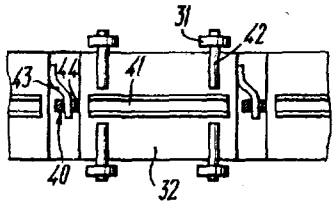

FIG. 5

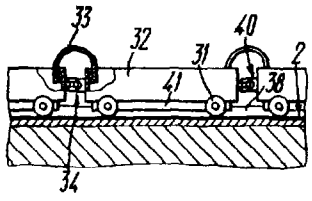

FIG. 6

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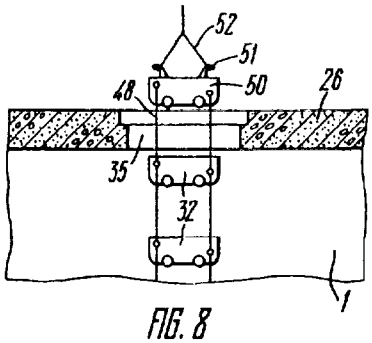

FIG. 8

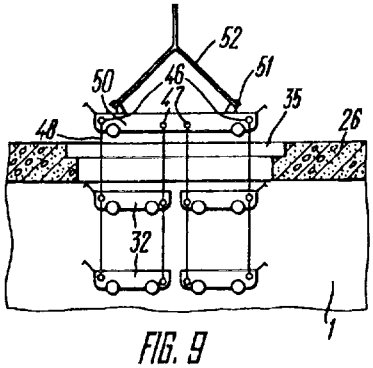

FIG. 9

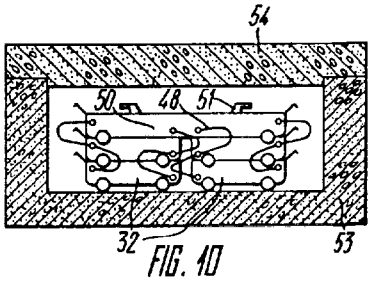

FIG. 10

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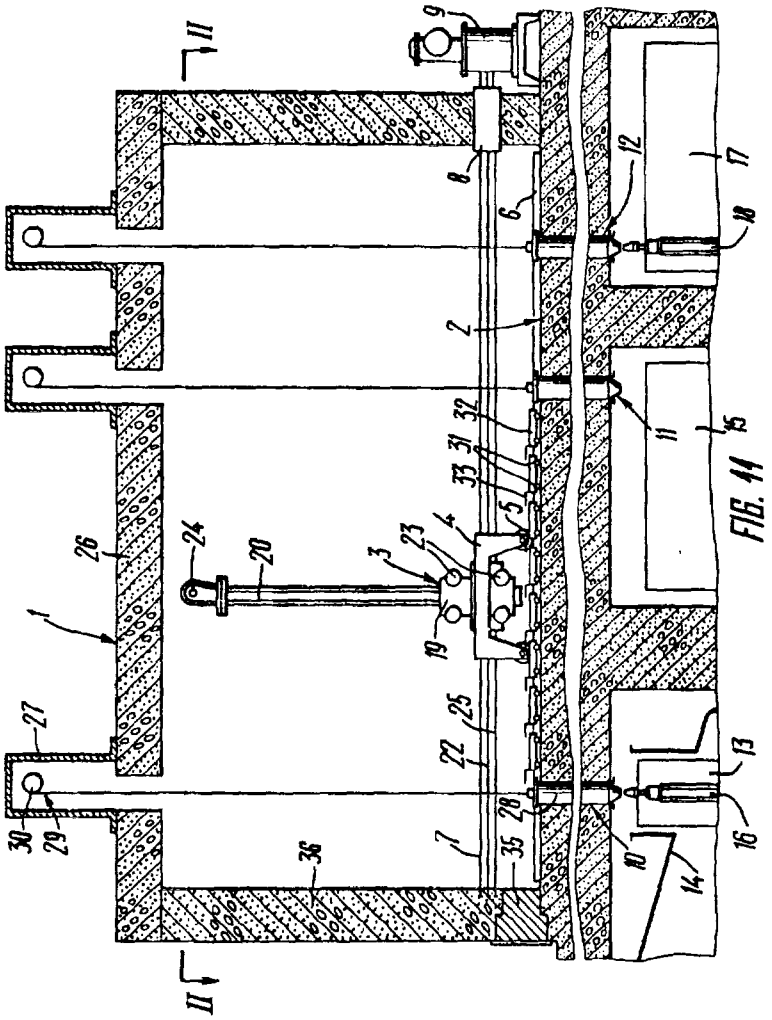

FIG. 11

1559436 COMPLETE SPECIFICATION
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Sheet 6

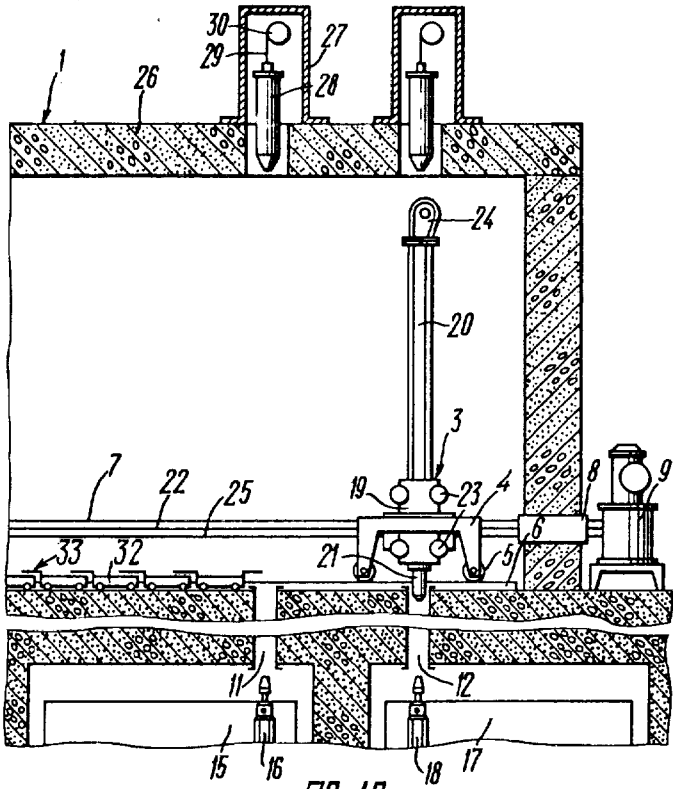

FIG. 12