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[54] **FUEL HANDLING SYSTEM FOR A NUCLEAR REACTOR**

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[51] **Int. Cl.**[4] **G21C 19/20**

[52] **U.S. Cl.** **376/261**; 376/272; 376/264; 376/362; 376/270; 376/404

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[57] **ABSTRACT**

A pool type nuclear fission reactor has a core, with a plurality of core elements and a redan which confines coolant as a hot pool at a first end of the core separated from a cold pool at a second end of the core by the redan. A fuel handling system for use with such reactors comprises a core element storage basket located outside of the redan in the cold pool. An access passage is formed in the redan with a gate for opening and closing the passage to maintain the temperature differential between the hot pool and the cold pool. A mechanism is provided for opening and closing the gate. A lifting arm is also provided for manipulating the fuel core elements through the access passage between the storage basket and the core when the redan gate is open.

3 Claims, 7 Drawing Figures

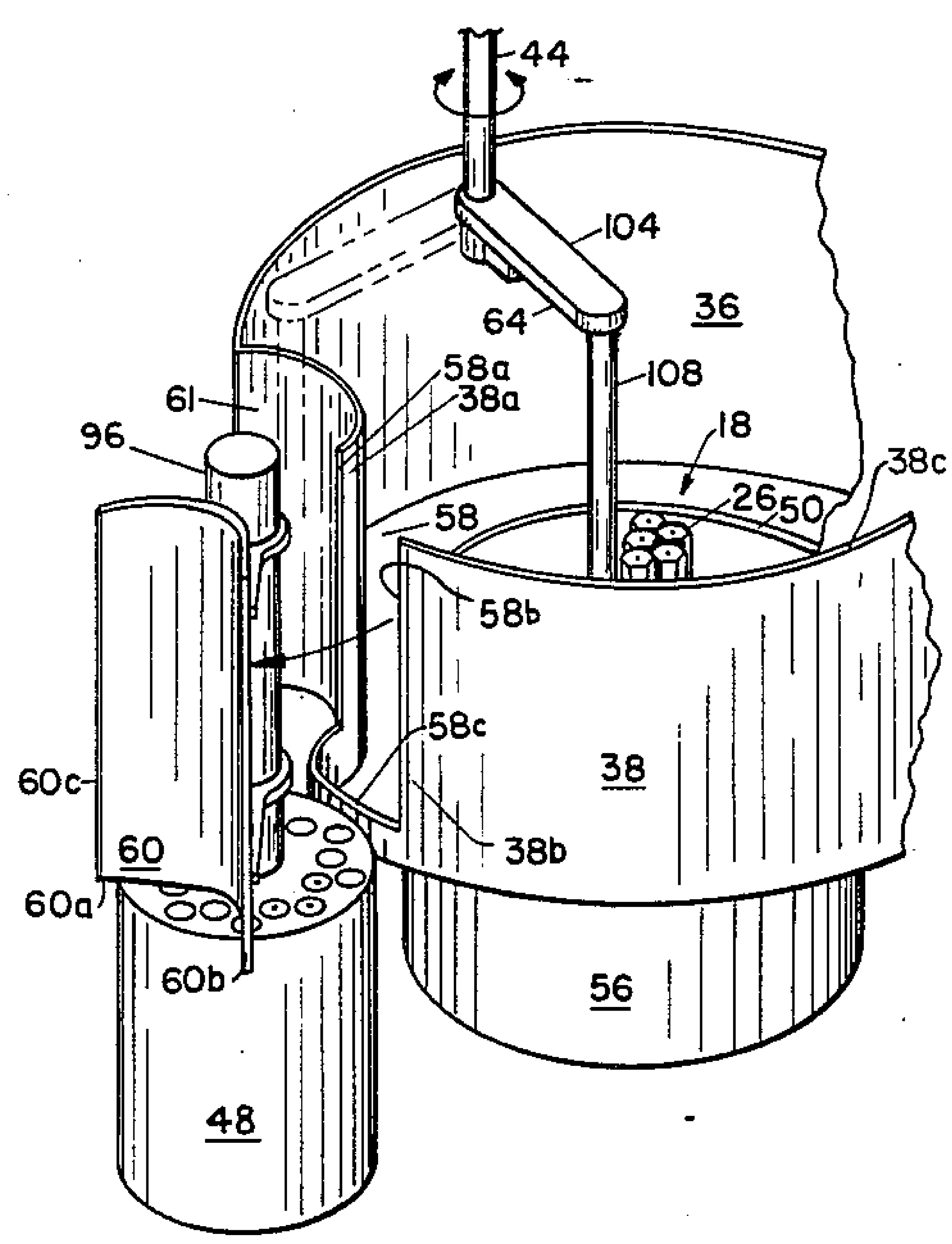


FIG-1

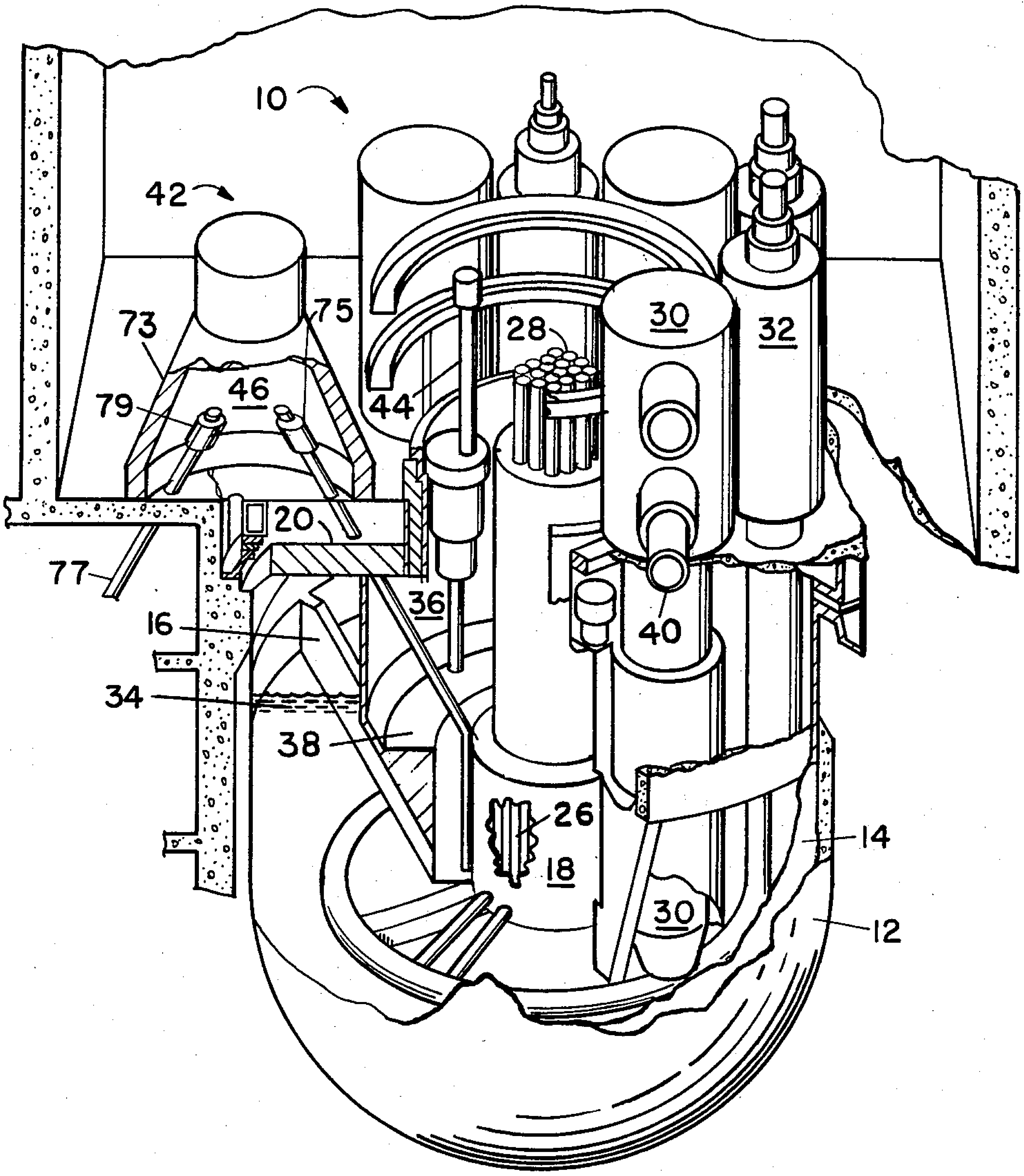
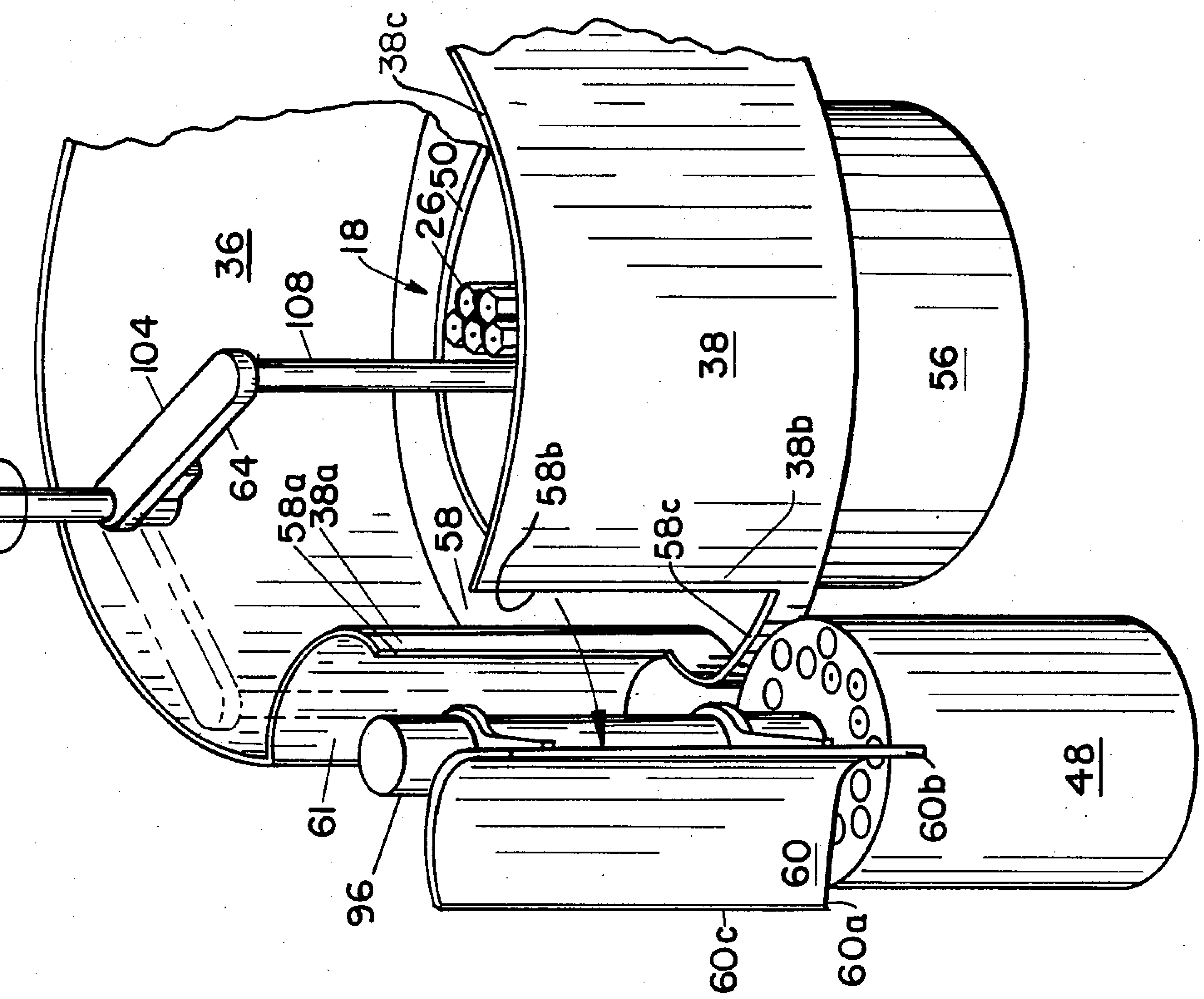


FIG-3



36
38
56
48
60
61
96
104
108
18
26
50
38c
44
64
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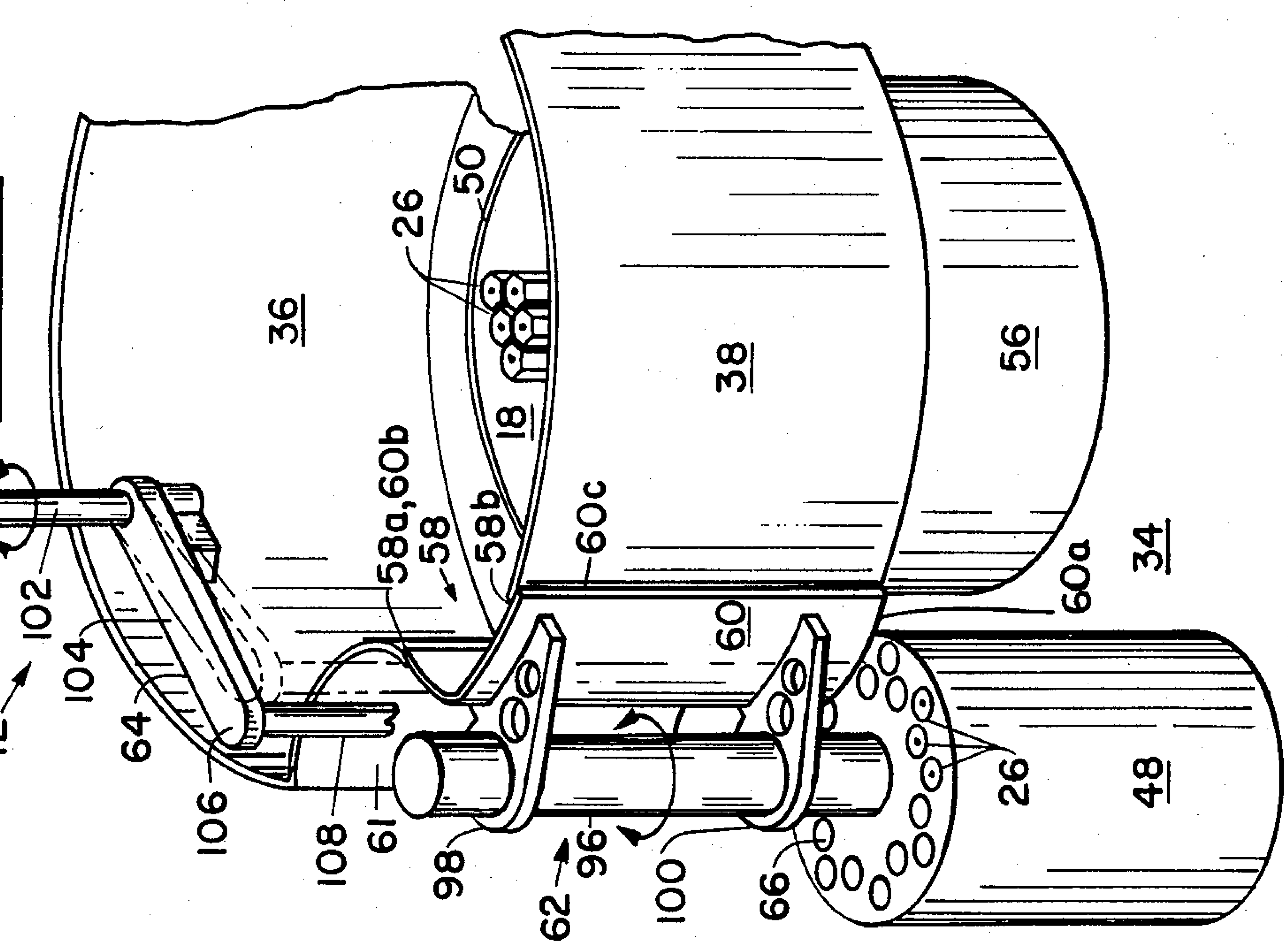
58a
38a
58b
58c
38b
60a
60b
60c

FIG-2



36
38
56
48
34
18
26
50
44
102
42
104
64
106
108
61
98
62
96
100
66
58
58a,60b
58b
60
60a
60c

FIG-4

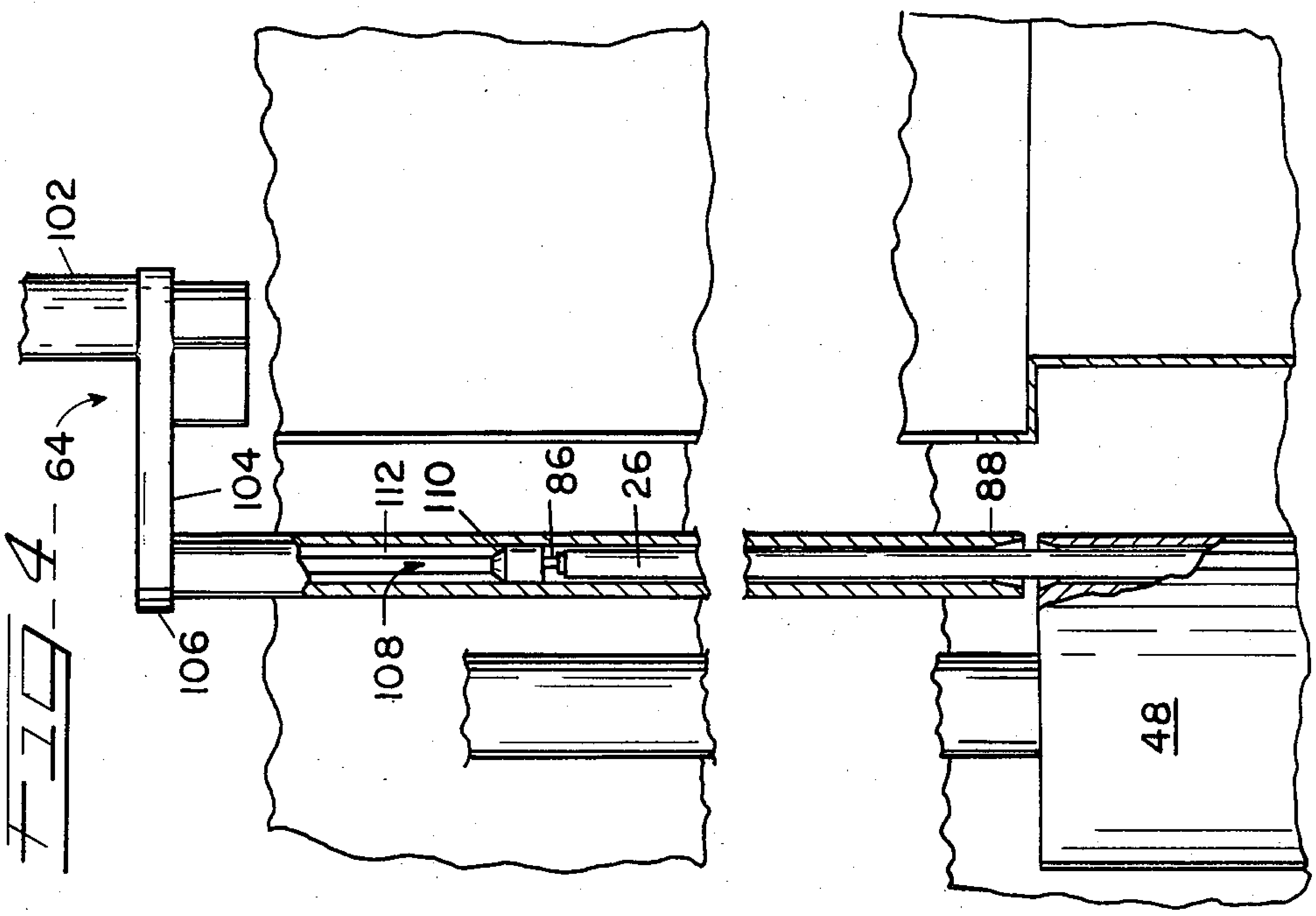

102
64
104
112
110
86
26
88
106
108
48

FIG-5

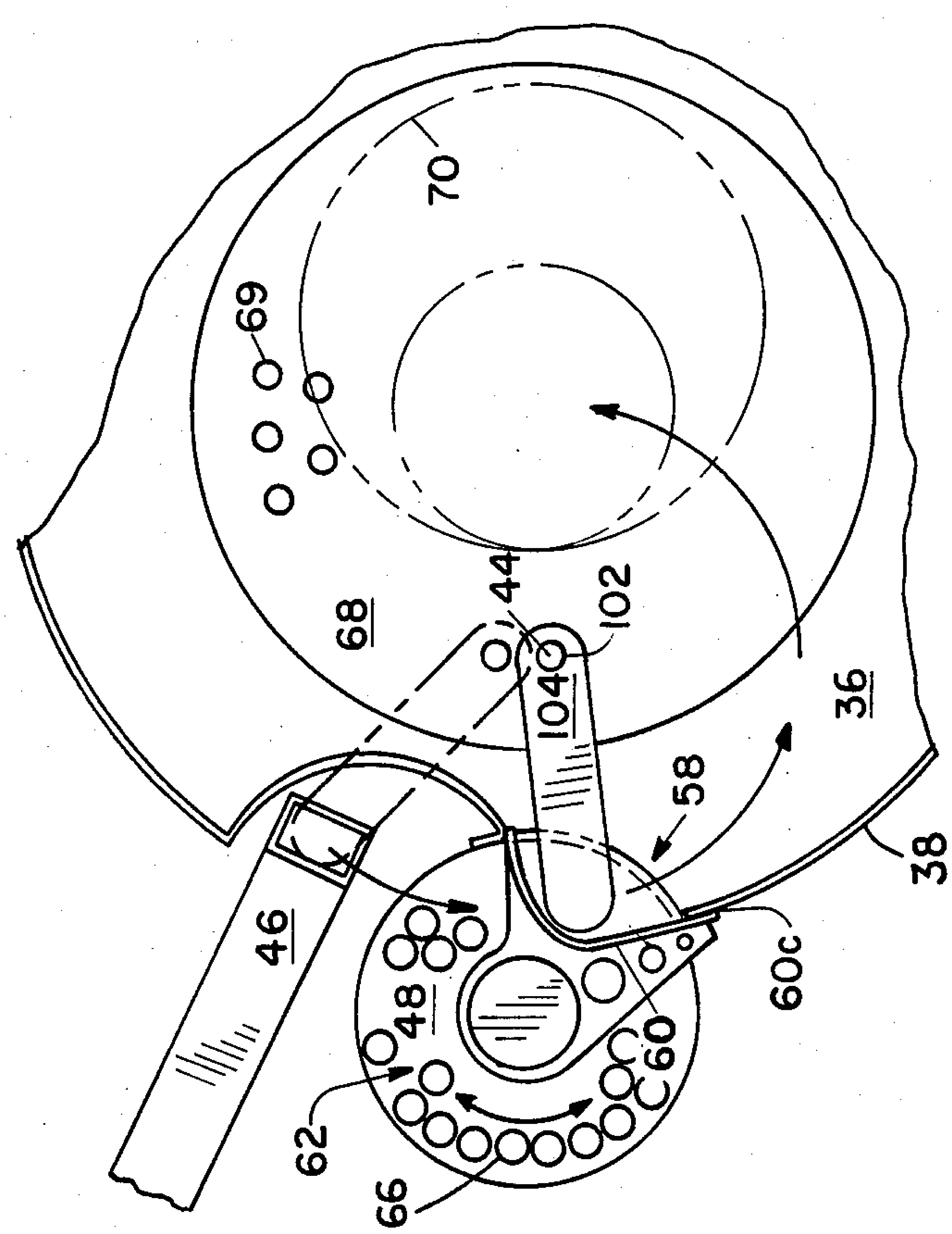

70
69
68
44
102
104
36
58
38
60c
60
48
46
62
66

FIG. 7

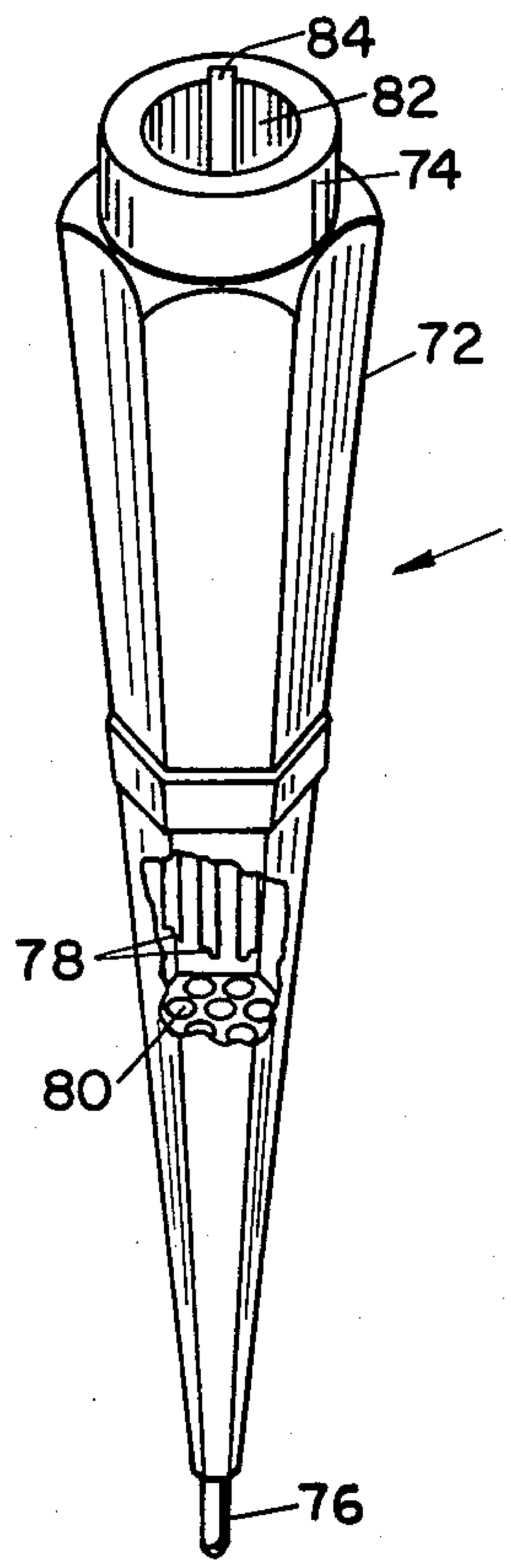
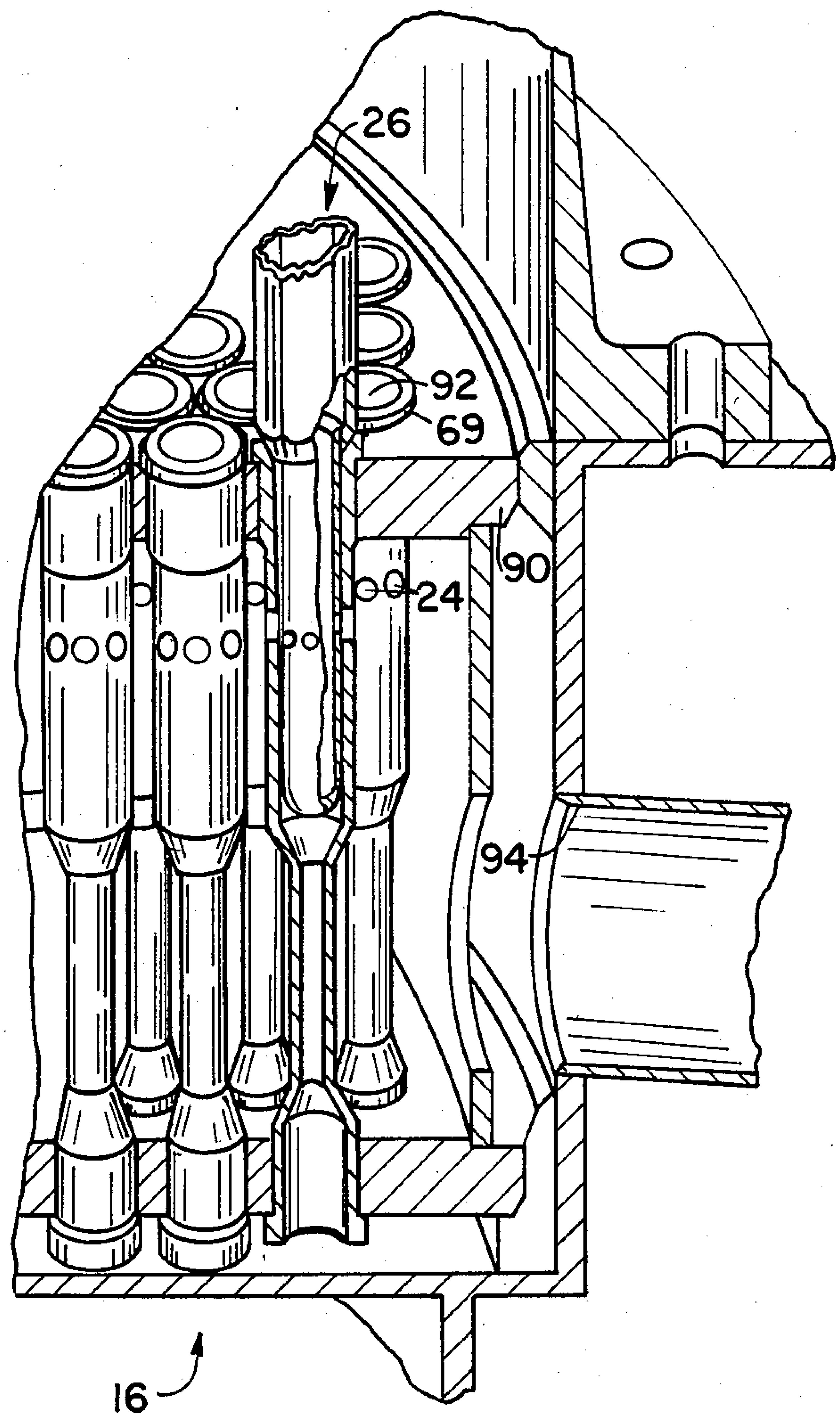


FIG. 6



FUEL HANDLING SYSTEM FOR A NUCLEAR REACTOR

CONTRACTUAL ORIGIN OF THE INVENTION

The United States Government has rights in this invention pursuant to contract number W-31-109-ENG-38, between the U.S. Department of Energy and the University of Chicago representing Argonne National Laboratory.

BACKGROUND OF THE INVENTION

A nuclear reactor has a core defining many parallel passages. Within the core are a plurality of fuel core assemblies containing fuel elements of radioactive material and a plurality of control elements supported in interrelated matrixes. The fuel elements create heat. The presence of the control elements relative to the fuel elements determines the reactivity of the fuel, and thus the output of the reactor. Coolant is forced through the passages over the fuel core assemblies and control elements for transferring the generated heat to a heat exchange mechanism, whereby steam can be produced externally of the reactor and used to perform useful work.

One form of nuclear reactor, known as the liquid metal fast breeder reactor uses molten sodium as the coolant. A pool type liquid metal nuclear reactor has a pool of molten coolant (typically sodium), a core submerged in the pool and pump and piping for circulating the coolant from a "cold pool" upwardly through the core to an overlying "hot pool" area and then through a heat exchanger and back to the cold pool at a reduced temperature. An intermediate fluid line through the heat exchanger picks up the heat for transfer to heat conversion means outside of the reactor.

Some reactors provide for a separate fuel storage vessel of coolant outside of the reactor and a storage basket for spent core assemblies in this vessel. Storage is necessary for spent fuel to allow fission decay cool down. New core assemblies are also positioned in the storage basket prior to use to allow temperature equalization.

In some reactors the storage basket is located in the reactor vessel, which eliminates the need for a separate storage vessel. Again, replacement of the core assemblies is periodically required. Accordingly, internal fuel handling equipment, including a lifting mechanism, are provided within the reactor vessel. The assembly handling equipment generally includes an exit ramp which allows for the mechanical movement of the core assemblies to and from the reactor vessel.

When the storage basket is contained in the reactor vessel, it normally is placed in the redan or hot pool area for it to be accessible to the assembly handling machine. This is not preferred, as the storage basket and assembly handling equipment are subjected to higher temperature and thermal transients. In the present system the storage basket and handling system are located in the cold pool, in order to reduce the temperature of the core assemblies during cool down. In addition, cooler temperatures reduce wear on the assembly handling equipment. However, a means of opening and closing the redan or "hot pool" container is required for such a system.

Prior art patent showing various methods of refueling nuclear reactors may be found in the following U.S. Patents; U.S. Pat. Nos.; 4,366,113, Gigou; 3,935,062,

Keller et al.; 3,635,792, Barker; 4,450,134, Soot et al.; 3,600,277, Germer; and 3,271,262, Hutchinson et al.

OBJECTS AND SUMMARY OF THE INVENTION

This invention relates generally to nuclear reactors and more particularly to an apparatus for moving fuel core assemblies from within a redan in a nuclear reactor.

A pool type nuclear fission reactor has a core, a plurality of core assemblies containing fuel elements and a redan structure, i.e. a container for confining coolant as a hot pool at a first end of the core. The redan usually is constructed as a vessel which separates the coolant in the hot pool from coolant in the cold pool at a second end of the core. It is an object of the present invention to provide a fuel core assembly handling system with a storage basket in the cold pool area of the reactor, and to provide means for opening and closing a portion of the redan in order to utilize such a system. An access passage in the redan structure allows such movement of core assemblies from the hot pool into the cold pool for storage for the fuel core assemblies located in the storage basket. A redan gate is provided for selectively closing the access passage through the redan structure. The gate is substantially liquid tight when closed. A mechanism is also provided for opening and closing the gate. An additional mechanism commonly referred to as a fuel handling arm is provided for manipulating the fuel core elements back and forth between the storage basket and the core when the redan gate is open. In addition, the fuel handling arm removes fuel core assemblies from the storage basket and places them on a conveyor for removal from the reactor.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** of the drawings is a front perspective view, partially cut away, of a nuclear reactor used in conjunction with the present invention.

FIG. **2** of the drawings is a front perspective view of the redan structure and fuel handling system of the nuclear reactor of FIG. **1**.

FIG. **3** of the drawings is a front perspective view of the redan structure and fuel handling system of FIG. **2** showing in particular the redan gate in an open position.

FIG. **4** of the drawings is a vertical section of the fuel handling system of FIG. **3** showing in particular transfer of fuel core assembly from the hot pool to the storage basket.

FIG. **5** of the drawings is a top view of the redan and fuel handling system of FIGS. **2** and **3** of the drawings.

FIG. **6** of the drawings is a front perspective cut away view of a portion of the nuclear reactor of FIG. **1** of the drawings showing in particular a core assembly being removed from the core support grid in the reactor.

FIG. **7** of the drawings is a front perspective view, partially cut away, of a core assembly for use in the nuclear reactor of FIG. **1** of the drawings.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

While the present invention is susceptible of embodiment in many different forms, there is shown in the drawings and will herein be described in detail, several specific embodiments with the understanding that the embodiments illustrated are an exemplification of the principals of the invention and are not intended to limit the invention to the embodiments illustrated.

Referring now to the drawings, and in particular to FIG. 1, a pool type nuclear fission reactor **10** is shown having guard vessel **12** about its periphery. A reactor vessel **14** is disposed within guard vessel **12**. Similarly, a core support structure **16** is disposed within reactor vessel **14**. A reactor core **18** supported by the core support structure **16** is disposed within the reactor vessel **14**. A deck **20** closes the open top of the reactor.

Core **18** of nuclear reactor **10** has a plurality of parallel passages **24** (best seen in FIG. 6) within which fuel core assemblies **26** and control elements **28** are supported in interrelated matrixes. The clustering together of radioactive fuel core assemblies **26** creates heat. The presence of the control elements **28** relative to the fuel core assemblies **26** determines the reactivity of the fuel, and thus the output of the reactor. Coolant is forced through the passages **24** over the core assemblies **26** and control elements **28** for transferring the generated heat to a heat exchanger mechanism **30** or the like whereby steam can be produced externally of the reactor **10** and used to perform useful work, such as drawing electric generators.

Nuclear reactor **10**, in one embodiment, is a liquid metal fast breeder reactor which uses molten sodium as the coolant. A pool type liquid metal nuclear reactor has a pool of molten coolant (typically sodium), a core **18** submerged in the pool and pump **32** and piping for circulating the coolant from a "cold pool area" **34** upwardly through the core **18** to an overlying "hot pool area" **36** contained within a redan structure **38** which separates cold pool area **34** from hot pool area **36** and then through heat exchanger **30** and back to the cold pool area **34** at a reduced temperature. An intermediate fluid line **40** through the heat exchanger **30** picks up the heat for transfer to heat conversion means (not shown) outside of the reactor **10**.

As seen in FIGS. 1 and 2, nuclear fuel core assemblies **26** and control elements **28** are arranged in matrix patterns within the core **18**. Replacement of these fuel core assemblies **26** are periodically required. Accordingly, internal fuel handling equipment **42**, including a lifting mechanism **44**, are provided in the reactor vessel **14**. The assembly handling equipment **42** generally includes a conveyor system **46** (FIG. 1) which allows for the mechanical movement of the fuel core assemblies **26** into or from the reactor vessel **14**.

As seen in FIG. 2, a storage basket **48** for spent fuel core assemblies **26** is provided in reactor vessel **14**. Storage is necessary for spent fuel to allow fission decay cool down, and new fuel core assemblies **26** are positioned in the storage basket **48** prior to use to allow temperature equalization. Storage basket **48** is placed in the cold pool area **34** for it to be more accessible to the fuel handling equipment **42**. In addition, this location is preferred as the storage basket **48** and assembly handling equipment **42** are subjected to lower temperature and thermal transients.

As further seen in FIG. 2, redan structure **38** confines coolant in a hot pool area **36** at a first end **50** of the core **18** Redan structure **38** is preferably constructed as a vessel having vertical walls **38*c***. The redan structure **38** separates the coolant in the hot pool area **36** from coolant in the cold pool area **34** at a second end **56** of the core. An access passage **58** in the redan structure **38** allows movement of fuel core assemblies **26** from the hot pool area **36** into the cold pool area **34** for storage in the storage basket **48**. A redan gate **60** is provided for selectively closing the access passage **58** and the redan structure **38**. The gate is substantially liquid tight when closed. A mechanism **62** is also provided for opening and closing the gate **60**. Fuel handling arm **64** is provided for manipulating the fuel core assemblies **26** back and forth between the storage basket **48** and the core **18** when the redan gate **60** is open. In addition, the fuel handling arm **64** removes fuel core assemblies **26** from the storage basket **48** and places them on a conveyor **46** (best seen in FIG. 1) for removal from the reactor **10**.

As best seen in FIG. 3 of the drawings, when redan gate **60** is in an open position, assembly handling arm **64** may be moved into position for engagement with one of the fuel core assemblies **26**. Assembly handling arm **64** may then be raised with fuel core assembly **26** attached thereto and moved through passage **58** in redan **38**. Once located in position over storage basket **48**, as seen in FIG. 4, assembly handling arm **64** may be lowered so as to telescopically engage fuel core assembly **26** in tubular apertures **66** in storage basket **48**.

As further seen in FIGS. 2 and 3, redan gate **60** is constructed in a curved configuration, and is positioned so as to matingly engage with vertical edges **58*a*** and **58*b*** of access passage **58**. In addition, bottom surface **60*a*** of redan gate **60** is slidingly positioned on bottom edge **58*c*** of access passage **58**. Redan gate **60** is outwardly curved so that vertical edge **60*b*** of redan gate **60** is matingly engaged against vertical edge **58*a*** of access passage **58** on the inside wall **38*a*** of redan structure **38**. Conversely, vertical edge **60*c*** of redan gate **60** extends onto the outside wall **38*b*** of redan structure **38** when redan gate **60** is closed. As a result, a substantial liquid tight seal is created between redan gate **60** and access passage **58**.

As best seen in FIG. 3, when redan gate **60** is pivoted in a clockwise direction, vertical edge **60*c*** of redan gate **60** swings about to the opposite side of storage basket **48**. Vertical edge **60*b*** of redan gate **60** passes through access passage **58** until it is also located on the opposite side of storage basket **48** from redan structure **38**. Sealing engagement is also accomplished by having redan structure **38** inwardly curved in section **61** so that vertical edge **58*a*** interlaps with vertical edge **60*b***. As a result, a simple effective method of sealing redan gate **60** to the redan **38** is provided.

As mentioned previously, redan gate **60** is opened and closed by gate closing mechanism **62**. In the embodiment shown, gate closing mechanism **62** consists of a pivotable shaft **96** vertically disposed adjacent to redan gate **60** and connected thereto by a pair of support braces **98** and **100**. Pivotable shaft **96** in turn may be pivoted by a drive train (not shown) connected to an electric motor.

Storage basket **48** may similarly be rotated about shaft **96**. Mechanical means for causing such rotation, although not shown in the drawings, consist of a centrally disposed shaft extending through shaft **96** and fixedly attached to storage basket **48** for effecting rotation thereof. Such a centrally disposed shaft, would of course be mounted in a bearing mechanism within shaft **96** and would be connected at one end to a mechanical drive and power source such as an electric motor. In rotation both of the storage basket and of the redan gate, because of the precise positioning required, a stepper type electric motor is utilized for precisely positioning both the redan gate and the storage basket. A computerized control is also utilized.

Turning now to FIGS. 3 and 5 of the drawings, core assemblies **26** are positioned for telescopic engagement with fuel handling arm **64** by means of rotatable plugs **68** and **70**. Tubular apertures **69**, are vertically positioned in large plug **68** so that when plugs **68** and **70** are rotated, fuel core assemblies **26** are positioned beneath fuel handling arm **64**. Fuel handling arm **64** is then lowered for engagement with fuel core assemblies **26**. Individual core assemblies **26** may then be raised and moved through access passage **58**, past open redan gate **60**, and deposited in storage basket **48**.

In addition to transfer from core **18** to storage basket **48**, core assemblies **26** may be raised from storage basket **48** after cool down and positioned on conveyor system **46** for removal from the reactor **10**. As best seen in FIG. **1**, conveyor mechanism **46** comprises, in this embodiment, an inclined conveyor which opens into a shielded chamber **73**. A valve **75** is provided to allow passage of the fuel core assemblies into chamber **73**. An oppositely disposed conveyor **77** exits from the chamber **73**. A valve **79** is interposed on conveyor **77** to seal the chamber **73**, except when fuel core elements **26** are being passed therethrough. In this manner, both spent fuel core assemblies and new fuel core assemblies may be transferred into or out of reactor vessel **14**.

Turning now to FIG. 7 of the drawings an individual fuel core assembly **26** is shown. Fuel core assembly **26** is constructed as a tubular duct **72** having a top end fitting **74** and a bottom end fitting **76**. Contained within the tubular duct **72** are a plurality of fuel elements **78** which are vertically disposed therein. Separating the fuel elements are grid plates **80** which precisely position the fuel elements **78**. At the top of tubular duct **72** is top end fitting **74**. Top end fitting **74** contains an aperture **82** and, in this embodiment, a slot **84**. Slot **84** is adapted for engagement with a corresponding claw assembly **86** (best seen in FIG. 4) moveable towards the distal end **88** of fuel assembly handling arm **64**. Following such engagement, fuel assembly, **26** may be raised and lowered or moved from side to side by means of arm **64**.

As shown in FIG. 6 of the drawings, core support structure **16** has a core support grid **90** containing a plurality of vertical tubular passages **92** through core support structure **16**. Tubular passages **92** are adapted for telescopic engagement with fuel core assemblies **26**. Parallel passages **24** allow the flow of coolant from coolant inlet **94** through the fuel core assemblies **26** and control elements **28**.

As also shown in FIGS. 2, 3 and 4 of the drawings, fuel handling equipment **42** utilizes fuel handling arm **64** for placing fuel elements **26** in core **18**, for removing fuel elements **26** from core **18** and placing them into storage basket **48**, and for removing fuel elements **26** from storage basket **48** and placing them onto conveyor **46**. This is accomplished by providing a mechanism for both raising and lowering fuel handling arm **64** and for pivoting fuel handling shaft **102** of fuel handling arm **42** either clockwise or counter clockwise. Such clockwise or counter clockwise movement causes rotation of laterally extending beam **104**. Rotation of fuel handling shaft **102** is effected by means of a power source such as an electric motor, (not shown) connected by means of a drive train (not shown) to shaft **102**. Again, an electrically driven stepper type motor is preferably utilized which may be controlled by means of a microprocessor.

As best shown in FIG. 4, at the distal end **106** of beam **104** is a downwardly extending gripper mechanism **108**. Gripper mechanism **108** utilizes a wire pulley mechanism **112** which is in turn connected to its gripper head **110**. Gripper head **110** may contain a claw assembly **86** for gripping the top end **74** of fuel element **26**. Alternatively, gripper head **110** may contain a key (not shown) adapted for insertion into and interlocking with slot **84** shown in FIG. 7. Following such interlocking, fuel handling assembly **42** may be raised so as to raise fuel core assemblies **26** either from storage basket **48** or from core **18**. As a result of the provision of the abovelisted fuel handling assembly **44**, fuel core assemblies **26** may be safely and efficiently conveyed into core **18** or removed therefrom without maintaining a high transient temperature within reactor **10**.

The foregoing description and drawings merely explain and illustrate the invention and the invention is not limited thereto except in so far as those who have the disclosure before them will be able to make modifications and variations therein without departing from the scope of the invention.

What is claimed is:

1. In a pool type nuclear fission reactor having a core, a plurality of fuel core elements and a redan structure in the form of a vessel for confining coolant in a hot pool area at a first end of said core separated from a cold pool area at a second end of said core, a fuel handling system comprising;

- a core element storage basket located outside of said redan structure in said cold pool area;
- an access passage in said redan structure:
- a gate to close said passage;
- means for opening and closing said gate; and
- means for manipulating said fuel core elements through said access passage between said storage basket and said core when said gate is open.

2. In a nuclear reactor having a core composed of a plurality of fuel core assemblies, a liquid coolant for passing through said core assemblies, a hot pool area and a cold pool area for said coolant, and a redan structure for separating said hot pool area from said cold pool area, said redan structure comprising:

- a vertical wall assembly substantially concentrically disposed about said core assemblies, and having a passageway therethrough, said vertical wall assembly further having an inner wall, an outer wall and an inwardly curved section adjacent said passageway;
- an outwardly curved moveable gate having first and second oppositely disposed vertical side edges;
- means for moving said moveable gate into a first position substantially sealing said passageway, with said first vertical edge abutting against said inner wall of said wall assembly and said second vertical edge abuttig said outer wall of said vertical wall assembly so as to retain liquid coolant in said redan; and
- means for moving said moveable gate to a second position so as to open said passageway and allow the selected movement of said core assemblies into and out of said redan structure.

3. In a nuclear reactor having a core composed of a plurality of fuel core assemblies, a liquid coolant for passing through said core assemblies, a hot pool area and a cold pool area for said coolant, and a redan structure for separating said hot pool area from said cold pool area, an apparatus for moving said fuel core assemblies into and out of said redan structure comprising:

- a moveable redan gate;

means for moving said gate to either an open or closed position;

a storage basket for storing said fuel core assemblies, said storage basket being positioned outside of said redan structure;

conveying means for conveying said fuel core assemblies into and out of said reactor; and

means for moving said fuel core assemblies from said conveying means to said storage basket, from said storage basket through said moveable redan gate and into said reactor, and for the reverse movement thereof.

* * * * *