United States Patent [19]

Kreider et al.

[11] **3,737,553**

[45] **June 5, 1973**

[54] **VACUUM ELECTRIC FURNACE**

[75] Inventors: **Benjamin A. Kreider**, Richboro; **William R. Jones**, Chalfont; **William J. Metalsky**, Warminster; **Thomson B. Gibb**, Warrington, all of Pa.

[73] Assignee: **Abar Corporation**, Feasterville, Pa.

[22] Filed: **Dec. 9, 1971**

[21] Appl. No.: **206,383**

[52] **U.S. Cl.** **13/25**, 13/31, 219/343, 219/347, 263/40

[51] **Int. Cl.** **H05b 3/10**

[58] **Field of Search**......................219/343, 347, 349, 219/350, 390, 391, 395, 405; 13/20, 25, 31; 263/40, 41

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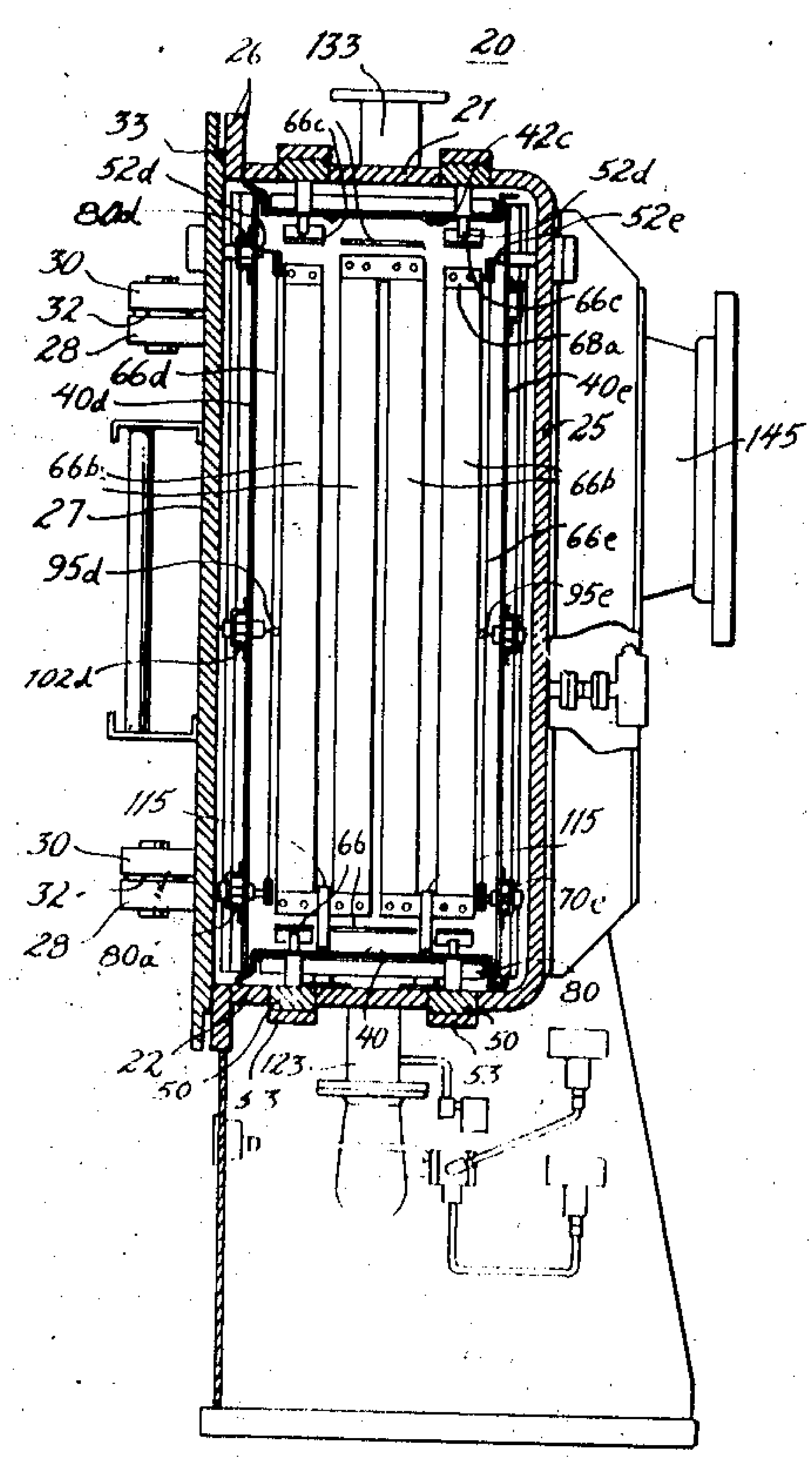
Primary Examiner—Roy N. Envall, Jr.
Attorney—Zachary T. Wobensmith, II

[57] **ABSTRACT**

An electric furnace is disclosed for operation at vacuum with or without inert gas with an external water cooled enclosure having an access door and within which enclosure large areas low mass quick heating resistance elements are provided for the back and front, sides, top and bottom with independent control of the heating elements, programmed if desired, the heating units being shielded to minimize heat loss outside the enclosure by low mass shielding elements including a baffle in one wall which permits rapid gas exit for fast pump down to obtain a fast cycle time while limiting external thermal radiation losses from the shielded area.

12 Claims, 15 Drawing Figures



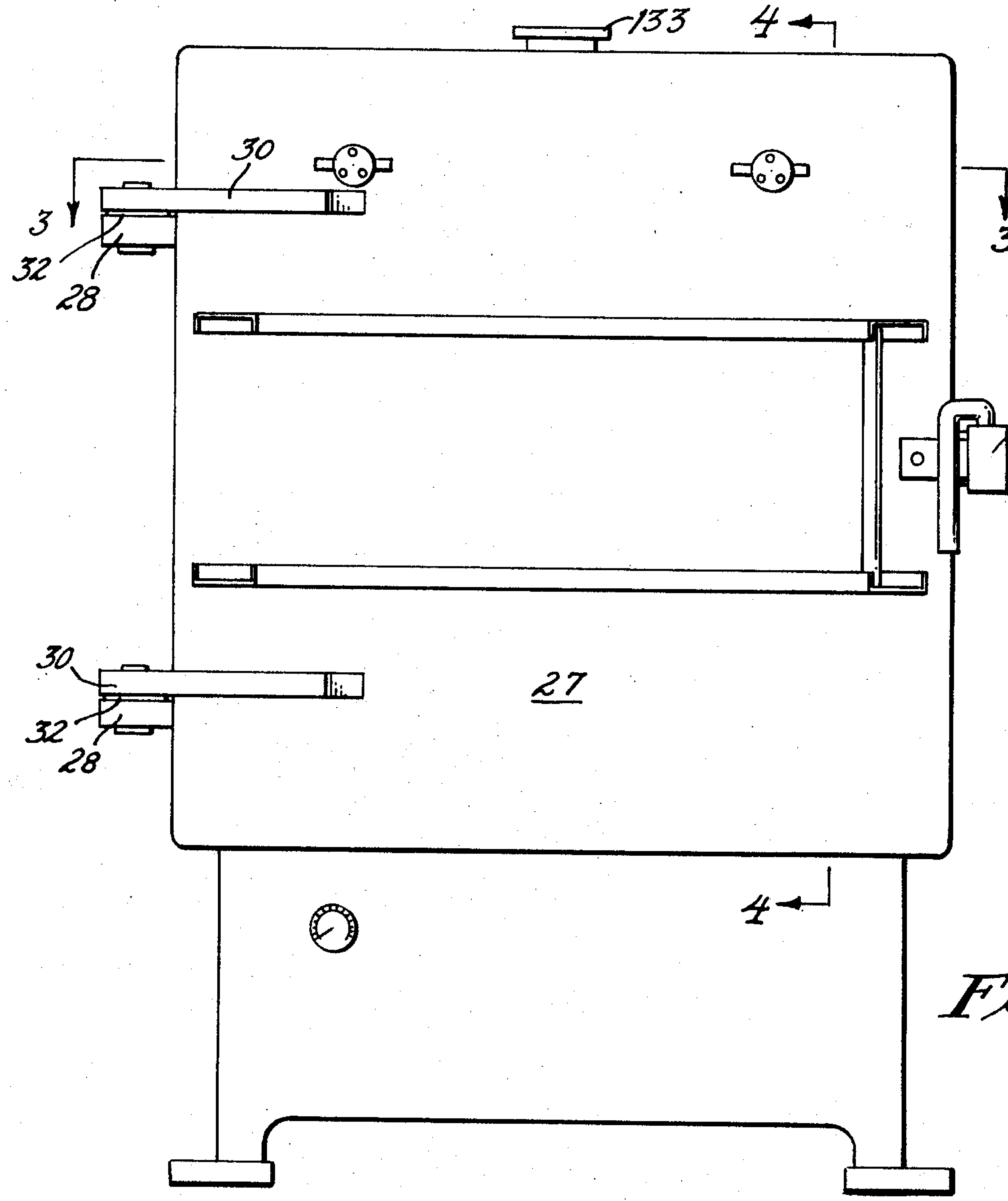


Fig.1.

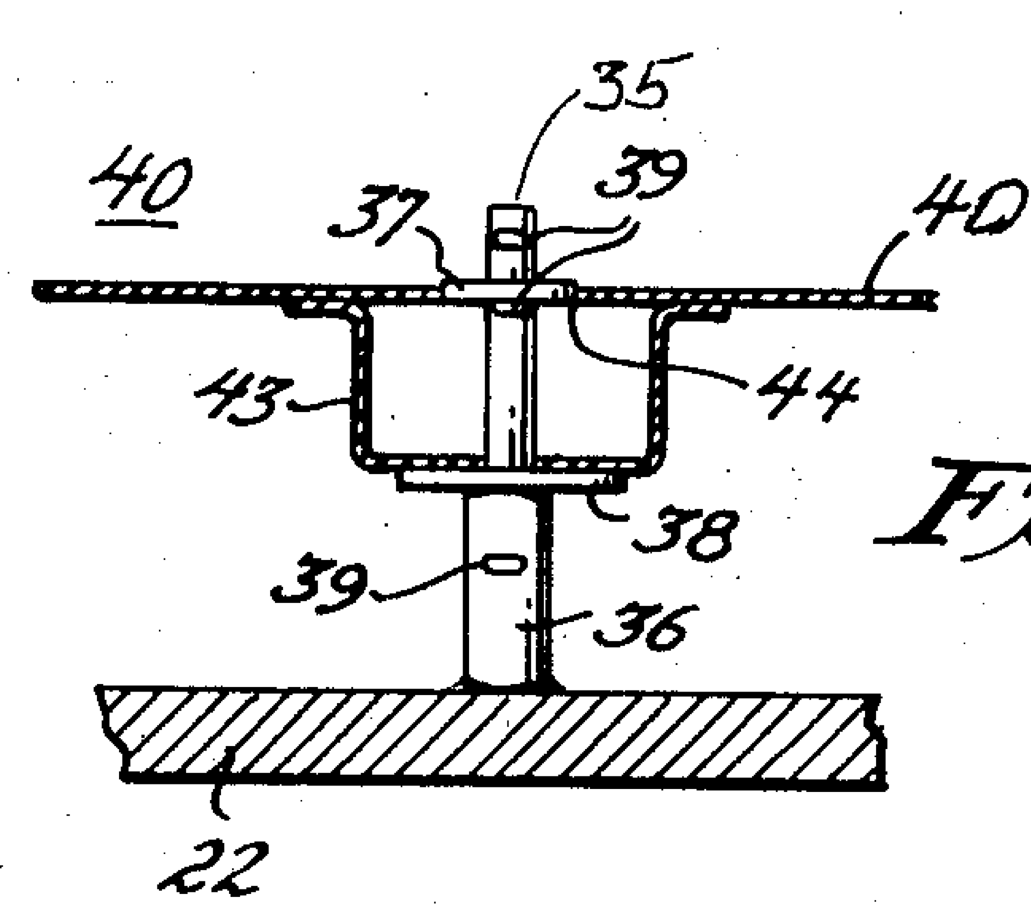
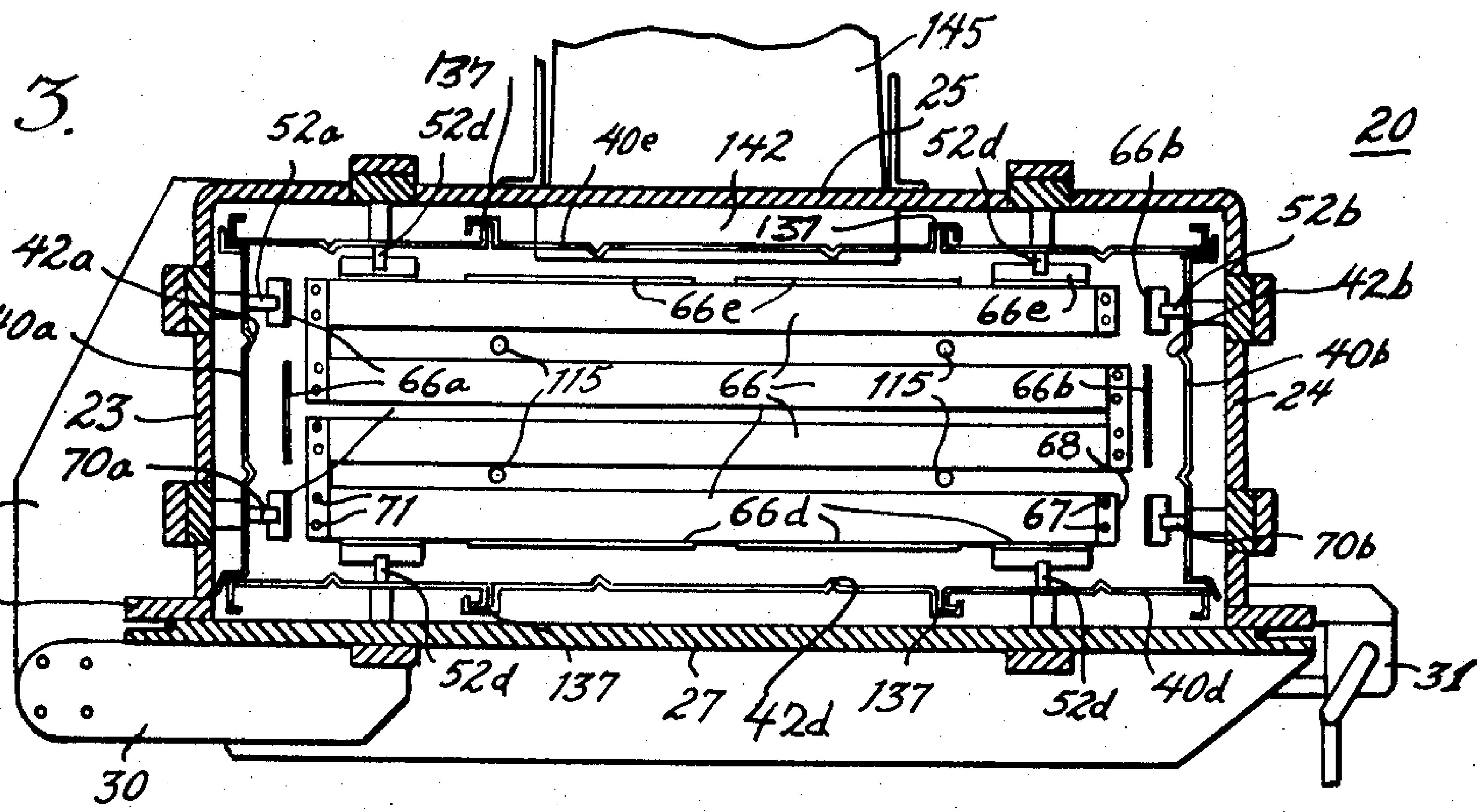


Fig. 6.

Fig. 3.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66a
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23
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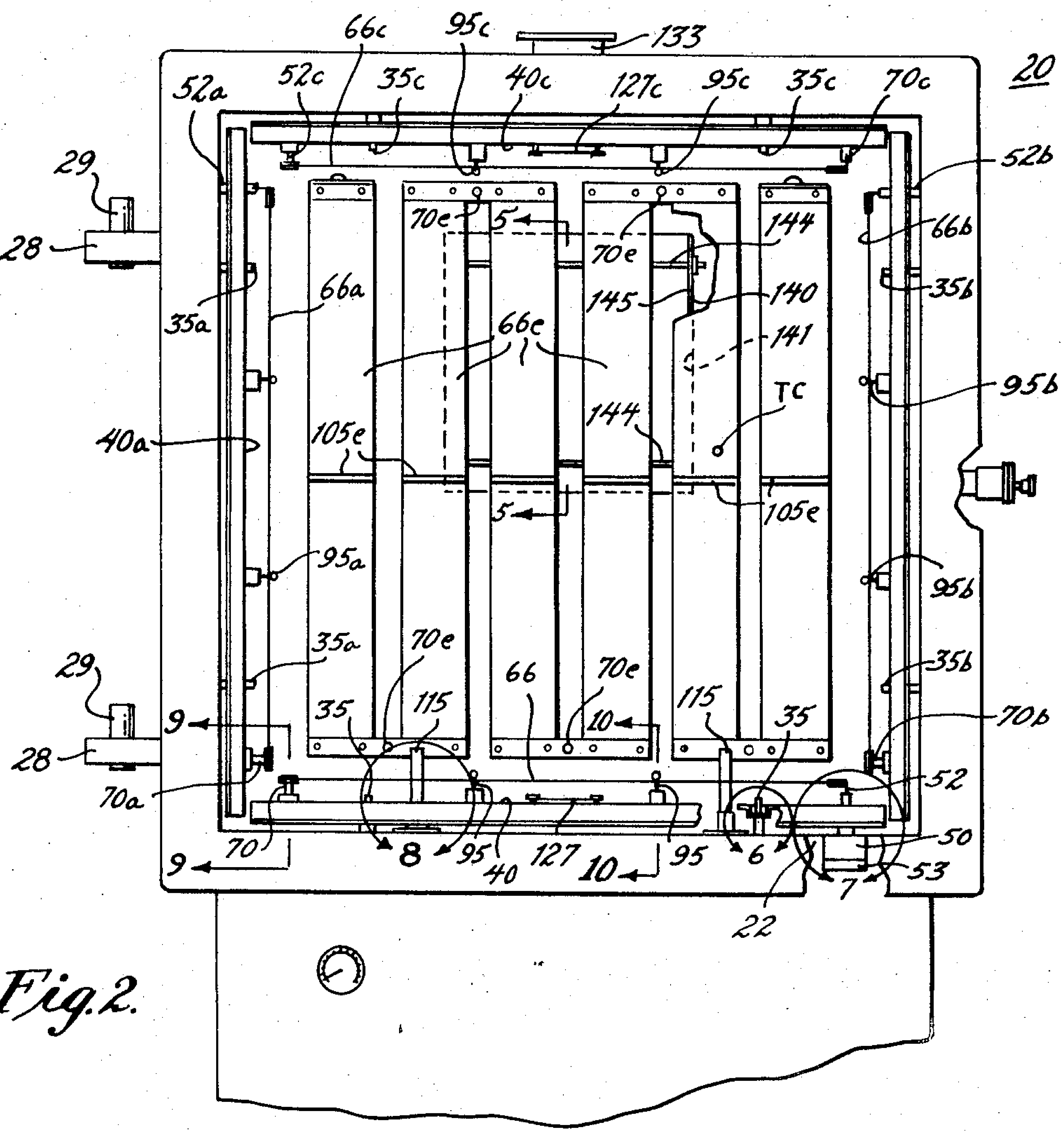
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Fig. 2.

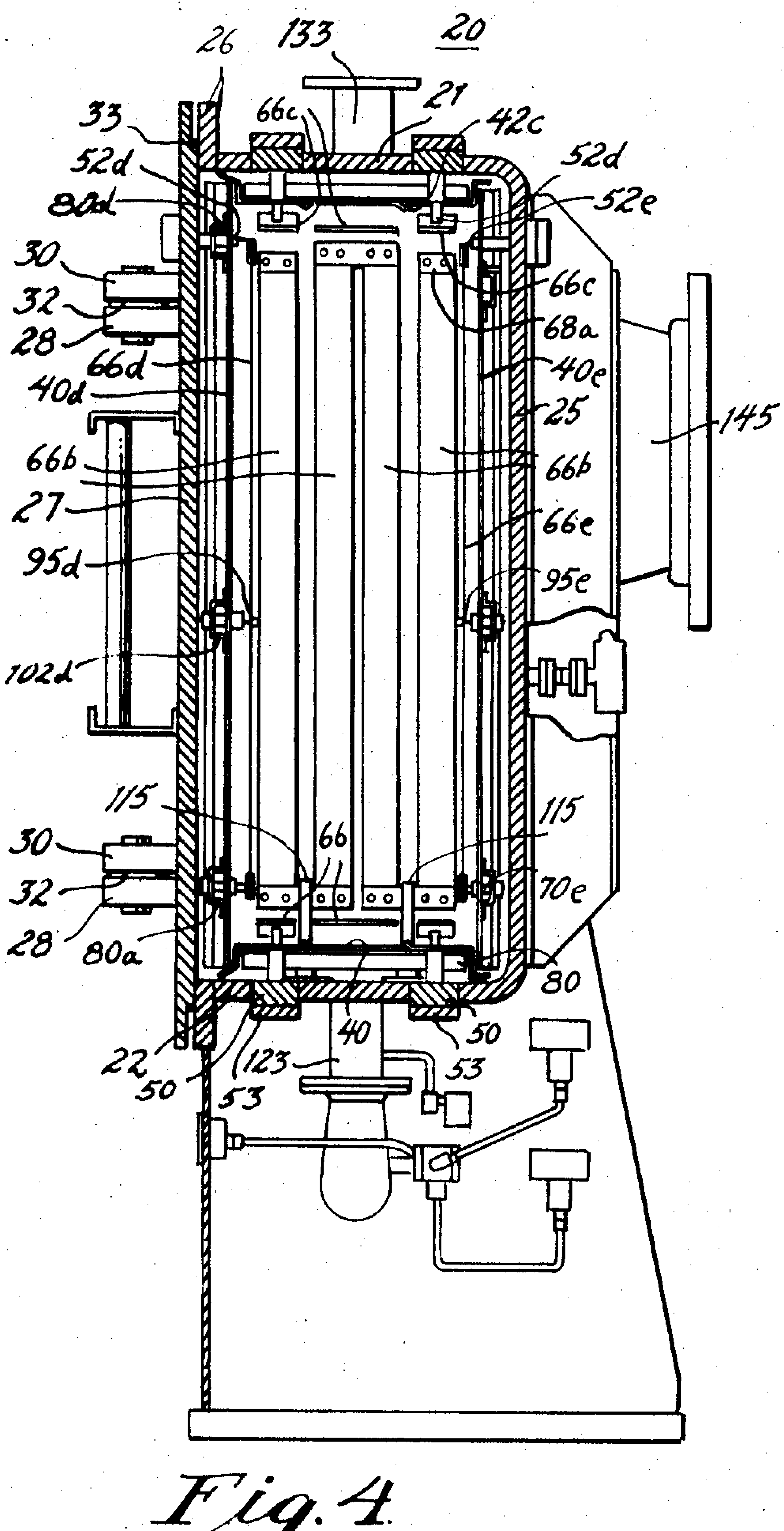
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Fig. 4

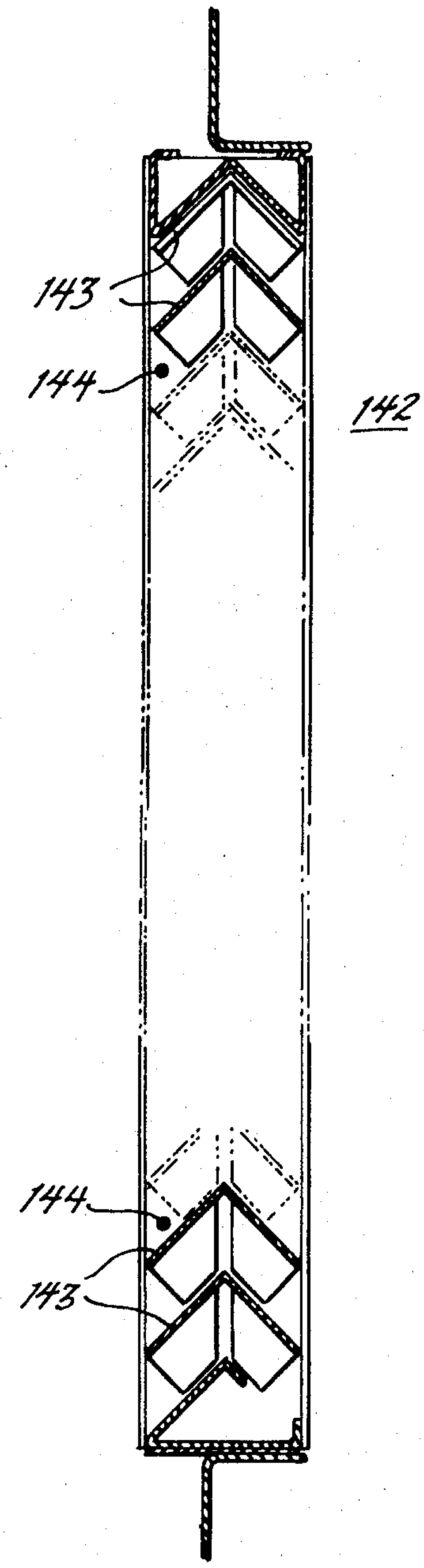
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Fig. 5

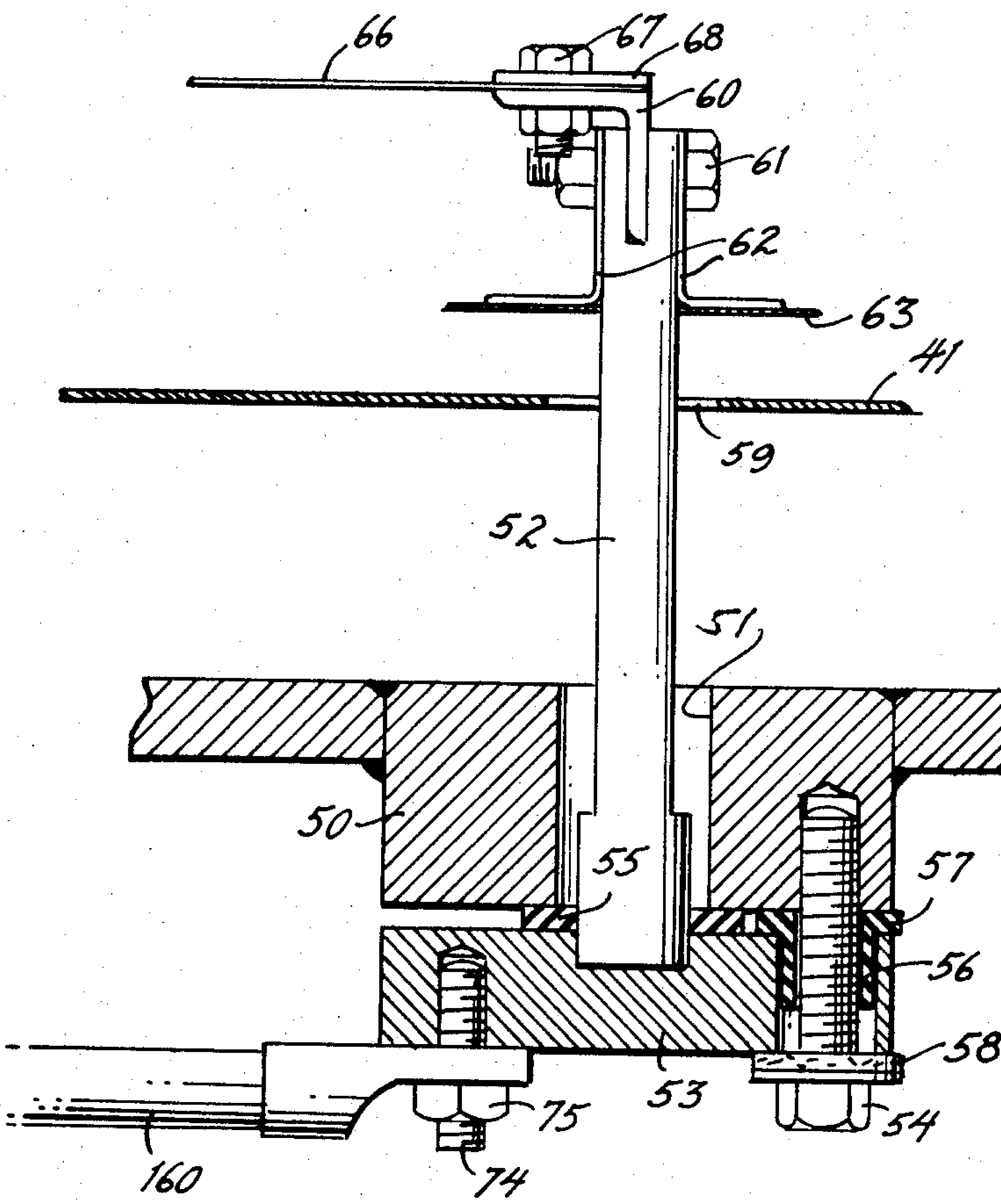
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Fig. 7.

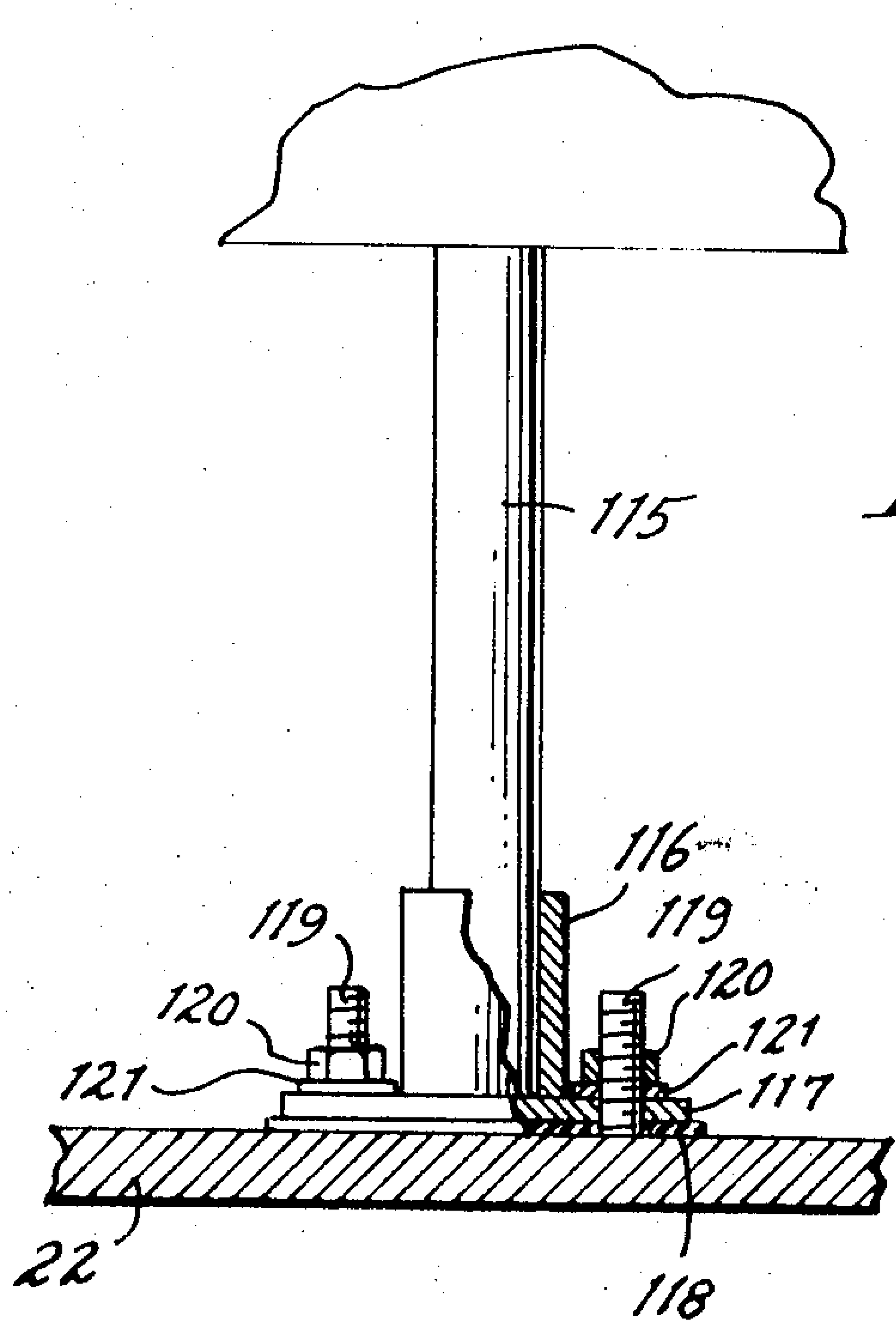
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Fig. 8.

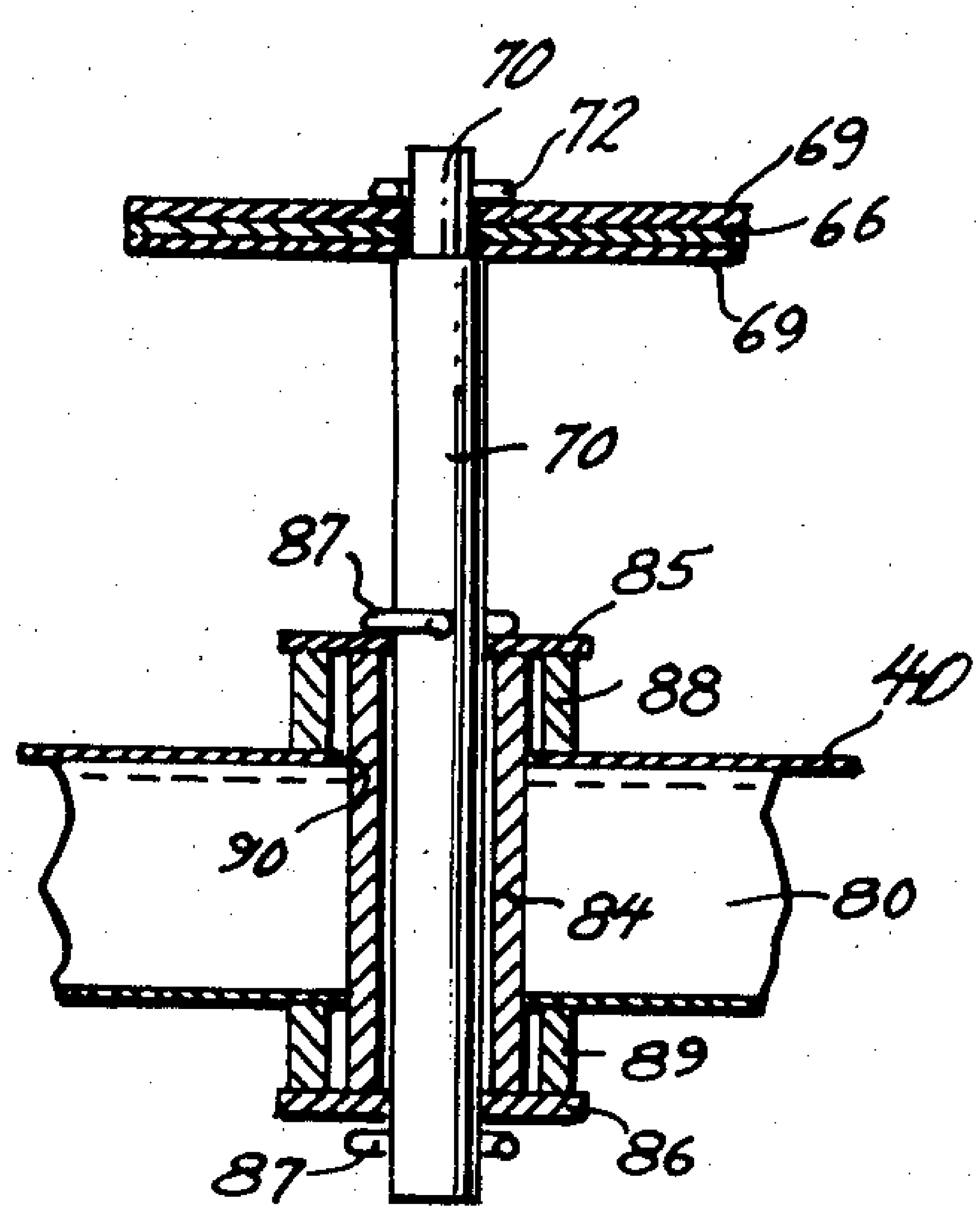


Fig. 9

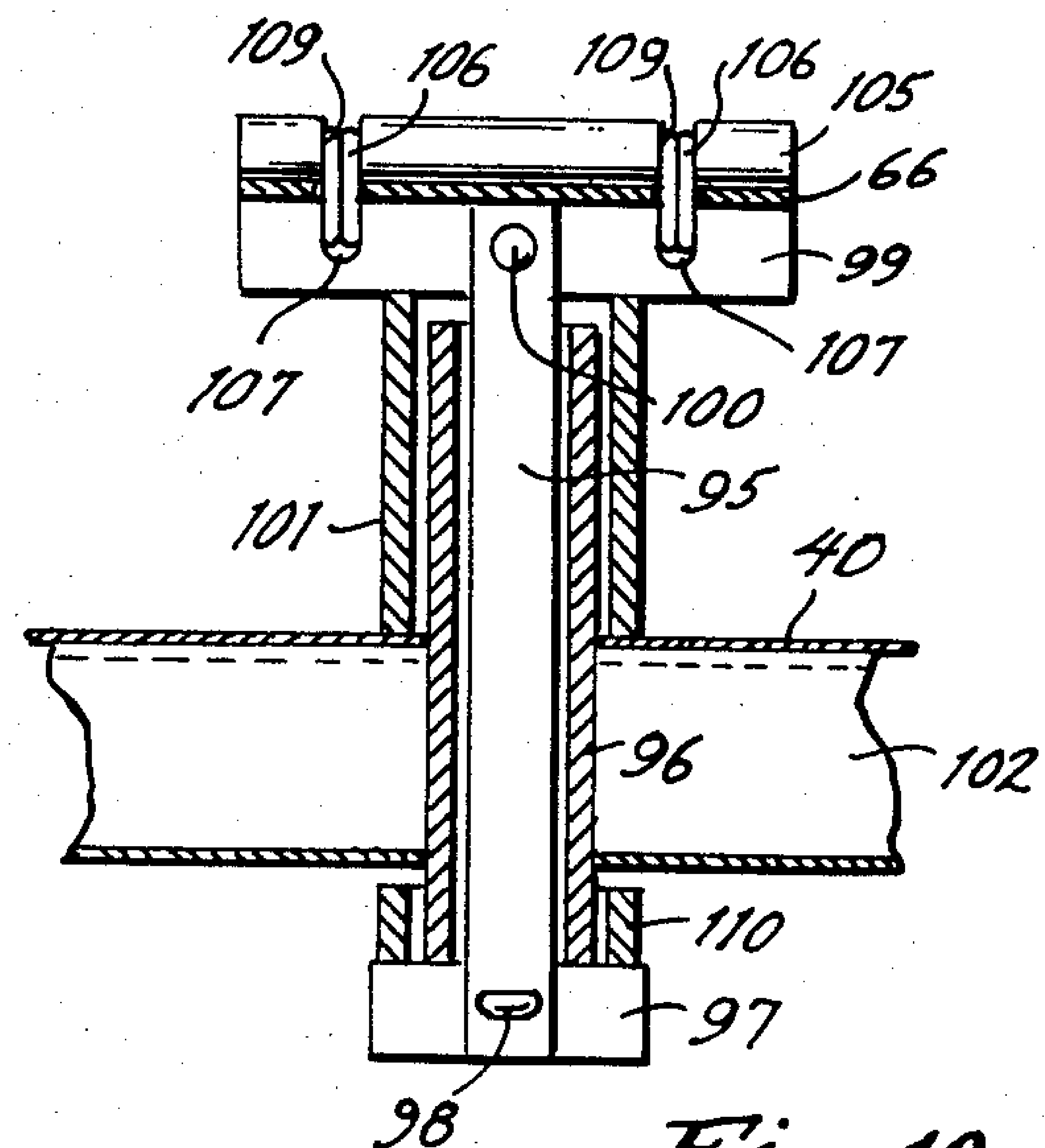


Fig. 10

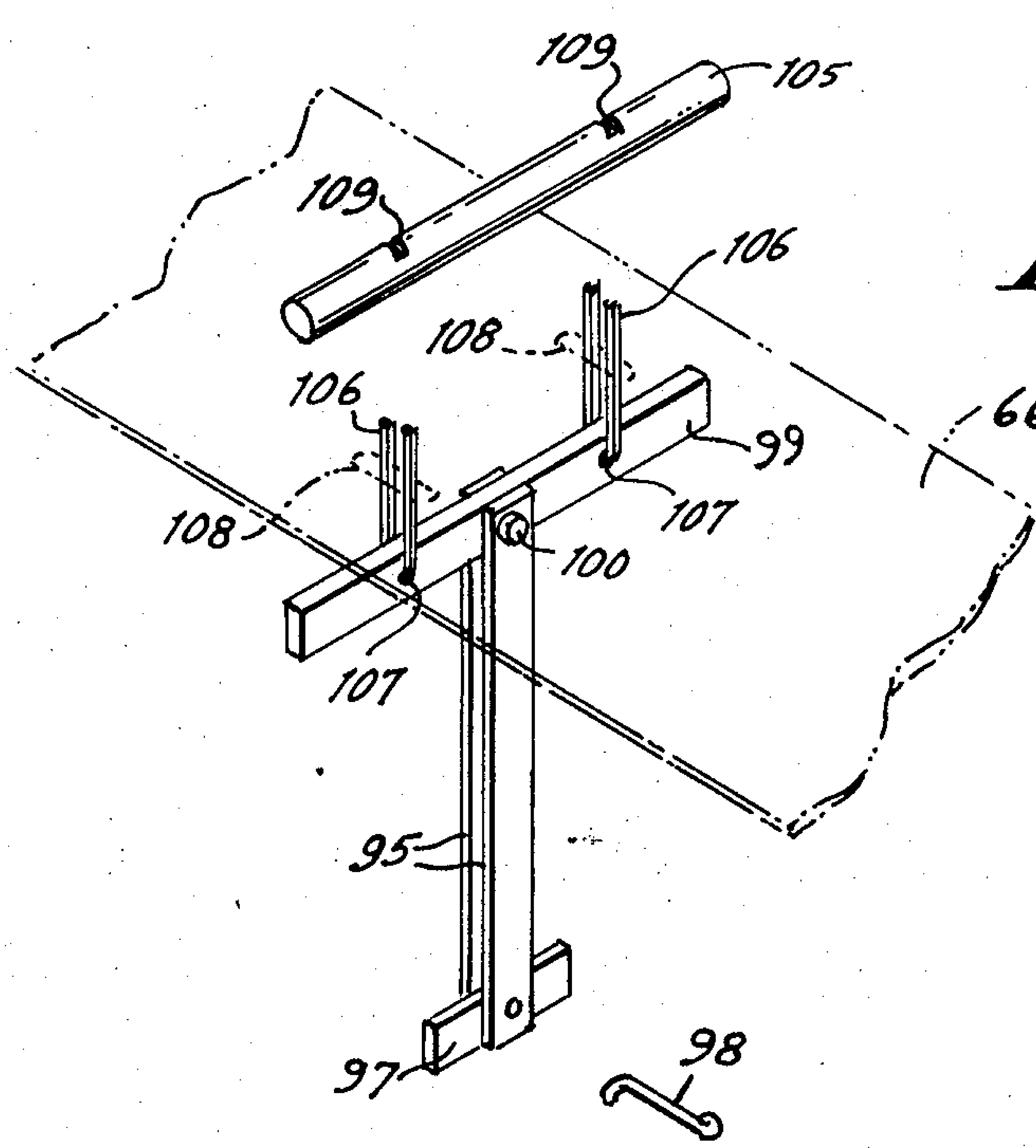


Fig. 11

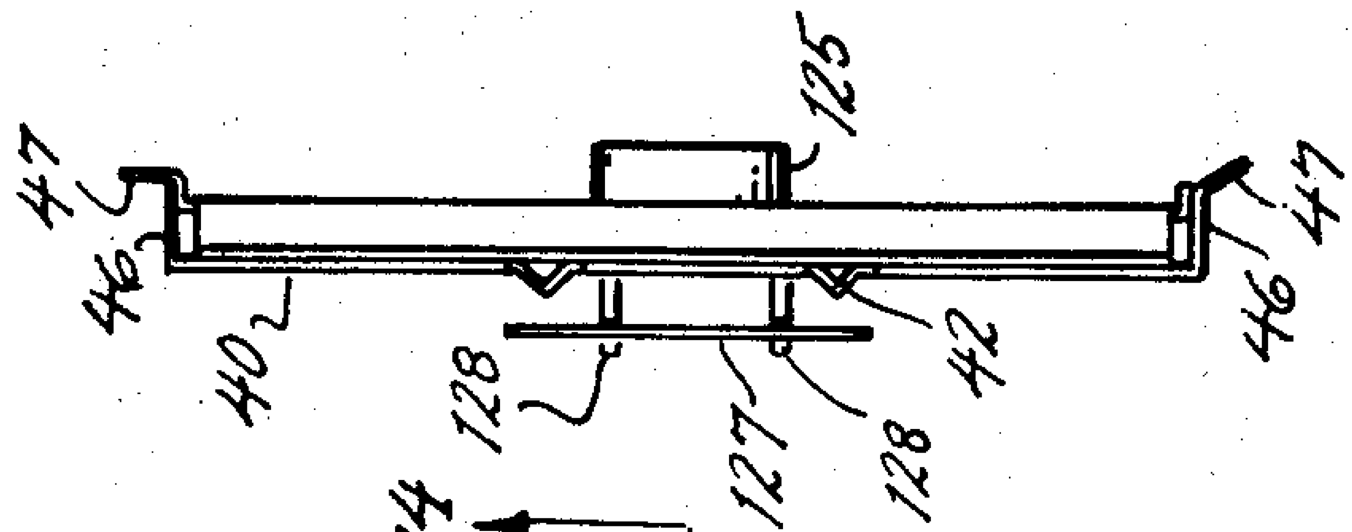


Fig.13.

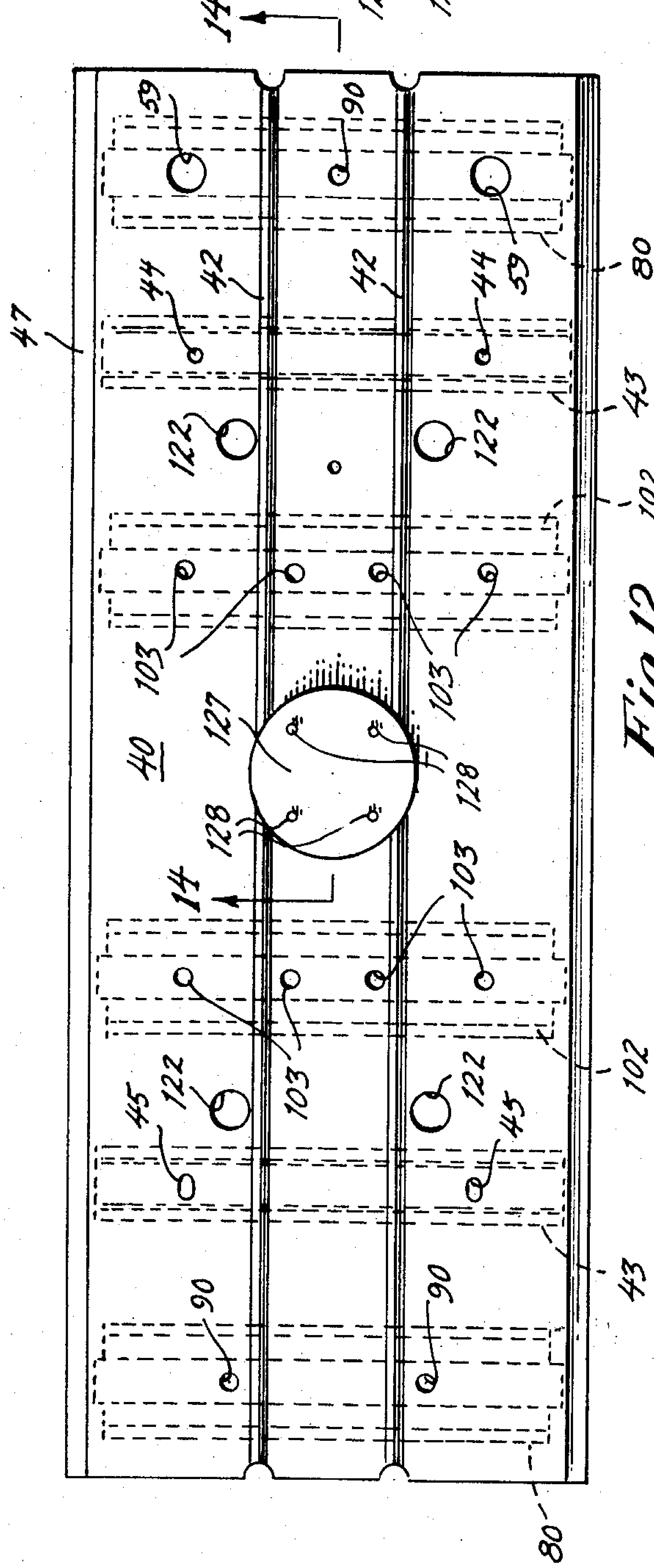


Fig.12.

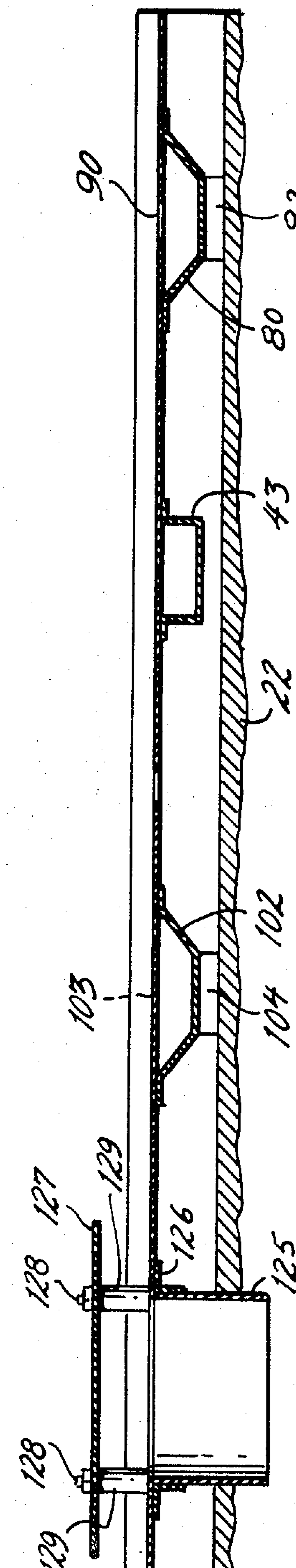
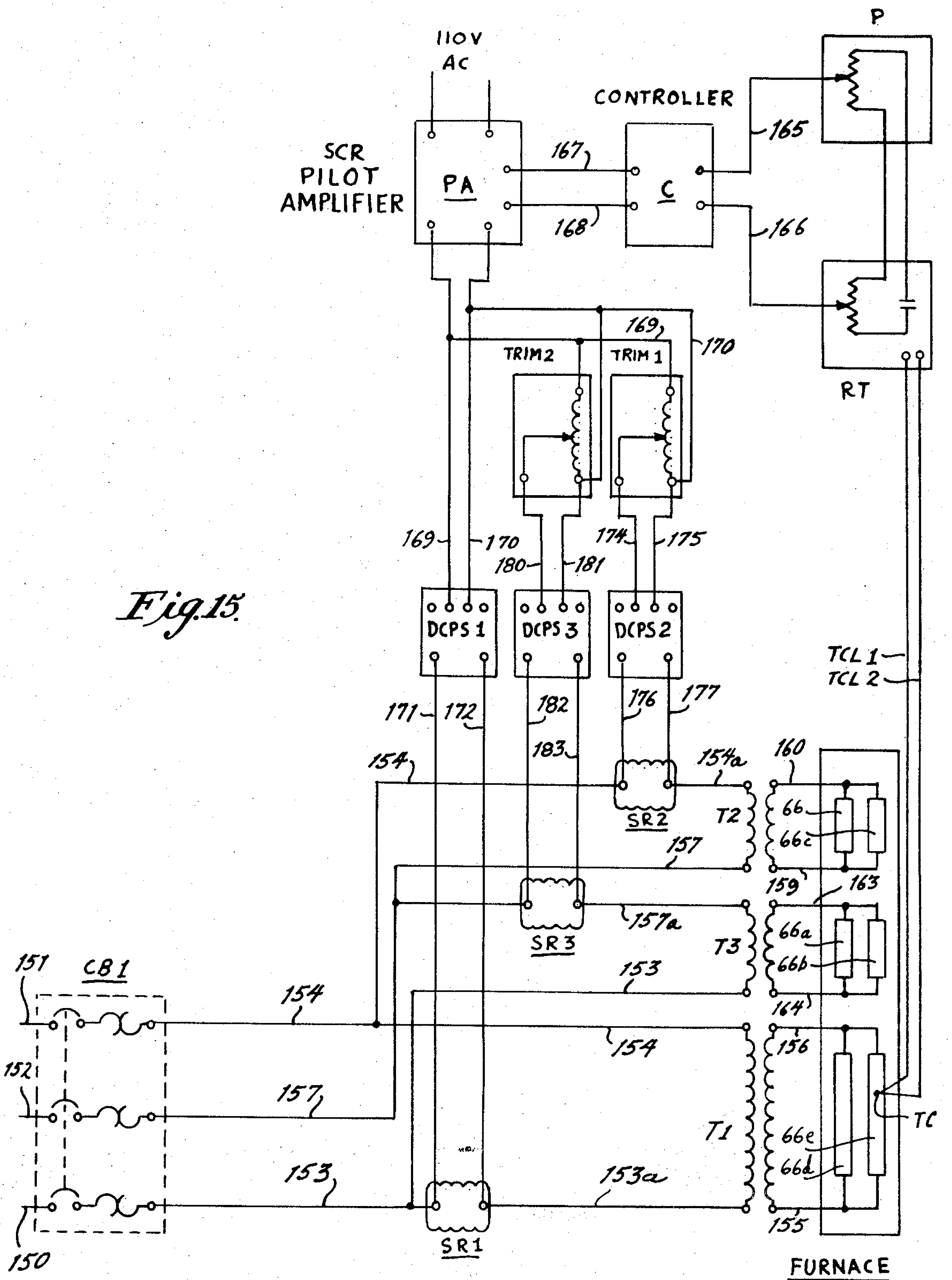


Fig.14.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TRIM 1
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170
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175
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DCPS 1
DCPS 3
DCPS 2
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176
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TCL 1
TCL 2
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154a
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SR2
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66c
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T3
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66b
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CB1
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164
154
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152
157
TC
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66d
153
153a
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SR1
155
FURNACE

Fig. 15.

VACUUM ELECTRIC FURNACE

BACKGROUND OF THE INVENTION

This invention relates to electric furnaces for vacuum operation.

DESCRIPTION OF THE PRIOR ART

It has heretofore been proposed to provide vacuum electric furnaces with shielding, conventional designs having a plurality of and usually four to eight, parallel radiation shields, which include at least seven surfaces cold enough for condensation of condensible materials. These condensation surfaces are the inner wall of the tank and the front and back of inner shields. Condensation does not usually occur on the innermost shield because of its higher operating temperature.

It has also heretofore been the accepted practice to use heavy bars or rods for constructing the heating elements with such mass that slow heating and slow cooling occurs. Such bars also do not, because of their spacing and limited area, provide uniformity of heating of the work space.

It has heretofore been the accepted practice to employ a large round of cylindrical vacuum chamber with excessive unutilized volume.

In the heating chambers heretofore employed in vacuum furnaces it has been common practice for the gases to escape by diffusion through the cracks and gaps in the shielding, this type of circulation, however, being slow.

The furnace of the present invention departs from prior practice in substantial respects so as to provide a faster operating cycle than heretofore, the heating elements and shielding elements having relatively low mass and thus low thermal inertia thereby permitting quick heating and cooling.

SUMMARY OF THE INVENTION

In accordance with the invention a vacuum electric furnace is provided in which the vacuum chamber is preferably rectangular in cross section to eliminate wasted interior space, preferably has a full front opening door for access to the interior, the chamber being water cooled, and valved for high speed vacuum pumping, the six walls having thin low mass heating elements substantially covering their surfaces, the temperatures of these heating elements being closely controlled, with programming of the energization of the heating elements, and with thin low mass shields surrounding the hot zone and arranged for gas escape without radiation escape to avoid condensation on the shields. The thermal losses inherent in a furnace having a single shield, as described, is compensated for by a faster response to heating and cooling due to low thermal inertia of the shielding and heating elements.

BRIEF DESCRIPTION OF THE DRAWINGS

The nature and characteristic features of the invention will be more readily understood from the following description taken in connection with the accompanying drawings forming part hereof, in which:

FIG. 1 is a front elevational view of a furnace in accordance with the invention;

FIG. 2 is a front elevational view of the interior of the furnace with the door removed;

FIG. 3 is a horizontal sectional view taken approximately on the line 3-3 of FIG. 1;

FIG. 4 is a vertical sectional view taken approximately on the line 4—4 of FIG. 1;

FIG. 5 is a vertical sectional view, enlarged, taken approximately on the line 5—5 of FIG. 2;

FIG. 6 is a fragmentary sectional view, enlarged, taken at the area 6 of FIG. 2;

FIG. 7 is a fragmentary sectional view, enlarged, taken at the area 7 of FIG. 2 and illustrating one of the terminals;

FIG. 8 is a fragmentary sectional view, enlarged, taken at the area 8 of FIG. 2 and illustrating one of the work support pins;

FIG. 9 is a vertical sectional view, enlarged, taken approximately on the line 9—9 of FIG. 2;

FIG. 10 is a vertical sectional view, enlarged, taken approximately on the line 10—10 of FIG. 2 and showing one of the bottom heating elements and its electrical terminal connection;

FIG. 11 is an exploded perspective view of the structure of FIG. 10;

FIG. 12 is a plan view of the bottom shield;

FIG. 13 is an end view of the shield shown in FIG. 12;

FIG. 14 is a longitudinal vertical sectional view taken approximately on the line 14—14 of FIG. 12; and

FIG. 15 is a schematic wiring diagram of the furnace power control.

It should, of course, be understood that the description and drawings herein are illustrative merely and that various modifications and changes can be made in the structure disclosed without departing from the spirit of the invention.

Like numerals refer to like parts throughout the several views.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now more particularly to FIGS. 1 to 14 of the drawings, the furnace in accordance with the invention includes a metallic tank 20 having spaced parallel horizontal top and bottom walls 21 and 22, spaced parallel vertical side walls 23 and 24, and a vertical rear wall 25 connecting the top, bottom and side walls 21, 22, 23 and 24 in vacuum tight relation.

The walls of the tank 20 are of sufficient thickness to withstand the forces to which they are subjected under vacuum and when internally heated. The tank 20 has a front vertical peripheral flange 26 formed thereon.

A vertical front door 27 is provided, hingedly carried on brackets 28 on one of the side walls, such a side wall 23, with hinge pins 29 engaged by hinged brackets 30 on the door 27, and held in closed position by a clamp 31. Shims 32 may be employed on the hinge pins 29. Any suitable packing or gasket 33, such as an O-ring, can be provided to prevent leakage when the door 27 is in closed position on the tank 20.

The walls 21, 22, 23, 24 and 25 and the door 27 are preferably cooled by tubing secured thereto on the exterior and through which liquid for cooling is circulated. Such cooling structure is well known in the electric furnace art and the tubing and fluid circulating and control system have been omitted in the interest of clarity.

The tank 20 can be supported in any desired manner in spaced relation to the floor.

The bottom wall 22, at a plurality of spaced locations, is provided with vertically extending heat shield mounting pins 35 (see FIG. 6) with lower surrounding enlargements **36** having upper and lower retaining washers **37** and **38** and retainer wires **39** penetrating the pins **35** for retention.

A heat radiation shield **40** composed of a single thickness flat plate portion of reflective material and preferably of stainless steel 0.015 inches thick has spaced longitudinal stiffening ridges **42** thereon and transverse box stiffeners **43** secured thereto on their undersides. The upper portions of the mounting pins **35** extend upwardly through openings **44** and **45** in which the washers **37** are disposed, the openings **45** being elongated to accommodate expansion and contraction. The lower faces of the box stiffeners **43** rest on the washers **38**.

The shields **40** have side rims **46** with outwardly extending flanges **47** for overlapping relation with other flanges to reduce reflective leakage at their margins, as hereinafter explained.

The bottom wall **22** (see FIG. 7) also has a plurality of inserts **50** with openings **51** therethrough for the reception of heating element mounting pins **52** which provide exteriorly accessible terminals. The pins **52** at their outer ends are seated in contact pin blocks **53** which are mounted on the inserts **50** by bolts **54** in threaded engagement therein. The blocks **53** are electrically insulated from the inserts **50** by insulating packing gaskets **55** which also prevent vacuum leakage at these locations. The block **53** in FIG. 7 is shown as having an electrical conductor **160** mounted on a stud **74** and held by a nut **75** for supplying electrical energy for heating the heating element.

The bolts **54** are electrically insulated from the inserts **50** and blocks **53** by cylindrical gaskets **56**, circular gaskets **57** and washers **58**.

The heating element mounting pins **52** extend through clearance openings **59** in the heat shield plate **40**. The inner or upper ends of the pins **52** are slotted for the reception of brackets **60**. The brackets **60** are held in place by bolts **61** which also carry brackets **62** to which reflective shields **63** are secured to shield the clearance openings **59** against radiation leakage.

The heating elements on the bottom wall **22** comprise a plurality of thin flat strips **66** of suitable resistance material, preferably of sheet nickel or nickel alloy, four strips being shown, and which may be 0.005 inches by 2½ inches.

The combined exposed area of the strips **66** facing the working space in the furnace and in which the work pieces are disposed is preferably in a range from 40 percent to 80 percent of the interior surface of the bottom wall **22**. A smaller area of heating surface gives rise to hot spots in the furnace and lack of uniformity of heat application to the work piece and variable temperature gradient where uniformity is desired.

The heating elements as described provide for rapid transfer of energy to the work with uniform heating. The high resistance of the relatively thin sheet nickel elements enables rapid heating and fast thermal response for dynamic temperature control at low temperatures of the order of **1000** degrees F, and permit obtaining furnace temperatures, if desired, of the order of 2,150° F.

The same area relationship of heating elements and shielding elements is preferably maintained on the other walls **23, 24, 25** and **21** and the door **27**.

In a specific embodiment an exposed area of heating element to wall area of 60 percent has been found to be quite satisfactory.

The first strip **66** is secured at one end to the bracket **60** by bolts **67** which extend through clamping plates **68** and at its other end extends between upper and lower supporting plates **69** carried on a supporting pin **70** (see FIG. **9**). The supporting plates **69** (see FIGS. **3** and **9**) are held in engagement with the ends of the first and second strips **66** by bolts **71** and retainer wire **72.**

The supporting pin **70** is supported by the plate **40** and a transverse box stiffener **80**, a similar box stiffener **80** being provided near the other end of the plate **41.**

The box stiffener **80** has a flange **82** at each end (see FIG. **14**) to space it upwardly from the floor **22.**

In order to locate the supporting plates **69** with respect to the shield plate **40**, and electrically insulate the strips **66** therefrom (see FIG. **9**) an inner insulating sleeve **84** is provided surrounding the pin **70**, engaged at the top with an upper disc **85** and at the bottom with a lower disc **86**, the discs **85** and **86** being limited by retainer wires **87**. Outer insulating sleeves **88** and **89**, are interposed respectively between the disc **85** and the sheet **40** and between the bottom of the box stiffener **80** and the disc **86.**

The insulating sleeve is accommodated in an opening **90** in the sheet **40.**

The second strip **66** and the contiguous end of the third strip **66** are similarly supported, and insulated, the opening **90** in the sheet **40** for the pin **70** at the right being shown on FIG. **12.**

The other end of the third strip **66** and the contiguous end of the fourth strip **66** are supported and insulated in a similar manner with the second end of the fourth strip **66** having a terminal connection as previously described and illustrated in FIG. **7.**

The strips **66** are preferably supported and electrically insulated from the wall **22** intermediate their ends (see FIGS. **10** and **11**) by rectangular supporting rods **95** which have an inner insulating sleeve **96** and an outer insulating sleeve therearound. The sleeves **96** and **110** bear on a transverse arm **97** held together by retainer wires **98.** The upper ends of the rods **95** have a cross arm **99** secured thereto by fasteners **100**, such as rivets. The cross arm **99** is held in spaced relation to the shield plate **40** by the outer upper insulating sleeve **101.** The plate **40** has box stiffeners **102** through which the rods **95** and sleeves **96** extend, the plate **41** having openings **103** for this purpose.

The box stiffeners **102** have a spacing flange **104** similar to flange **82** (see FIG. **14**).

A lower insulating sleeve **110** surrounding the sleeve **96** is interposed between the bottom of the box stiffener **102** and the transverse arm **97.**

The cross arm **99** has clamping rods **105** thereabove, and retainer wires **106** extending through opening **107** in the arm **99**, through longitudinally elongated openings **108** in the strips **66** and into notches **109** in the rods **105** (see FIG. **11**). The openings **108** accomodate expansion and contraction of the strips **66** upon change of temperature.

In order to support the work and/or work supports within the furnace the bottom wall **22** (see FIG. **8**) at the desired locations has vertical work pins **115** carried in sockets **116** on horizontal base plates **117.** The plates **117** are held in place, with washers **118** therebelow, by studs **119** welded to the bottom wall **22** and extending through the plate **117**, and having nuts **120** and washers **121** thereon.

The work pins **115** extend through openings **122** in the plate **40** and between strips **66**.

The bottom wall **22** is also provided with a central gas admission opening (see FIGS. 4 and 14) for cooling gas admission connected to a valve controlled fluid connection **123** and above the bottom wall **22** a gas duct **125** communicating therewith is secured to the sheet **40** by a flanged ring **126**. A radiation shield and baffle **127** is held by bolts **128** and spacers **129** is spaced relation above the plate **40**.

The side walls **23** and **24** each have heat radiation shields **40***a* and **40***b*, similar to the heat shield **40**, with vertical longitudinal stiffening ridges **42***a* and **42***b*, transverse box stiffeners similar to the box stiffeners **43**, transverse box stiffeners similar to the box stiffeners **102** and upper and lower transverse box stiffeners similar to the box stiffeners **80**.

The heat shields **40***a* and **40***b* are held with respect to the side walls **23** and **24** in a manner similar to that previously described for the heat shield **40** by mounting pins 35a and 35b.

The side walls **23** and **24** also have heating element mounting and terminal pins **52***a* and **52***b*, similar to the mounting pins **52**, extending through the heat insulating shields **40***a* and **40***b*, for supporting heating element strips **66***a* and **66***b*, similar to the strips **66**, with supporting pins **70***a* and **70***b* for the intermediate ends of the strips **66***a* and **66***b*, and intermediate supporting rods **95***a* and **95***b*, and associated structure, similar to the rods **95**, for supporting the strips **66***a* and **66***b* intermediate their ends.

The top wall **21** has a heat radiation shield **40***c*, similar to the heat shield **40**, with vertical longitudinal stiffening ridges **42***c*, and transverse stiffeners similar to the box stiffeners **43** and **80**, and a box stiffener **102**.

The heat shield **40***c* is held with respect to the top wall **21** in a manner similar to that previously described for the heat shield **40** by mounting pins **35***c*.

The top wall has heating element mounting and terminal pins **52***c*, similar to the mounting pin **52** extending through the heat insulating shield for supporting heating elements strips **66***c* with supporting pins **70***c* for the intermediate ends of the strip **66***c*, intermediate supporting rods **95***c* and associated structure for supporting the strips **66***c* intermediate their ends.

The top wall **21** is also provided with a central gas outlet opening for cooling gas discharge, connected to a valve controlled fluid connection **133** and below the top wall **21** duct **135** communicating therewith is secured to the shield **40***a* in a manner similar to the duct **125** and with a baffle **127***c* similar to the baffle **127** (see FIGS. 2 and 4).

The door **27** on the interior thereof, has a heat radiation shield **40***d*, similar to the heat shield **40**, but made in three vertical sections with overlapped joints **137** to accommodate expansion, with ribs **42***d*, box stiffeners similar to the box stiffeners **43** and **80**, and with a central box stiffener **102**d corresponding to the box stiffener **102**.

The heat shield **40***d* is supported by pins **35***d* similar to the pin **35**.

The door **27** has heating element mounting pins **52** extending through the shield **40***d* for supporting heating element strips **66***d* similar to the strips **66** but of a width of the order of five inches, with end supporting pins **70***d*, and an intermediate supporting rod **95***d*.

The rear wall **25**, on the interior thereof, has a heat radiation shield **40***e*, similar to the shields **40** and **40***d*, and like the heat shield **40***d* made in three vertical sections with overlapped joints **137** to accommodate expansion, and with horizontal box stiffeners **80***e* and **102***e*, similar to the box stiffeners **80** and **102**.

The heat shield **40***e* is held with respect to the rear wall in a manner similar to that previously described by mounting and terminal pins **35***e*.

The rear wall **25** has a heating element mounting pin **52***e* extending through the shield **40***e* for supporting heating element strips **66***e*, similar to the strips **66** but with widths corresponding to the widths of the strips **66***d*, and with supporting pins **70***e* and an intermediate supporting rod **95***e* for securement of rods **105***e*.

The rear wall **25** has an opening **140** aligned with an opening **141** in the rear baffle **40***e* for the reception of a baffle **142** which is optically dense but has very low resistance to gas flow.

The baffle **142**, as shown in FIG. **5**, includes a plurality of superposed horizontally disposed inverted V-shaped baffle walls **143**, the front margins of each wall **143** extending downwardly at least as far as the upper margin of the wall **143** of the baffle element therebelow. The baffle **142** is mounted on rods **144** which are secured in forwardly extending clips **146** carried by the rear wall **25** (see FIG. **2**).

The baffle walls **143** are spaced apart for gas movement through the baffle **142** but by reason of their overlap interpose a barrier to thermal radiation from the interior of the tank **20**.

It will be noted in FIG. **3** that the heat shields **40***a* and **40***e*, **40***e* and **40***b*, **40***b* and **40***d*, and **40***d* and **40***a* have their vertical rims and flanges **47** in overlapped relation and in FIG. **4** that the heat shields **40** and **40***d*, **40***d* and **40***c*, **40***c* and **40***e*, and **40***e* and **40** have their horizontal rims and flanges **47** in overlapped relation to block the escape of thermal radiation from the interior.

A valve controlled fluid exhaust connection **145** connects the interior of the tank **20** to an exhausting system of any desired type to quickly achieve and maintain the desired vacuum within the tank **20**. Such system can include motor driven roughing and holding pumps and a diffusion pump if desired.

Referring now to FIG. **15**, a schematic wiring diagram is shown which for furnace power control includes a connection through input leads **150, 151** and **152**, from a source of three phase current and through a circuit breaker **CB1**.

The power supply for the heating elements can be obtained in any desired manner such as by the use of variable reactance transformers or saturable core reactors, the latter being hereinafter specifically referred to.

One phase is preferably connected by conductors **153, 153***a* and **154** to the primary winding of a step down transformer **T1** with the conductor **153***a* connected through a saturable core reactor **SR1** to vary the output of the transformer **T1** as required.

The secondary of the transformer **T1** is connected by conductors **155** and **156** to the mounting pins **52** at the opposite ends of the door mounted heating element strips **66***d* and the rear wall mounted heating element strips **66***e* so that these strips act together.

Another phase is preferably connected by conductors **154, 154***a* and **157** to the primary winding of a step down transformer T2 with the conductor **154** connected through a saturable core reactor SR2 to vary the output of the transformer T2 as required.

The secondary of the transformer T2 is connected by conductors **159** and **160** to the mounting pins **52** at the opposite ends of the top wall mounted heating element strips **66***c* and the bottom wall mounted heating element strips **66** so that these strips act together.

The remaining phase is preferably connected by conductor **153** and **157, 157***a* to the primary winding of a step down transformer T3, with the conductor **157, 157***a* connected through a saturable core reactor SR3 to vary the output of the transformer T3 as required.

The secondary of the transformer T3 is connected by conductors **163** and **164** to the mounting pin **52** at the opposite ends of the side wall mounted heating element strip **66***a* and **66***b* of the side walls **23** and **24** so that these strips act together.

A thermocouple TC is provided in the interior of the tank **20** and is preferably secured to one of the rear wall mounted heating element strips **66***e* so as to "see" the working space, and about half the distance between the top and bottom of the strip **66***e*, and at a location in from the interior of a side wall, such as side wall **24.** A suitable location is on the second strip **66***e*, from the right at the location marked TC. The leads TCL from the thermocouple TC can extend rearwardly in the space between the first and second strips **66***e* from the right, rearwardly and upwardly, and through a suitable sealing glad in the top wall **21.**

The thermocouple leads TCL1 and TCL2 preferably are connected to a temperature recorder and controller RT for recording the actual furnace temperature and for providing a process variable voltage and a programmer P can be utilized providing a set point voltage for making available through conductor **165** with the signal from the temperature recorder RT through conductor **166** as inputs to a controller C, having proportional band, rate response and reset.

The controller C provides a control signal through conductors **167** and **168** to an SCR pilot amplifier PA. From the power amplifier PA conductor **169** and **170** are connected to a direct current power supply DCPS1 from which a variable d-c voltage (rectified a-c signal) is made effective through conductors **171** and **172** to the saturable core reactor **SR1** to control the output of the transformer **T1.**

The controller C also provides a signal through conductors **174** and **175** through an autotransformer trimmer TRIM **1,** for adjustment, to a direct current power supply DCPS2 from which a variable d-c voltage is made effective through conductors **176** and **177** to the saturable core reactor SR2 to control the output of the transformer T2.

The controller C also provides a signal through conductor **180** and **181,** through an autotransformer trimmer TRIM **2,** for adjustment, to a direct current power supply DCPS3 from which a variable d-c voltage is made effective through conductors **182** and **183** to the saturable core reactor SR3 to control the output of the transformer T3.

The power input to the respective heating element strips in pairs can thus be controlled so that the desired temperature as called for by the programmer P can be attained and maintained for the desired time period.

Upon the completion of the operation in the furnace, the furnace can be backfilled with dry inert nitrogen or argon, the furnace opened and the work pieces removed.

The low mass of the heating strips **66** to **66***e*, and of the radiation shields **40** to **40***e*, permits rapid cooling.

Where the furnace is reloaded, the low mass of the heating elements **66** to **66***e* permits rapid heating with evacuation effected with minimized loss through the baffle **142** to which the entire interior space within the radiation shields **40** to **40***e* is accessible. No withdrawal through relatively impervious walls is required.

We claim:

1. A vacuum electric furnace comprising

a closed tank having a plurality of enclosing walls and a removable closure wall providing in the interior a working space,

each of the said walls having a self-sustaining reflective radiation shield member spaced inwardly therefrom,

means carried by said walls for supporting said shield members,

each of said shield members having spaced inwardly therefrom a resistance heating element with terminal ends and comprising flat strips of metal covering a substantial portion of the corresponding shield member, and

means carried by each of said shield members for supporting said resistance heating elements at a plurality of spaced locations.

2. A vacuum electric furnace as defined in claim **1** in which

the exposed area of said heating elements is in the range of from 40 to 80 percent of the exposed area of the radiation shield members.

3. A vacuum electric furnace as defined in claim **1** in which

said heating elements each comprises a plurality of parallel strips disposed in a plane bounding the working space in the furnace.

4. A vacuum electric furnace as defined in claim **1** in which

each of said shield members for each wall comprises a single thickness of reflective metal.

5. A vacuum electric furnace as defined in claim **1** in which

means is provided for controlling the energy supplied to said heating elements, and

said means includes temperature responsive sensing means in the interior of said tank.

6. A vacuum electric furnace as defined in claim **5** in which

said temperature responsive sensing means has a portion secured on the inward facing portion of one of the strips.

7. A vacuum electric furnace as defined in claim **1** in which

the marginal edges of each of said shield members are in meeting relation to the marginal edges of contiguous shield members.

8. A vacuum electric furnace comprising

a closed tank having a plurality of enclosing walls and a removable closure wall providing in the interior a working space,

each of said walls having a radiation shield member spaced inwardly therefor,

each of said shield members having spaced inwardly therefrom and carried thereby a resistance heating element with terminal ends and comprising flat strips of metal covering a substantial portion of the corresponding shield member, and

the shield member of one of said walls having an opening therethrough closed by an optically dense fluid flow baffle for gas withdrawal therethrough.

9. A vacuum electric furnace as defined in claim **8** in which

said baffle member includes a plurality of parallel walls angularly disposed with respect to the contiguous shield member to permit rapid discharge of gas therethrough and with their respective edges disposed to block passage of thermal radiation through said baffle.

10. A vacuum electric furnace as defined in claim **1** in which

said enclosing walls comprise opposite parallel vertical side walls, horizontal top and bottom walls, a vertical rear wall and said removable closure wall is a front wall.

11. In combination

a flat radiation shield member of a single thickness of reflective metal for attachment to a furnace wall, and

a resistance heating element in spaced relation to and secured to said shield member comprising a plurality of flat parallel strips of metal with their edges in closely spaced relation,

said shield member being self-sustaining and having stiffening portions extending between marginal edges thereof.

12. The combination defined in claim **11** in which each of the heating strips is of a single thickness of metal.

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