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(71) **Demandeur/Applicant:**
LEE, ANDREW O., US

(72) **Inventeur/Inventor:**
LEE, ANDREW O., US

(74) **Agent:** ROBIC

(54) **Titre :** PROCEDE ET APPAREIL DE VALORISATION DES DECHETS
(54) **Title:** REFUSE DERIVED BRIQUETTE GASIFICATION PROCESS AND BRIQUETTING PRESS

(57) **Abrégé/Abstract:**

Urban waste is compressed into briquettes that can subsequently be gasified to produce fuel gas, which can subsequently be used to produce electricity and steam. Combustible refuse is fed into a briquetting machine. High compression is used in forming the briquettes to drive out much of the attendant water and produce a briquette that is resistant to decomposition. These briquettes can be used immediately or can be stored for relatively long periods of time before use. When the briquettes are gasified, the resulting fuel gases are of sufficiently high quality that they can be ignited and used to drive a jet turbine for producing electricity and subsequently to create steam. The steam so created can itself be used to drive electricity-generating turbines, or can be used as process steam in whatever capacity necessary.

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**(71) Applicant and**
**(72) Inventor: LEE, Andrew, O.** [US/US]; 6866 Crow Wing Lake Road SW, Ft. Ripley, MN 56449 (US).

**(74) Agent: BRUESS, Steven, C.**; Merchant & Gould P.C., P.O. Box 2903, Minneapolis, MN 55402-0903 (US).

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# REFUSE RECLAMATION PROCESS AND APPARATUS

## Background

The safe disposal of domestic and industrial waste is becoming increasingly important. A primary consequence of increasing mass consumption is the enormous and constantly growing volume of waste, particularly solid waste generated in urban areas. In years past, much of this waste was simply placed in landfills. Unfortunately, landfills containing unprocessed waste produces substantial problems such as ground water pollution, reduced property values and rodent infestation.

Sanitary landfills are somewhat more palatable from an ecological standpoint. Sanitary landfilling involves forming alternating layers of garbage and earth. Composting is a similar process in which bacteria present in the soil utilize the organic portion of the garbage as food. Essentially, this is one's backyard compost pile on a much larger scale. Composting, or bacterial decomposition, is a relatively slow process that is not well-suited to the production of waste in large metropolitan areas. Existing landfills are reaching capacity, yet new sites are increasingly difficult to find. Further, urban waste often contains highly toxic, non-degradable materials. As a result, the disposal of refuse in landfills or by composting is subject to a wide range of regulatory problems.

Other alternatives include controlled combustion of the refuse, with attendant utilization of the heat released. These processes typically gasify organic materials either by incineration, which is partial combustion, or by pyrolysis, which is a thermal decomposition of the materials involving indirect heating. Conventional incineration, while alleviating some of the problems associated with landfills, unfortunately can produce significant air pollution. Further, the resulting ash may not be biologically inactive and therefore may require landfilling or composting.

Pyrolysis is a process in which organic matter is decomposed and thermally cracked in an oxygen-deficient atmosphere at temperatures below about 600°C. Relatively low temperatures limit dispersion and oxidation of the heavy metals present within the waste material. As waste moves through a pyrolysis zone, the organic materials are vaporized and rise into a combustion zone. The resultant combustion produces the heat necessary to melt any heavy metals present within the waste. The heat released can be captured for use in producing electricity and steam, while the molten slag is quenched in a water bath.

Because such materials are typically rather voluminous relative to their energy energy content per unit of volume and a form that is readily adaptable to gasification. A particular form that has been found to be desirable is a puck-like briquette. Such briquettes may be stored and/or gasified by themselves or in combination with various other fuels in a gasification unit. Alternatively, it may be necessary to adapt an available furnace to be compatible therewith.

One type of commercially available equipment for forming such briquettes is a machine produced by the SPM Corporation. This equipment generally includes an apparatus having a power-driven flywheel that operates in conjunction with a crank shaft and connecting rod to transfer power, via a crosshead assembly, to a compression ram. Waste matter entering a compression chamber is compressibly rammed into an uncooled, split, forming die and wherefrom the compressed material exits via a clamped split-die assembly.

In using equipment of the above type, however, problems have arisen in that the available assemblies have not been designed from the standpoint of facilitating normal maintenance. An improvement to the SPM Corporation machine is found in Lee et al., U.S. Patent No. 4,599,911. Lee describes a compression machine that facilitates normal maintenance via a plurality of housing covers and prolongs the time between maintenance by providing cooling at critical heat generating portions of the apparatus, by separating the ram scraper rings and oil seals and by attention to the manner in which the reciprocating ram is supported at the points of maximum load.

A need remains for an apparatus that can produce usable briquettes from urban waste in a cost effective, energy effective manner. A need remains for a process that can utilize such briquettes in a process that reduces urban waste in an economical, ecologically friendly process, capturing the available energy within the waste.

## Summary

The invention describes a process whereby urban waste, possibly including a small fraction of non-combustible material, is compressed via a high compression densification (HCD) process into briquettes that can be gasified. Waste material is fed into an HCD machine such as the machine described hereinafter. The high compression used in forming the briquettes drives out much of the attendant water from the waste material. The densification resulting from the high compression rates results in a material that is resistant to decomposition and that can produce relatively pure fuel gases upon gasification. As a result, the resulting briquettes can be used immediately or can be stored for relatively long periods of time before use.

Accordingly, the invention is found in a method for harnessing the chemical energy present in combustible refuse. This method includes compressing the combustible refuse to form solid briquettes via high compression densification, wherein the solid briquettes are storage-stable and gasifying the briquettes in a gasification unit at a temperature of at least about 1000 to 1200 °C. The briquettes can be gasified to produce fuel gases that can be vented or combusted to derive mechanical, thermal or electrical energy from the gas.

The invention is also found in an improved high compression densification apparatus that has a flywheel-driven ram slide assembly for compressively forming briquettes from combustible raw materials by compressing the raw material through a clamped, liquid-cooled, split, tapered die assembly. The improved briquette forming apparatus includes a design of the ram slide housing assembly which provides for a plurality of housing covers extending over selected portions of the assembly. One of the housings that covers the die includes a cross-member brace. In another embodiment, one of the housing covers accommodates an additional air cleaner. Periodic maintenance of the oil seals, scraper rings, ram bearings and split die is thereby facilitated. Die cooling and ram cooling are also separately achieved via respective water cooling and oil cooling systems.

## Brief Description of the Drawings

Figure 1 shows a partial perspective view of the housing of the high compression densification apparatus, less the pre-feeder assembly.

Figure 2 shows a partially sectioned, cross-sectional view taken along section lines 2--2 of Figure 1.

Figure 3 shows a perspective assembly view of the crosshead assembly.

Figure 4 shows a perspective assembly view of the ram slide assembly.

Figure 5 shows a perspective assembly view of the pre-feeder assembly.

Figure 6 shows a perspective assembly view of the split die.

Figure 7 shows a schematic diagram of the die cooling system.

Figure 8 shows a cross-sectional view taken along section lines 8--8 of Figure 2 of the split die housing.

Figure 9 taken along section lines 9--9 of Figure 2, shows a partially sectioned end view of the split die clamp assembly in its open and closed positions.

Figure 10 shows a schematic diagram of the lubrication system.

Figure 11 is a flowchart illustrating the individual steps of the waste reclamation process.

## Detailed Description

Urban waste is compressed into briquettes that can, for example, be gasified to produce high quality fuel gas that can be used to produce electricity and or steam steam. Combustible material, including urban waste, is fed into a high compression densification machine. High compression is used in forming the briquettes to drive out much of the attendant water and produce a briquette that is resistant to decomposition. These briquettes can be used immediately or can be stored for relatively long periods of time before use. When the briquettes are gasified, the resulting fuel gases are of sufficiently high quality that, if ignited, can be used to drive a jet turbine for producing electricity and subsequently to create steam. The steam so created can itself be used to drive electricity-generating turbines, or can be used as process steam in whatever capacity necessary.

It is to be understood that the term "briquette" as used herein refers to a highly compressed solid that has been subjected to a compression pressure of least about 83 megapascals. At this compression rate, small amounts of rock, glass and metal are comminuted to a sufficient degree that they will not materially affect subsequent combustion processes. The compression rate results in compacted waste material, preferably in briquette form, having an average density of at least about 640 kilograms per cubic meter, preferably at least about 960 kg/m$^3$ and more preferably at least about 1350 kg/m$^3$.

The diameter and cross-sectional profile of the briquette is determined by the particular die used in the compression apparatus and can be varied according to the intended use of the briquettes. For example, the briquettes can be circular in cross-section, or can alternatively be square or rectangular in cross-section, resulting in a brick-shaped briquette. The briquettes can also be formed in longer lengths so simplify handling and transport.

It is to be understood that the terms “refuse”, “waste” or “material” as used herein are intended to include any combustible solid waste; that is, any combustible type of municipal, industrial, commercial or agricultural waste material. Such material includes varying quantities of both organic and inorganic materials such as sawdust, paper, plastic, rubber, food waste, leaves, cornstalks and other materials frequently produced in large quantities. Preferably, the solid waste used herein contains little or no non-combustible material.

If desired, the waste material can include a substantial amount of coal and wood products. The coal can include coal dust and small particles of coal while the wood products can include sawdust, wood chips and other wood materials such as waste pulp from paper making operations. These materials can be included to increase the potential thermal energy content of the resultant briquettes.

A variety of separation techniques are known by those of skill in the art, and can readily be applied if necessary to obtain solid waste having desirable non-combustible and water contents. These techniques include, for example, separation by density, manual sorting and magnetic separation, and the like.

If necessary, a drying phase can also be used prior to compression if desired. While not required, such a moisture-reduction step may be helpful if the waste material is excessively wet. Examples of possible waste materials where a drying phase may be beneficial include food waste, which frequently has a water content of more than 50 weight percent. In fact, some refuse can contain as much as about 30 to 60 weight percent water or even higher. If so, this waste is preferably dried somewhat prior to further processing. Preferably, the solid waste has a total water content prior to compression of no more than about 12 percent water. Removing excess water reduces further processing expenditures as less mass must be compressed. However, it is preferable that the waste material have at least some water prior to compression. The heat generated during compression vaporizes much of the water present in the material. This has the effect of cooling the compression apparatus. If the material lacks sufficient water, the apparatus may require additional cooling.

If a drying step is necessary, a variety of options are available to those of skill in the art. These options include atmospheric vaporization, in which wet waste is simply exposed to ambient atmospheric conditions in either an indoor or outdoor facility. The difference in moisture content between the relatively wet waste material and the relatively dry atmosphere will drive water out of the wet waste material and into the dry atmosphere in an evaporative process. If a greater level of dryness is desired, or a faster drying process, more elaborate processes are available, including heat, forced air and compression or drainage.

Refuse typically is found in a wide variety of shapes and sizes. Consequently, the refuse used to form the solid briquettes described herein preferably undergoes two shredding steps. The first step is similar to that used typically today to treat garbage exiting a garbage truck. The raw or unprocessed waste material can be dumped into a tub grinder, which preferably grinds the waste material to an average size of about 5 centimeters. The second grinding step typically involves use of a hammer mill and results in waste material having an average size of about 1 to 2 centimeters or less. The waste material can include items of every imaginable shape, so maximum size is defined as the maximum dimension of each particle, clump or piece of waste material. Average size, therefore, is defined as the average of the maximum sizes.

During high compression densification, waste material is subjected to a compression pressure of least about 83 megapascals. At this pressure, small amounts of rock, glass and metal are comminuted to a sufficient degree that they will not materially affect subsequent combustion processes. The compression rate results in compacted waste material, preferably in briquette form, having an average density of at least about 640 kilograms per cubic meter, preferably at least about 960 kg/m$^3$ and more preferably at least about 1350 kg/m$^3$. This represents an average volume reduction of at least about 80 percent. Typical solid briquettes so produced have an average diameter of about 10 centimeters and an average thickness of about 1 to 3 centimeters. The briquettes can also be formed into logs that are about 10 centimeters in diameter and about 20 to 30 centimeters in length to simplify handling and transport.

High compression densification results in the formation of briquettes having significant storage stability, due in part to substantially reduced moisture and viable microbial contents. During compression, frictional forces produce significant heat. A portion of this thermal energy vaporizes much of the water originally present within the waste material. The heat also destroys much of the bacteria that would otherwise cause the material to biologically decompose. It has been found that briquettes processed this way are relatively odorless. Preferably, the briquettes formed are stable for up to three years.

Compression also serves to enhance the heating value of the briquettes. The compressed waste material contains heating values ranging from about 11 to 15 kilojoules per cubic centimeter of compressed waste material. Consequently, one ton of collected waste equates to about 8400 megajoules.

## Description of Process

The thermal energy values denoted above represent the chemical energy that can be released in the form of heat during combustion. Combustion is generally defined as the oxidation of carbon to carbon dioxide. Incomplete combustion produces poisonous gases such as carbon monoxide. Gasification of the briquettes takes place within a gasification unit, in which the solid briquettes are exposed to high temperature in an oxygen-deficient atmosphere that limits or even prevents combustion within the gasification unit. The gasification unit can be a simple chamber, or can be a fluidized bed reactor. An electric heater can be used to initially heat the gasification unit to the desired temperature. Preferably, gasification occurs at a temperature range of at least about 1000 to 1200 °C. More preferably, gasification occurs at a temperature greater than about 1400°C.

Once the gasification unit has reached a desired operating temperature, its temperature can be regulated by controlling the oxygen content of the air supplied to the gasification unit. Without wishing to be limited by theory, it is believed that a small portion of the fuel gas produced by gasifying the solid briquettes is at least partially combusted within the gasification unit. This produces the heat necessary to maintain the gasification unit at constant temperature without addition of electric heat beyond the initial startup process. Depending on the particular parameters such as volume of solid briquette, oxygen consumption rate and the like, it may even be necessary to provide a certain level of cooling to the gasification unit to prevent excessive combustion within the gasification unit. A water stream can be used to remove excess heat from the gasification unit. The resulting warmed water stream can itself be used as a source of heat for other processes.

The resulting fuel gases leave the gasification unit at high temperature and pressure. Consequently, these gases exit at high velocities and have a high kinetic energy. Thus, these gases can be vented or combusted to derive mechanical, thermal or electrical energy therefrom. For example, the fuel gases can be passed through a turbine that can drive an electrical generator. It has been found that igniting the fuel gases prior to entry into the turbine greatly increases the temperature and pressure of the gases, thereby increasing the kinetic energy of the gas substantially. This kinetic energy, which is essentially a result of mass in motion and which has a value represented by $KE = \frac{1}{2} mv^2$ (m represents mass while v represents velocity), is sufficient to drive a jet turbine. As noted by the equation above, the kinetic energy of the gases is proportional to the square of the velocity. Obviously, it is desirable for the fuel gases to enter the turbine at as high a velocity as possible.

The jet turbine serves to capture some of the kinetic energy of the fuel gases, converting the kinetic energy of the gas into mechanical energy (in the form of the spinning turbine blades). Electricity can be generated by operably connecting a turbine to an alternator, or generator. The alternator or generator serves to convert the mechanical energy represented by the spinning turbine into electrical energy.

Once the gases run through the turbine, the temperature and pressure of the gases will have been reduced, producing reduced energy gases. However, these reduced energy gases still have sufficient thermal energy to be useful in producing high temperature or high pressure steam. Thus, the reduced energy gases can, if desired, be thermally contacted with a source of water, whereby thermal energy transfers from the gases to the water, resulting in high temperature or high pressure steam. Preferably, this thermal contact occurs within a boiler, although a heat exchanger could also be used. Preferably, the reduced energy gases are thermally contacted with a second source of water to produce low temperature or low pressure steam.

The steam produced herein can be used for a variety of purposes. It can be used to generate additional electricity. The steam can also be used to provide heat to other processes or to partially heat a building or other facility. The steam can also be used as process steam in a number of different operations.

The overall process of the invention is illustrated in Figure 11, which is a flowchart. The process begins with refuse, or waste material at block 210. The first step in the process is to form briquettes, as indicated at block 220. The briquettes so formed represent a solid fuel 230 that can be stored as necessary at block 240. Gasification occurs at block 250, generating fuel gases. In a particular embodiment, the fuel gases are ignited at block 255 and are used to drive a turbine at block 260, followed by generating high temperature steam at block 270 and low temperature steam at block 280. Finally, at block 290, the gases have cooled sufficiently for efficient release to the atmosphere.

## Description of Apparatus

In Figure 1, a perspective assembly view is shown of the cast metal base housing 2 of a preferred embodiment of the briquette making apparatus of the invention. Base housing 2 includes a lower lying oil sump portion 4 and an overlying ram slide portion 6. Associated with the ram slide portion 6, but not shown, are right and left flywheels, along with an adjoining crankshaft assembly and which together provide motive power via an electric motor and an intermediate speed reduction transmission. Preferably, the apparatus is driven by a 100 horsepower electric motor. Pre-feeder assembly 72 supplies raw material to ram slide 6. Pre-feeder assembly 72 will be described in greater detail hereinafter.

Mounted on base housing 2 are gasketed access covers 8 and 10, which permit access to oil sump 4. Covers 12 and 14 permit access to the crankshaft assembly (not shown) and the ram slide assembly, respectively. Preferably, cover 12 includes an aperture 12a, thereby permitting installation of diesel type air cleaner 12b. Beneath gasketed cover 14 is a ram slide housing cover 16 that provides direct access to the ram slide bearings, oil seals and scraper rings (not shown). Housing cover 18 overlies the split die and permits access thereto for maintenance and clearing jam conditions.

Figure 1 illustrates a cross-member brace 18a that is positioned in front of housing cover 18 and is preferably connected at either end to the cast metal base housing 2. The cross-member brace 18a provides additional resistance to the lateral forces otherwise applied to the housing cover 18 by the reciprocating ram and split die. In a preferred embodiment, the cross-member brace 18a also helps prevent flexing or movement of one side of the base housing with respect to the other side of the base housing.

A partially sectioned, cross-sectional view taken along section lines 2--2 of Figure 1 is shown in Figure 2. This view shows detail ram slide housing portion 6 and its internal assembly in greater detail. Oil sump portion 4 principally contains the lubricating oil, oil cooler, oil heater, oil pump and filter, and will be discussed in detail hereinafter. Figure 2 will be referred to in describing the ram slide housing portion 6 and its internal assembly. Ram slide housing portion 6 is constrained to act in a horizontal reciprocating fashion to compress the raw material as it passes from the compression chamber through the split die assembly. The crankshaft 20 is shown relative to its connecting rod 22 and sleeve bearing 24. Crankshaft 20 is supported at the sidewalls of base housing 2 by respective conventionally lubricated bearing assemblies 26 (Figure 1) and, thus, crankshaft 20 rotates freely with connecting rod 22 rotating in an eccentric fashion within base housing 2. The rotary, eccentric rotation of crankshaft 20 is coupled by connecting rod 22 to crosshead assembly 28, where it is converted to a transverse horizontal movement.

Specifically, each end of connecting rod 22 is split and coupled by bolts at one end about main bearing 24 at crankshaft 20 and at the other end about a crosshead pin 30 that is contained within a sleeve bearing 32 at the crosshead assembly. Coupled, in turn, to the opposite side of crosshead 34 is a split collar 36 that receives and retains one end of ram 38. Mounted in between collar 36 and the end of ram slide 38 is a ram pressure pad 40. It should be noted that a slight tolerance mismatch of approximately 0.05 millimeters is allowed within crosshead 34 in the region between the end of ram slide 38 and pressure pad 40. This space ensures that ram 38 stays centered relative to crosshead 34, during adjustment of crosshead 34. Also, oil is circulated within this space during ram motion.

In the embodiment illustrated in the Figures, the high compression densification apparatus employs a single crankshaft 20 and a single piston or ram 38. It is envisioned, however, that the briquette making apparatus could include a crankshaft configured to drive more than one piston or ram. In an alternate embodiment, the briquette making apparatus includes a double crankshaft that drives four pistons or rams. The decision to use a more complicated crankshaft configuration and additional pistons or rams is largely economic, as a multiple piston configuration can make more efficient use of the power provided by the electric motor driving the apparatus. However, there is a tradeoff as the crankshaft configuration becomes more complicated and therefore more expensive.

A multi-piston high compression densification apparatus can be arranged and configured in several different ways. In an embodiment, each piston drives a separate compression ram. Thus, an arrangement having four pistons would be capable of producing 4 lines of briquettes or logs simultaneously. The pistons can be arranged in a flat plane, or can be arranged radially to one another. An alternate embodiment would include the use or more than one piston to drive each compression ram. This arrangement is mechanically more complicated, however.

Figure 3 illustrates a more detailed view of crosshead assembly 28 and slideway assembly 44, which includes a pair of right angled slideway members 46 that are secured to base housing 2 by bolts. Above the right and left sides of members 46 individual keepers 48 and shims 50 are mounted. The crosshead 34 is thus slidably contained beneath and between the shims 50 and upon the slideway members 46 to move with the reciprocating motion of connecting rod 22. During setup and thereafter, the thickness and width of shims 50 may be adjusted as necessary to center crosshead 34 to ram 38.

At this point, it is to be noted that a further advantage of the present equipment over previously available equipment is obtained by the use of a rectangular slideway 44 in lieu of a wedge-shaped slideway. In particular, a rectangular slideway provides, greater supporting surface area over which the vertical forces imparted to crosshead 34 from connecting rod 22 are displaced. Also, shims 50 permit the adjustment of crosshead 34 relative to any induced sideways movement. Back to Figure 2, ram 38 is contained beneath bolted ram housing cover 16 and is supported between a pair of bronze sleeve bearings 52, each of which has a spiral lubricant receiving groove 54 formed therein. A hollowed region is also provided between the bearings 52 such that as oil is injected between the bearings 52 and over the ram 38, it is caused to follow the spiral grooves 54 to individual oil return ports (not shown) opposite the ends of the bearings 52 within the hollowed region and back to the oil sump 2. Thus, the ram slide 38 is continuously bathed in oil. This acts not only to lubricate the ram 38, but also to provide an oil bath for cooling ram 38. Also, because of ram housing cover 16, an operator is now able to more easily obtain access to the sleeve bearings 52 and ram 38 for inspection and/or replacement. Due also to the radial float built into the ram/ram slide connection, crosshead 34 may be adjusted for wear without affecting the alignment of ram 38.

Mounted beneath the forward end of ram housing cover 16 is a circular, cup-shaped ram oil-sealing housing 56. It is mounted within base housing 2 via a pair of jack screws (not shown) and contains a circular oil seal 58 that mounts between the front of seal housing 56 and a backing plate 60 (Figure 4). Oil seal 58 thus surrounds the ram 38 and acts to wipe oil from ram 38 as it slides back and forth. The oil then falls to the bottom of sump housing 2, where it collects and is again filtered and pumped to the wear regions.

Figure 4 also shows a perspective assembly view of ram 38 relative to oil seal housing 56, seal 58 and backing plate 60. Figure 4 also shows a secondary scraper ring 62 mounted within the bore of oil seal housing 56 in front of oil seal 58. Like oil seal 58, scraper ring 62 surrounds the ram, but it contains a convex leading edge, such that with each return stroke, it scrapes any foreign matter adhering to ram 38 therefrom and prevents it from entering oil sump housing 2. Finally, an "O" ring

64 seals the oil seal housing 56 against leakage and separates the lubricant in sump portion 4 from the compaction chamber.

With reference to FIGS. 2 and 5 it can be seen that mounted forward of secondary oil scraper ring 62 is a pair of primary oil scraper rings 66 each of which is mounted in spaced apart axial relation to one another between individual keeper housing rings 68. Primary scraper rings 66, like secondary scraper rings 62, each have a beveled leading edge and are mounted about ram 38 such that any raw materials adhering to ram 38 are scrapped therefrom during the return stroke. However, now because of the segmentation and separation of rings 66 and 62, any residual raw material that is missed by primary scraper rings 66, is typically caught and removed by secondary scraper rings 62. Thus, because of this displacement, the life of oil seal 58 is prolonged and the problem of the build-up of foreign matter in the lubricating system is reduced. Also, loss of lubricant to the compaction chamber and the attendant soaking of the raw material is minimized, since the backsides of scraper rings 66 and 62 also tend to prevent the oil from entering the compaction chamber.

Positioned immediately forward of primary scraper rings 66 is compaction chamber 70, which is preferably a cylindrical chamber. Because only a minimal amount of clearance is provided between overlying pre-feeder assembly 72 and the lower lying cast portion of base housing 2, a minimal amount of raw materials is permitted to collect within this space. This minimizes the probability of jams that might otherwise be induced. The length of compaction chamber 70 is sized to accommodate the ram stroke and is preferably about 20 centimeters long. The stroke length may be varied as necessary, depending upon the types of raw material to be compacted and the desired briquette density as well as other variables.

Pre-feeder assembly 72 is removably mounted above compaction chamber 70 and includes a hydraulically driven auger assembly that, upon being gravity fed with combustible raw materials, conveys the materials to compaction chamber 70. It has a vertical housing 74 and has a reversible hydraulic motor 76 attached to the upper end. Motor 76, in turn, drives a centered auger blade-containing spindle 78 via an associated interconnecting bearing assembly 77 that is contained within a bearing housing 79. Raw material is admitted to housing 74 via a side-mounted chute assembly 80 where it is received by auger blades 82 and controllably supplied to compaction chamber 70. Depending upon the type of raw material and/or feed desired, auger blades 82 may be configured in a screw-like fashion or as separate angulated baffles mounted to spindle 78.

In Figure 5, a more detailed view is shown of pre-feeder assembly 72, along with primary scraper rings 66. Upon removing pre-feeder assembly 72 from ram slide portion 6 of base assembly 2, compaction chamber 70 and primary scraper rings 66 are fully exposed in much the same fashion that the removal of ram housing cover 16 exposes ram 38 and ram bearings 52. Thus, should jams occur and/or it be necessary to dismantle pre-feeder assembly 72, it may easily be disassembled from base housing 2. Also, should primary scraper rings 66 need to be inspected and/or replaced, this can be accomplished by removing them from their keeper housings 68 and spacer 67.

Returning attention again to Figure 2, mounted forward of compaction chamber 70 and pre-feeder assembly 72 is a split die 84 and its associated split die housing 86. Preferably, split die 84 includes a tubular member having a receiver section 88 with an inwardly tapered bore where the raw materials are first received from compaction chamber 70. Upon leaving receiver section 88, the partially compacted materials are forced into an elongated split snout portion 90, the inside diameter of which is controlled by a pneumatic clamp assembly 92 that mounts about split die housing 86. Specifically, snout portion 90 contains four individual elongated segments, each of which are compressively clamped by clamp assembly 92 so as to determine the final outer diameter and density of the produced briquettes.

For the present embodiment, the briquettes are produced with a hockey puck-like shape and are formed by slicing segments from the tubularly compressed raw material as it leaves the end of snout 90. To control compaction density, either the taper of receiver section 88 or the amount of clamping pressure at clamping assembly 92 may be varied since either of these changes varies the inside diameter of the material flow path and causes a change in amount of compaction that occurs as the material traverses split die 84. Considering the energy content of the raw material, the compaction density may be varied for dissimilar materials so as to produce briquettes with similar energy contents.

Mounted adjacent to and forward of pre-feeder assembly 72 is housing cover 18 which secures housing 86 to ram slide portion 6 of base housing 2. Assuming that die clamp assembly 92 has been released, and split-die housing cover 18 has been removed, the operator gains access to slit-die 84 for inspection and replacement. In particular and referring to the perspective assembly view of split die 84 and split die housing 86 in Figure 6, it may be noted that split die 84 may be removed from split die housing 86, after releasing a pair of set screws (not shown) that mount within protrusions 94 on split die housing 86. It should be noted that split die 84 can advantageously be formed from a ceramic material. Split die housing 86, like snout portion 90, contains a plurality of lengthwise slits that segment die housing 86 into the same number of segments as snout portion 90. A longitudinal central recessed region of smaller surface diameter is also provided in split die housing 86 for receiving clamp assembly 92. Individual tapped protrusions 96 at the forward end of split die housing 86, in turn, permit the adjustment of individual set screws mounted therein. Specifically, upon mounting split die 84 within split die housing 86 and positioning the housing within clamping assembly 92, hydraulic pressure is exerted on each of the segments so as to controllably reduce the diameter of the extruded materials from that of receiver section 88 to some smaller diameter. If during operation further adjustment is still required, this may selectively be applied by adjusting the set screws (not shown) within protrusions 96.

Redirecting attention to Figure 2 and to split die housing cover 18, it is to be noted that it contains a plurality of cooling channels 98 that circumscribe receiving section 88 of split die 84. Because a substantial portion of the material compression occurs in this region, the greatest amount of heat is produced here, hence the need for cooling whereby heat may be substantially removed by the circulation of a cooling fluid through the cooling channels 98.

FIGS. 7 and 8 show the die cooling system. In particular, Figure 8 illustrates that cooling channels 98 form in respective housing cover 18 and lower lying portion of ram slide portion 6. The channels 98 of each half are essentially isolated from the other half. Thus, upon removing upper cover 18, one does not have to be concerned with water spillage, other than for the connection of the water supply to the coupler (not shown) at the collar half 18. Figure 7 also shows that circulating water is supplied to split die housing 86. This is desirable since additional heat is generated as the raw material is compressed further in snout portion 90. Specifically, individual lengthwise cooling channels 100 in each of the segments of split die housing 86 circulate fluid therethrough and cool snout portion 90 of split die 84. By also coupling individual temperature sensors 99 and 101 in circuit with the water channels 98 and 100, an operator is able to monitor the temperature of the fluid and thereby the heat produced from compaction. In response thereto, either of the gate valves 104 or 105 can be opened or closed to permit greater or lesser fluid circulation to the area(s) of concern. Finally, it is to be noted from Figure 7 that fluid cooling is also provided to the lubricant within the sump housing 2. This feature will be discussed hereinafter with respect to Figure 10.

Before referring to the lubricating system, though, attention is next directed to Figure 9 which depicts a partially sectioned cross-sectional view taken along section lines 9--9 of Figure 2 and showing die clamping assembly 92 in its open and closed conditions. Specifically, the open condition is shown to the left of the vertical center line and the closed condition is shown to the right of the center line. Essentially, clamping assembly 92 includes a yoke-shaped frame weldment 110 that contains a pair of upper and lower jaws 112 and 114, each jaw having a pair of contact points for compressively contacting the mating segments of split die housing 86 and split die 84. A hydraulically actuated piston assembly 116 mounted beneath lower jaw 114 controllably opens or closes jaws 112 and 114 and causes the previously mentioned adjustment of the split die diameter. The configuration of cooling channels 100 within each segment of the split die housing 86 which allows fluid to flow through each of the individual segments can be seen in Figure 9.

Turning attention now to Figure 10, a schematic diagram is shown of the lubrication system used with the present apparatus. The briquetting apparatus described herein employs a constant pressure system with a suitable volume capacity to accommodate most typically encountered oil leakage conditions, while still maintaining a constant pressure to the leaking wear point. The apparatus described herein incorporates a constant pressure lubrication system whereby, independent of the amount of leakage, a sufficient volume of lubricant, at constant pressure, is provided to each wear point to prevent against burn out that might otherwise occur.

Because these wear points are all contained within base housing 2, any oil which leaks therefrom is returned to oil sump 4 and recirculated after being filtered.

As shown in Figure 10, the present lubrication system includes an electrically actuated starter 119 and hydraulic pump 120 that pumps oil through a suitable filter 122 into the primary distribution manifold 124. A pressure sensor 126 and a pressure relief valve 128 are included to monitor the oil pressure. Pressure sensor 126 is set at a pressure approximately 1000 kilopascals less than that of relief valve 128 and acts to monitor the oil flow from filter 122 and produce an alarm condition at a console panel 130, if the pressure rises to the threshold of sensor 126, such as might occur with a plugged filter 122. If the pressure continues to rise, pressure relief valve 128 opens and returns the oil to sump 2 and/or provides further warning to the operator and/or to shutdown the system.

Generally, though, the oil is provided at approximately 700 kilopascals to the manifold 124 and where from it is distributed, via individual conduits, to various system wear points. One wear region is the location beneath ram housing cover 16, where the lubricant is supplied in the space between ram bearings 52 and thence via spiral grooves 54 back to sump 2. Also, it is circulated about the end of ram 38 in the region of pressure pad 40 and again returned to sump 2. Individual 700 kilopascal pressure sensors 131, 133, in turn, sense the oil pressure in these regions and advise the operator by lighting an appropriate pilot light at console 130, if the pressure should fall. Additionally, oil is supplied by the oil conduits to the bearings associated with connecting rod 22 at crosshead pin 30 and crankshaft 20 and at bearing housings 26 adjacent to the flywheels. Similarly, individually associated pressure sensors at these bearings monitor the oil pressure and provide an indication if it should fall below the set-point of the sensor.

Water cooling is also provided for the oil in sump housing 2 via heat exchanger 142 (Figure 10) and through which cooling fluid is appropriately circulated once a predetermined temperature (typically 10°C) is sensed at sump oil temperature sensor 144. Also, a shut off valve 146 is provided to permit the isolation of heat exchanger 142 from the fluid cooling system. In passing, it should also be noted that for start-up conditions and temperatures below 4°C, a heater 148 may be provided in sump 2 to heat the oil before beginning operation. Thus, upon heating the oil to approximately 4°C, starter 119 is enabled and thereby pump 120 and remainder of the apparatus.

While the present invention has been described with respect to its presently preferred embodiment, it is to be recognized that various modifications may be made thereto without departing from the spirit and scope thereof. For instance, it is contemplated that a multi-nozzle version might be configured about a crankshaft having more than one eccentric and wherein a number of the foregoing improved RAM slide assemblies would produce briquettes. Generally, too, the intent of the present invention is to provide briquette forming equipment having a ram slide path that is more easily accessed to permit periodic inspection and maintenance, without having to engage in a complete or substantial disassembly of the apparatus. This is achieved via a ram slide path having a plurality of top mounted access covers in the regions of the wear points.

The above specification, examples and data provide a complete description of the manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.

**WE CLAIM:**

1. A method for harnessing the chemical energy present in combustible refuse, the method comprising steps of:

compressing the combustible refuse by high compression densification to form solid briquettes, wherein the solid briquettes are storage-stable;

gasifying the briquettes in a gasification unit at a temperature of at least about 1000°C; wherein the solid briquettes are vaporized to form a fuel gas; and

venting and/or combusting the fuel gas and deriving mechanical, thermal or electrical energy from the gas.

2. The method of claim 1 wherein electrical energy is derived by passing the fuel gas through a turbine that drives an electrical generator.

3. The method of claim 2 wherein the fuel gas is ignited prior to passing through the turbine.

4. The method of claim 1 wherein thermal energy is derived by contacting the fuel gases with a source of water to produce steam.

5. The method of claim 1 wherein thermal and electrical energy are derived by the steps comprising:

passing the fuel gas through a turbine that drives an electrical generator, thereby producing turbine exhaust gases;

thermally contacting the turbine exhaust gases with a source of water to produce high temperature steam and reduced energy gases; and

thermally contacting the reduced energy gases with a source of water to produce low temperature steam and further reduced energy gases.

6. The method of claim 5 wherein the further reduced energy gases are at a temperature and pressure that can be safely vented to atmosphere.

7. The method of claim 5 wherein the step of thermally contacting the turbine exhaust gases with a source of water comprises use of a boiler.

8. The method of claim 5 wherein the step of thermally contacting the reduced energy gases with a source of water comprises use of a boiler.

9. The method of claim 1 wherein the combustible refuse is compressed at a pressure of at least about 83 megapascals.

10. The method of claim 1 wherein the solid briquettes are can be stored for up to about 3 years without further drying.

11. The method of claim 1 wherein the solid briquettes have a density of at least about 1350 kilograms per cubic meter.

12. The method of claim 1 wherein the solid briquettes have an energy content of about 11 to 15 kilojoules per cubic centimeter.

13. A high compression densification apparatus comprising:

an enclosed housing having a sump portion containing a lubricant and at least one overlying multi-segmented ram slide portion having a lengthwise bore;

an elongated ram slidably mounted within the bore of said ram slide portion for reciprocating movement therein;

means coupled to said ram for providing reciprocating motive power thereto;

means for controllably supplying combustible raw materials to a compaction chamber displaced along the bore of said ram slide portion;

die means receiving said raw materials from said compaction chamber and having a tapered bore of larger diameter at the end adjacent to said compaction chamber than at an output end for compressively extruding said raw material into a predetermined shape, upon exiting said output end, in response to the reciprocating movement of said ram;

a plurality of detachable housing covers overlying said ram slide portion and forming a part of said lenthwise bore and said compaction chamber, each of said housing covers being individually detachable from said ram slide portion for permitting access to regions subject to wear located along said ram slide portion, thereby facilitating the maintenance of said apparatus; and

a cross-member brace positioned to brace a housing cover positioned over the die means.

14. The apparatus of claim 13, wherein one of said covers comprises an aperture suitable to accept a diesel type air cleaner.

15. The apparatus of claim 13, further comprising first and second sleeve bearings mounted beneath a first of said plurality of housing covers in concentric relation to said ram, each of said sleeve bearings having a lengthwise bore including a spiral groove for directing lubricant from a region between said first and second sleeve bearings to the opposite ends of said first and second sleeve bearings, thereby lubricating and cooling said ram during its reciprocatory motion.

16. The apparatus of claim 15, further comprising oil seal means mounted in said ram slide portion forward of said first and second sleeve bearings in concentric relation to said ram for wiping oil from said ram during its reciprocatory motion and thereby preventing said lubricant from entering said compaction chamber; and first and second means axially displaced along said ram slide portion in concentric relation to said ram between said oil seal means and said compaction chamber for scraping raw material during each return stroke of said ram so as to prevent said raw material from entering said sump portion of said housing.

17. The apparatus of claim 13 wherein said means for controllably supplying combustible raw materials comprises:

an elongated tubular housing detachably mountable to said compaction chamber, said tubular housing having an opening whereat said combustible raw material is received; and a motor-driven spindle centrally disposed within said tubular housing, said spindle having a plurality of auger plates mounted therealong for receiving and conveying said raw material to said compaction chamber.

18. The apparatus of claim 17, further comprising means for sensing the pressure on said raw material in the region of said compaction chamber for controllably reversing the direction of rotation of said spindle upon detecting a first predetermined pressure and for resuming the forward rotation of said spindle after a predetermined delay period, thereby self-clearing jams from said compaction chamber.

19. The apparatus of claim 13, wherein a first of said plurality of housing covers overlies a portion of said die means, said first housing cover having a plurality of hollow coolant circulating channels contained therein the dissipating heat generated during the compacting of said raw material.

20. The apparatus of claim 19 also including coolant channels in said ram slide portion disposed beneath said first housing cover and wherein said coolant channels within said first housing cover and the underlying portion of said ram slide are separate of one another.

21. The apparatus of claim 13, wherein said die means includes an elongated die housing having a plurality of lengthwise slits and a central bore within which an elongated, slit tubular die having a tapered bore is mountable and also includes means for individually compressing the slit segments of said die and die housing to vary the diameter of said bore, said die housing further including coolant circulating channels within each of said segments for removing heat generated within said die during the compaction of said raw material.

22. The apparatus of claim 13, further comprising means for providing said lubricant to wear points at a constant pressure.

23. The apparatus of claim 21, including means disposed in said sump housing for cooling said lubricant.

24. The apparatus of claim 13, further comprising a rectangular crosshead slide assembly coupling said ram to a flywheel driven crankshaft assembly, said crosshead slide assembly including a pair of elongated right angled slidway members, a plurality of shims and a pair of keeper members for adjustably mounting said crosshead slide assembly relative to said ram and said slide portion.

25. The apparatus of claim 24 wherein said crosshead slide assembly includes a hollow pressure pad receiving region at the end of said ram and relative to which said ram is resiliently mounted and whereat lubricant may be received.

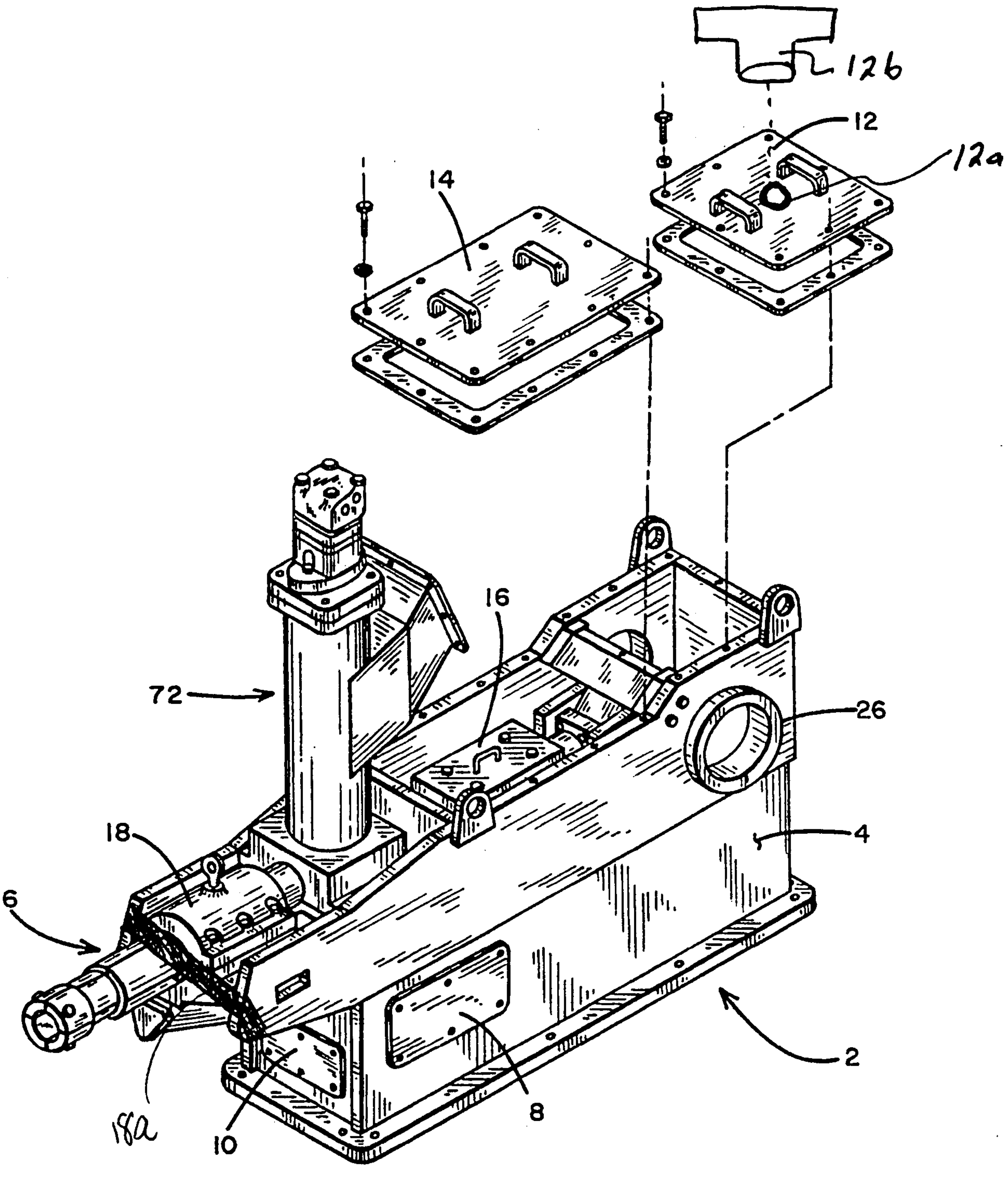

Fig. 1

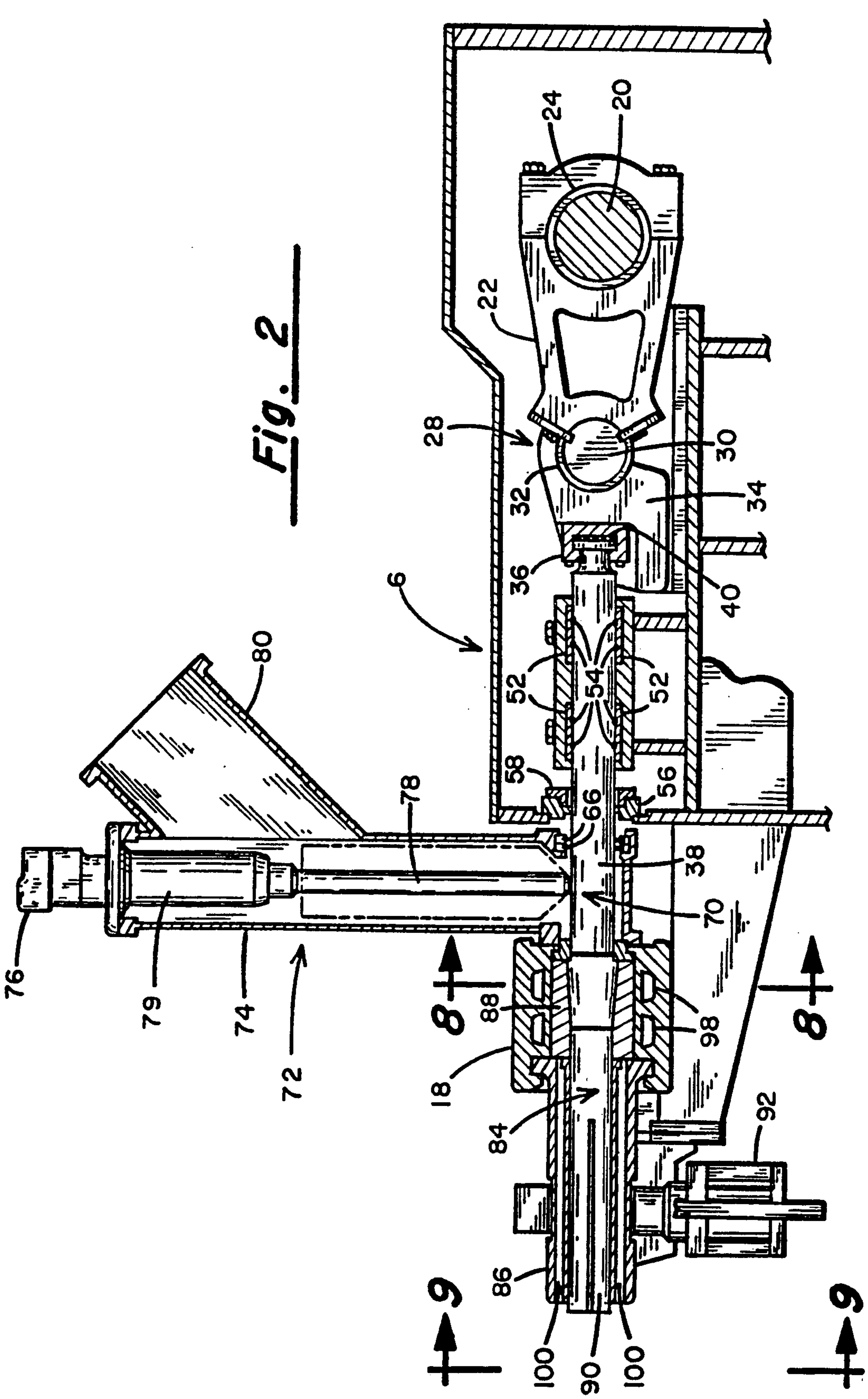
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Fig. 2

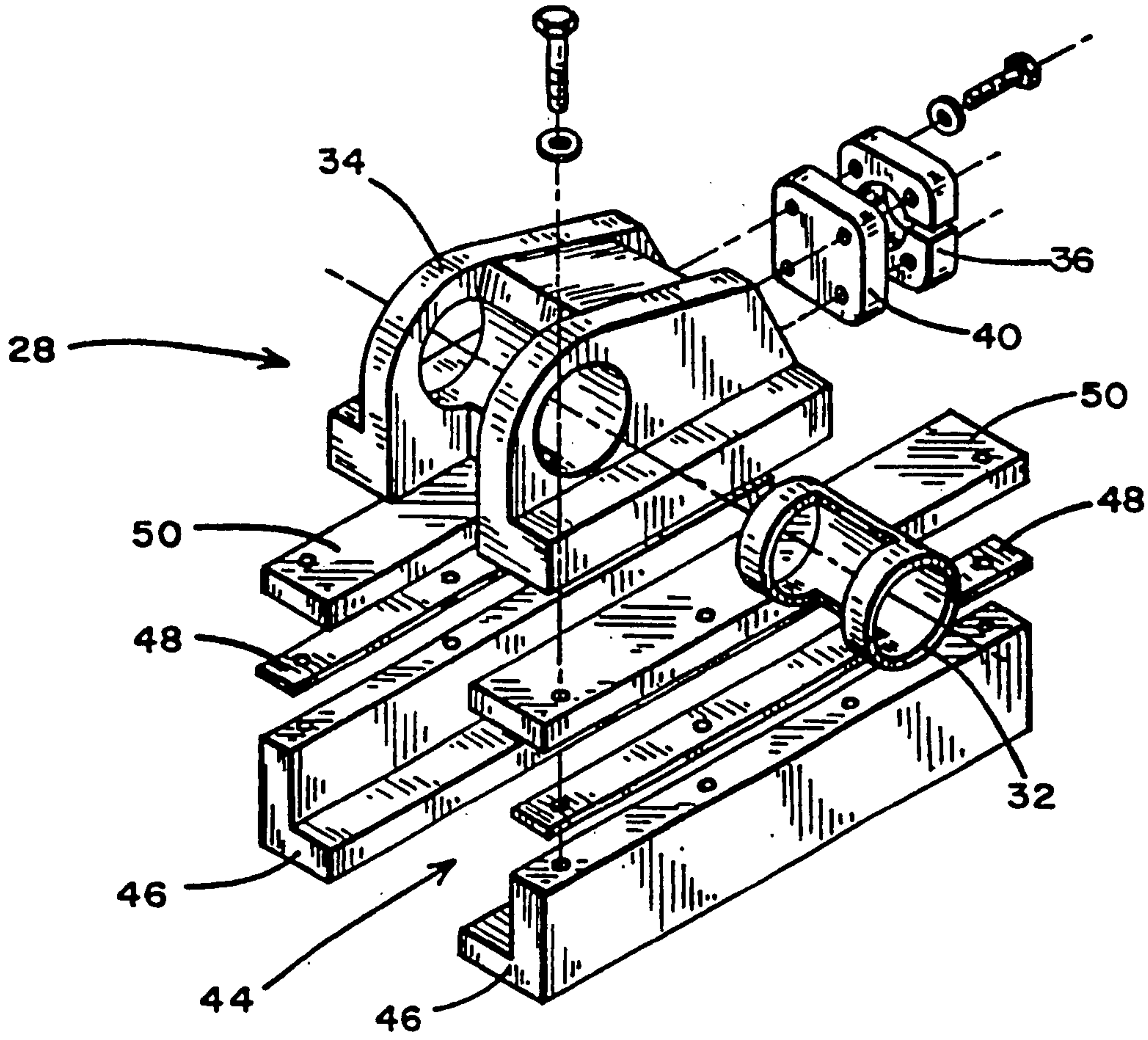


Fig. 3

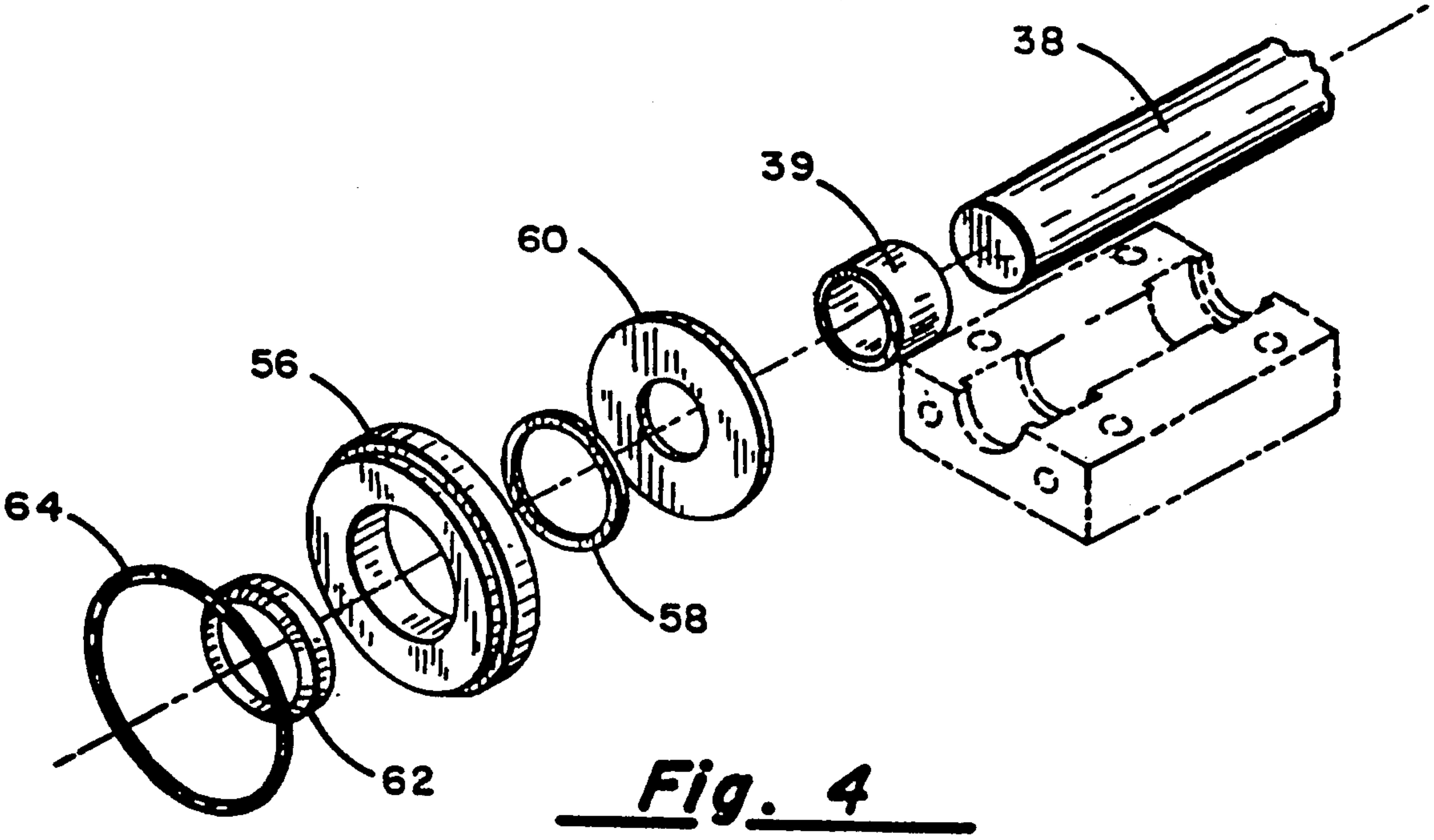


Fig. 4

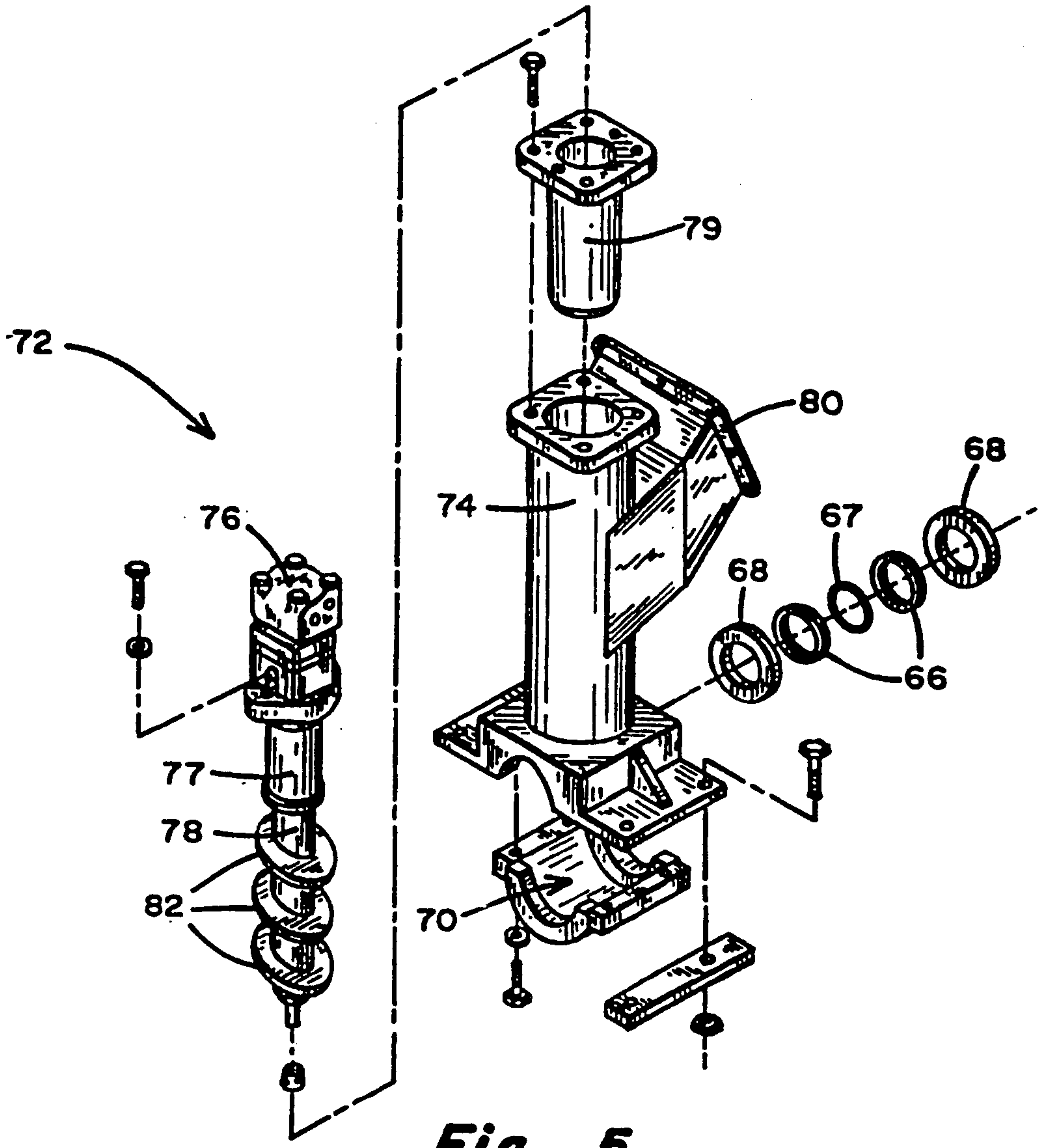


Fig. 5

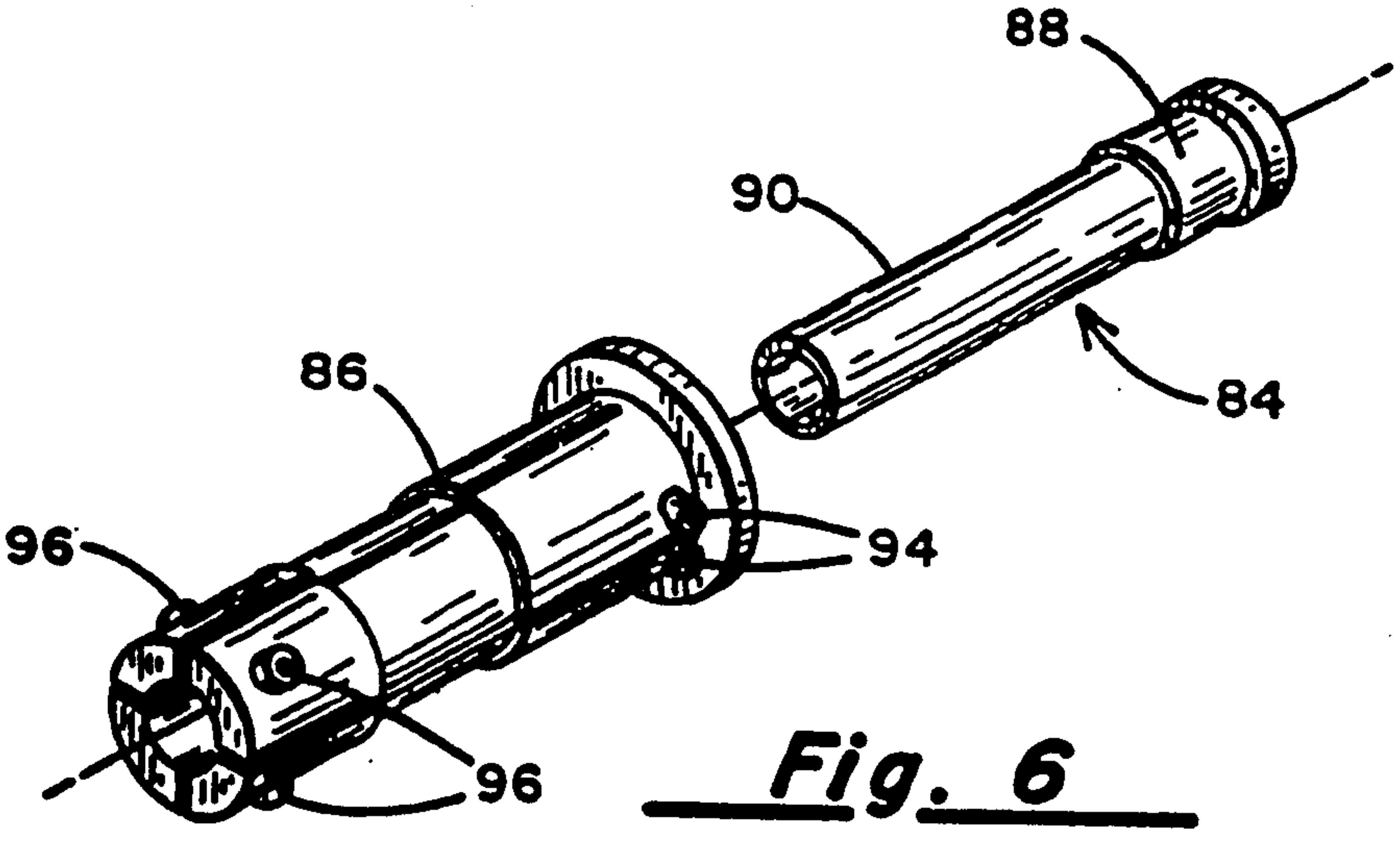
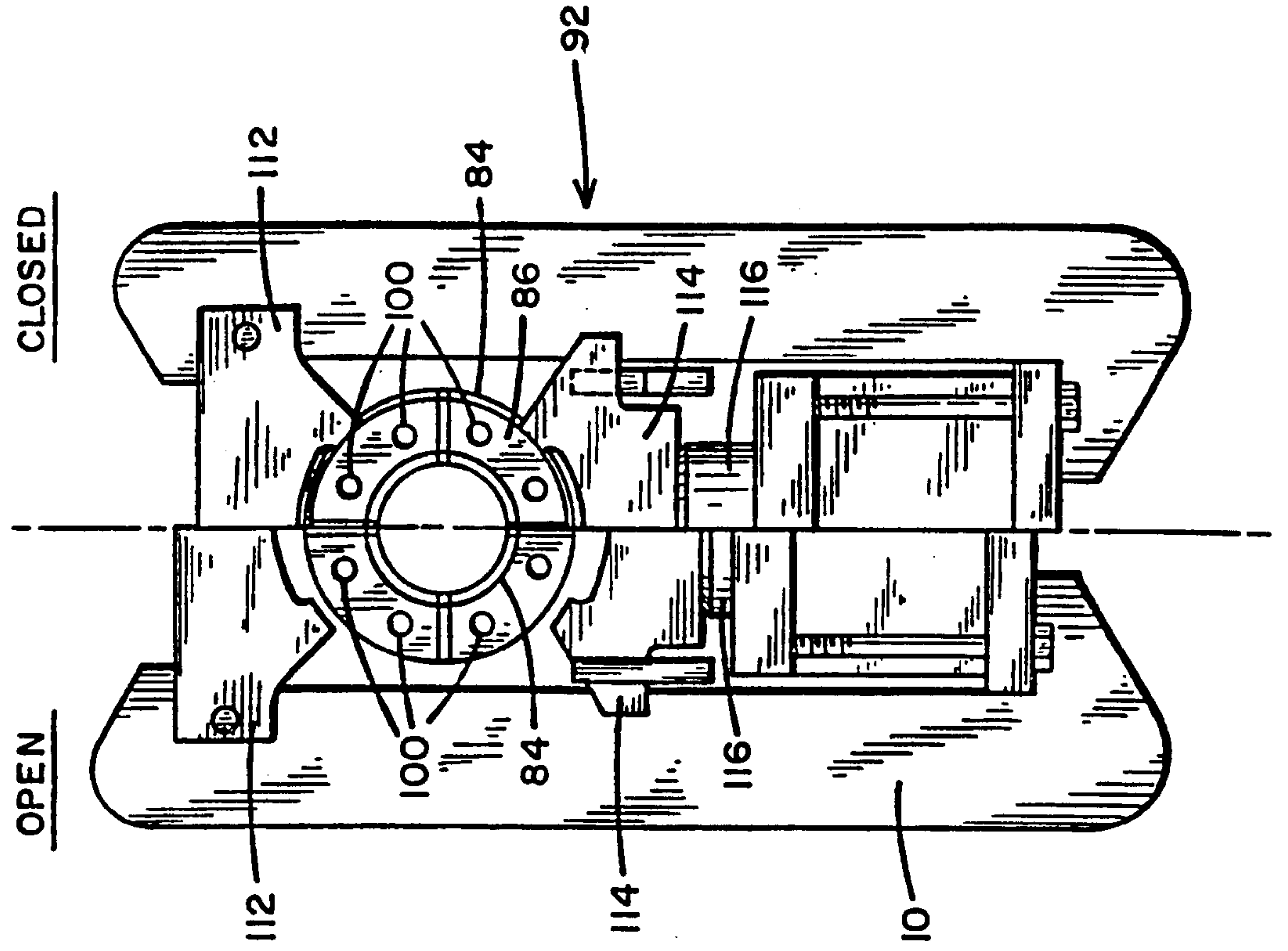


Fig. 6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OPEN
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112
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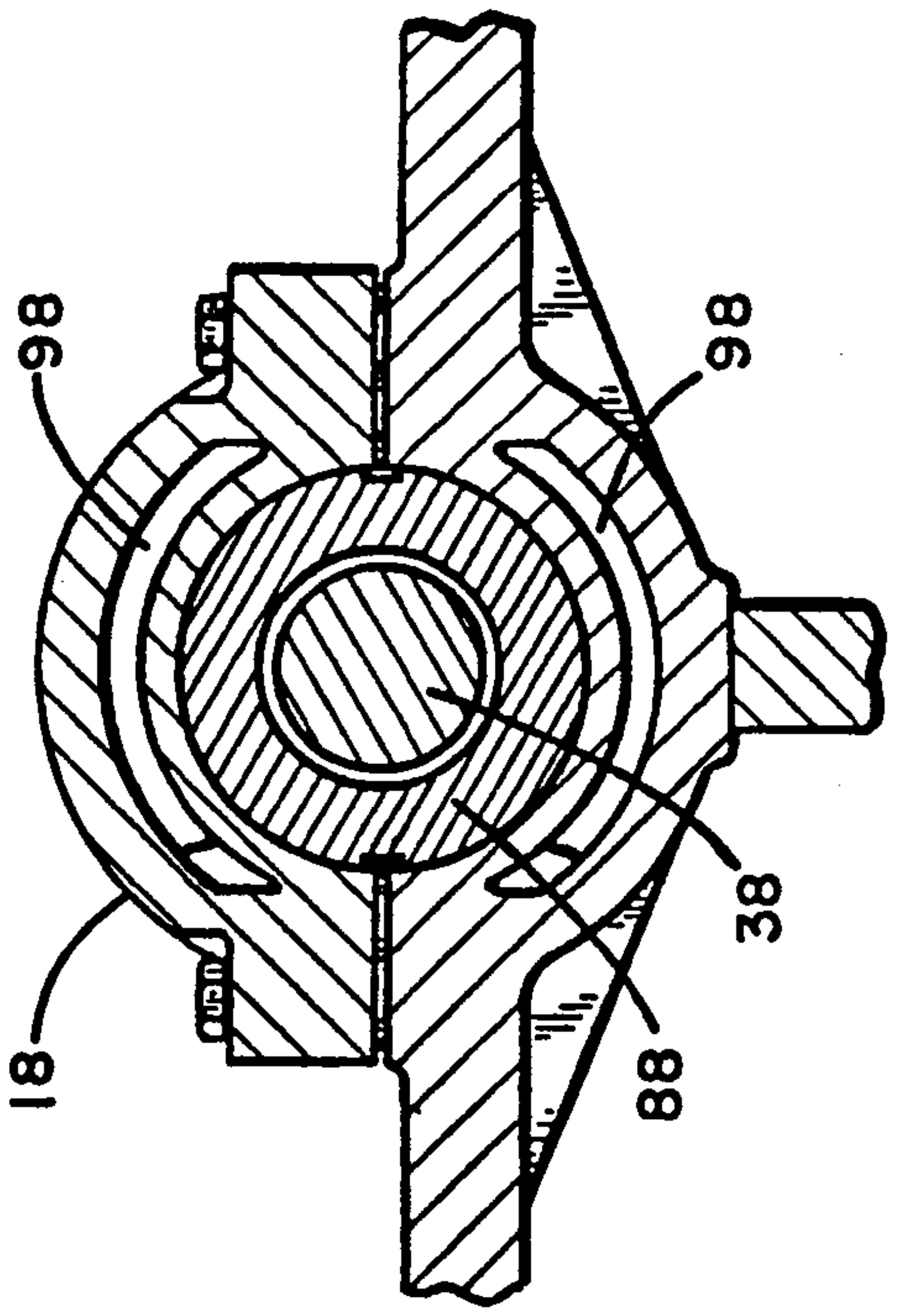
100
86
114
116
112
100
84
114
116
10

*Fig. 9*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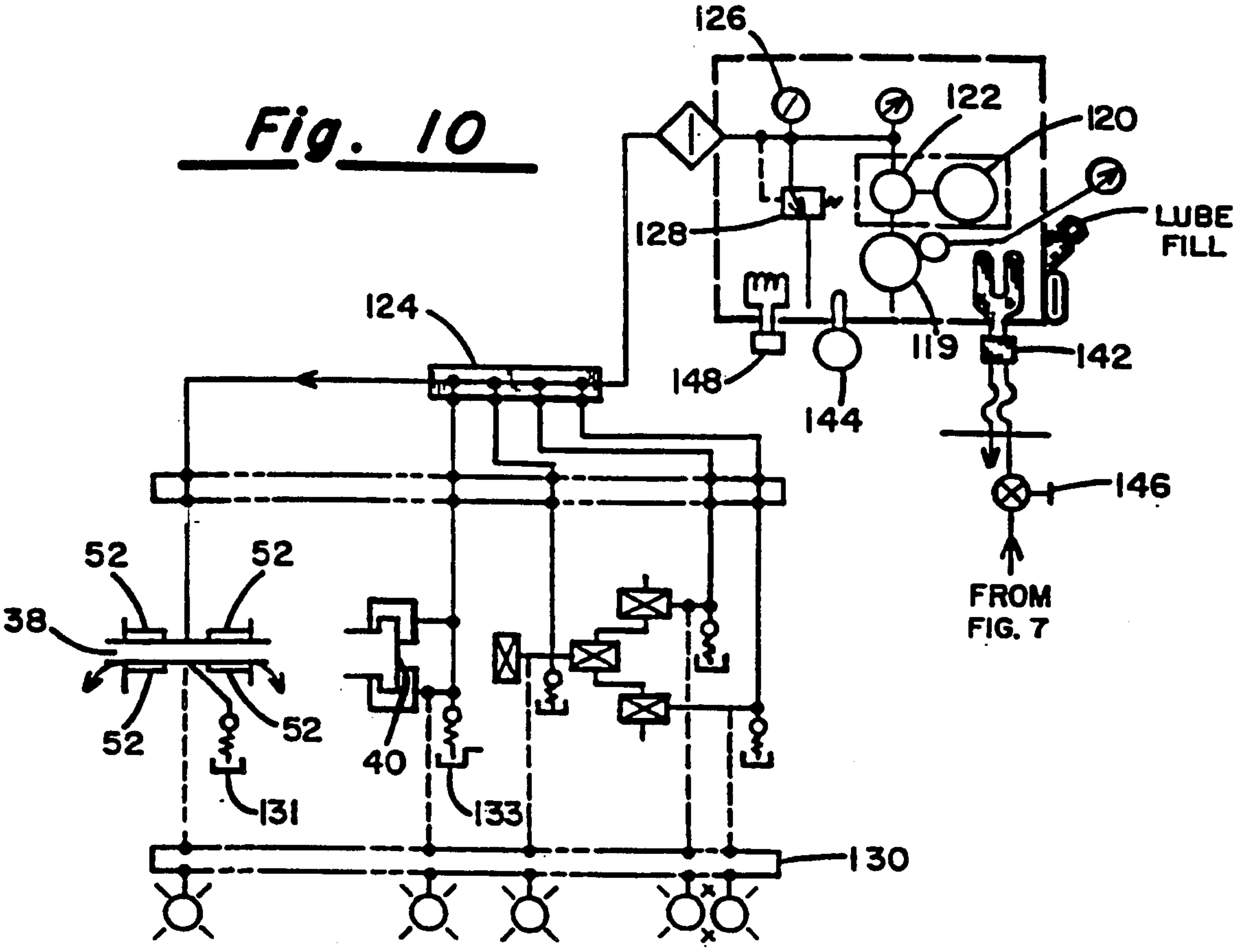
98
18
88
38

*Fig. 8*

Fig. 10


126
122
120
128
LUBE
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142
148
144
146
FROM
FIG. 7
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52
38
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52
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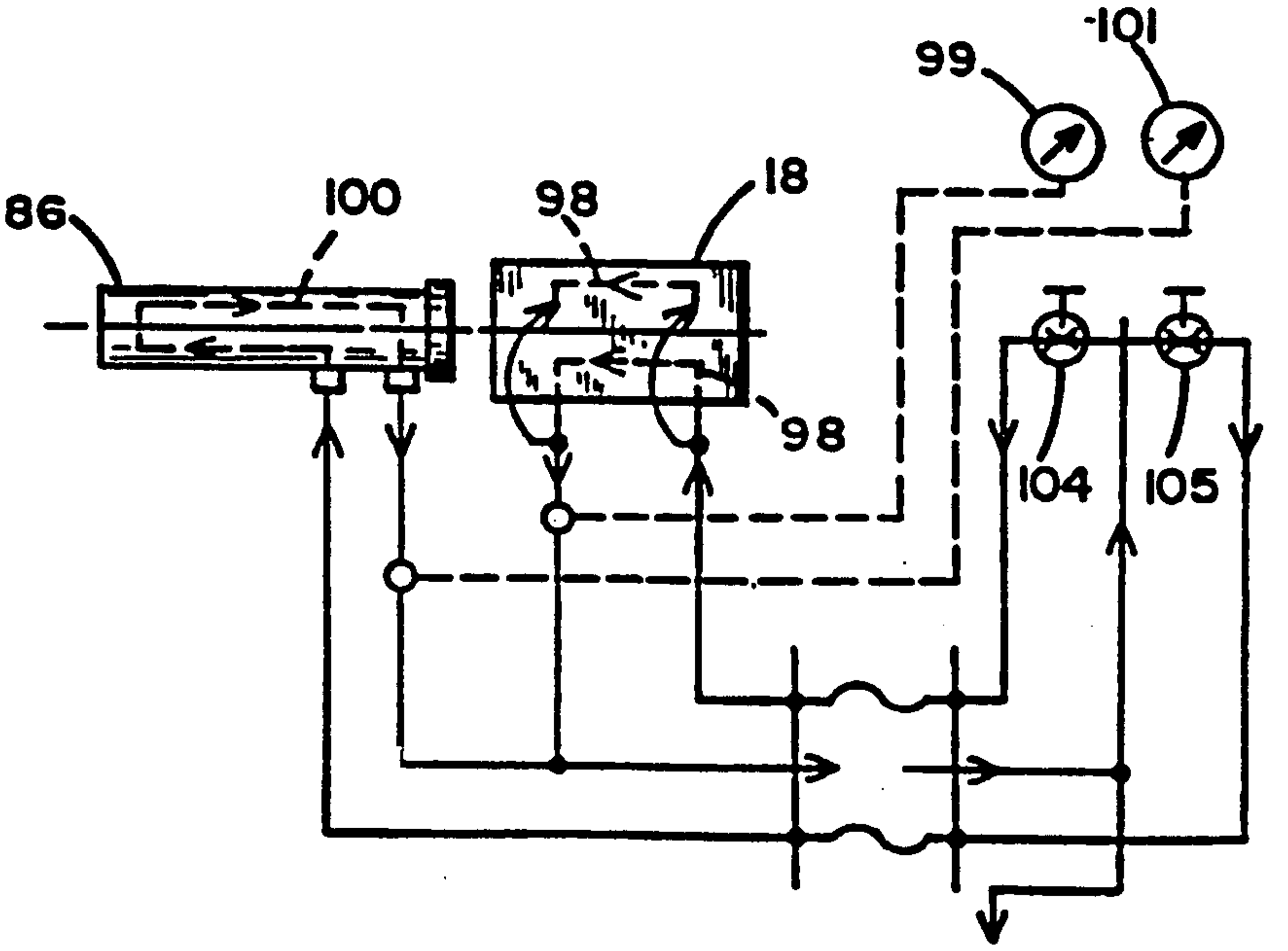
130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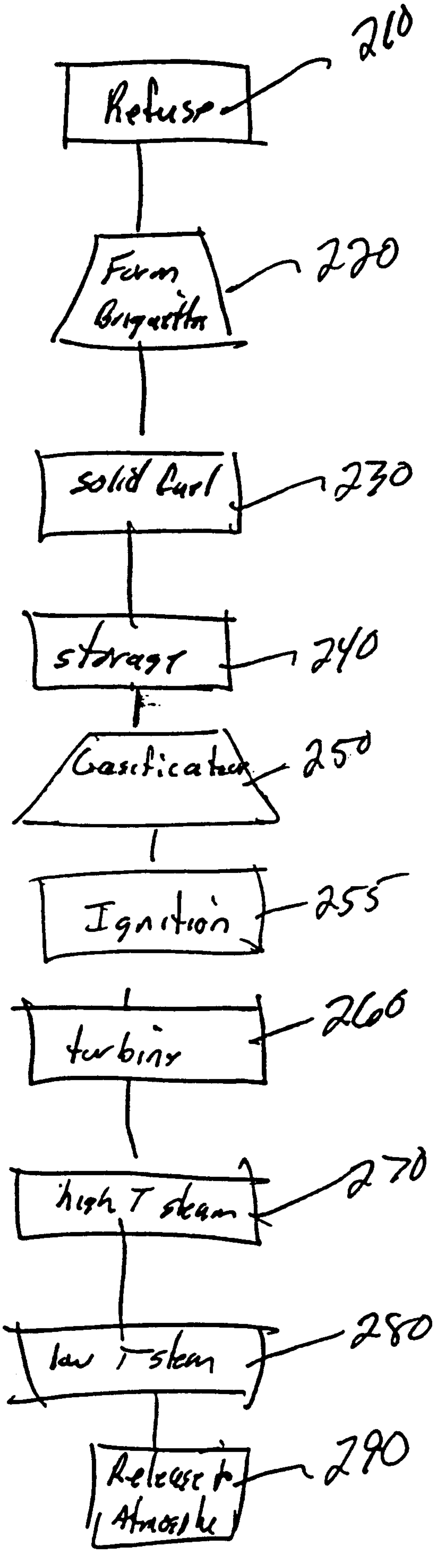
98
18
98
104
105
TO SUMP
(FIG. 10)

Fig. 7

FIG. 11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storage
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Gasification
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Ignition
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low T steam
290
Release to Atmosphere