Feb. 24, 1953 J. B. REPLOGLE 2,629,538

OSCILLATING ELECTRICAL COMPRESSOR

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Fig. 1

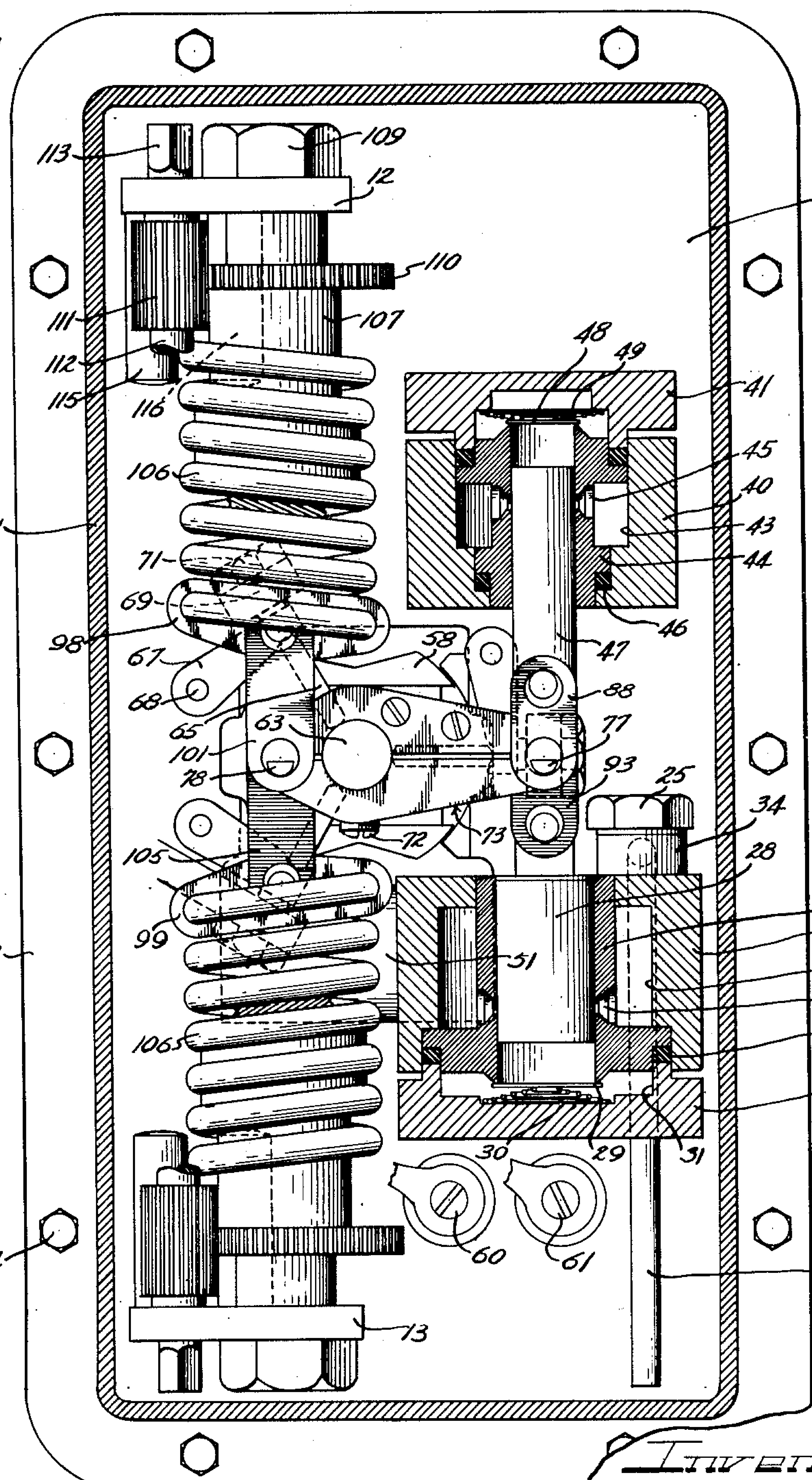

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Fig. 2

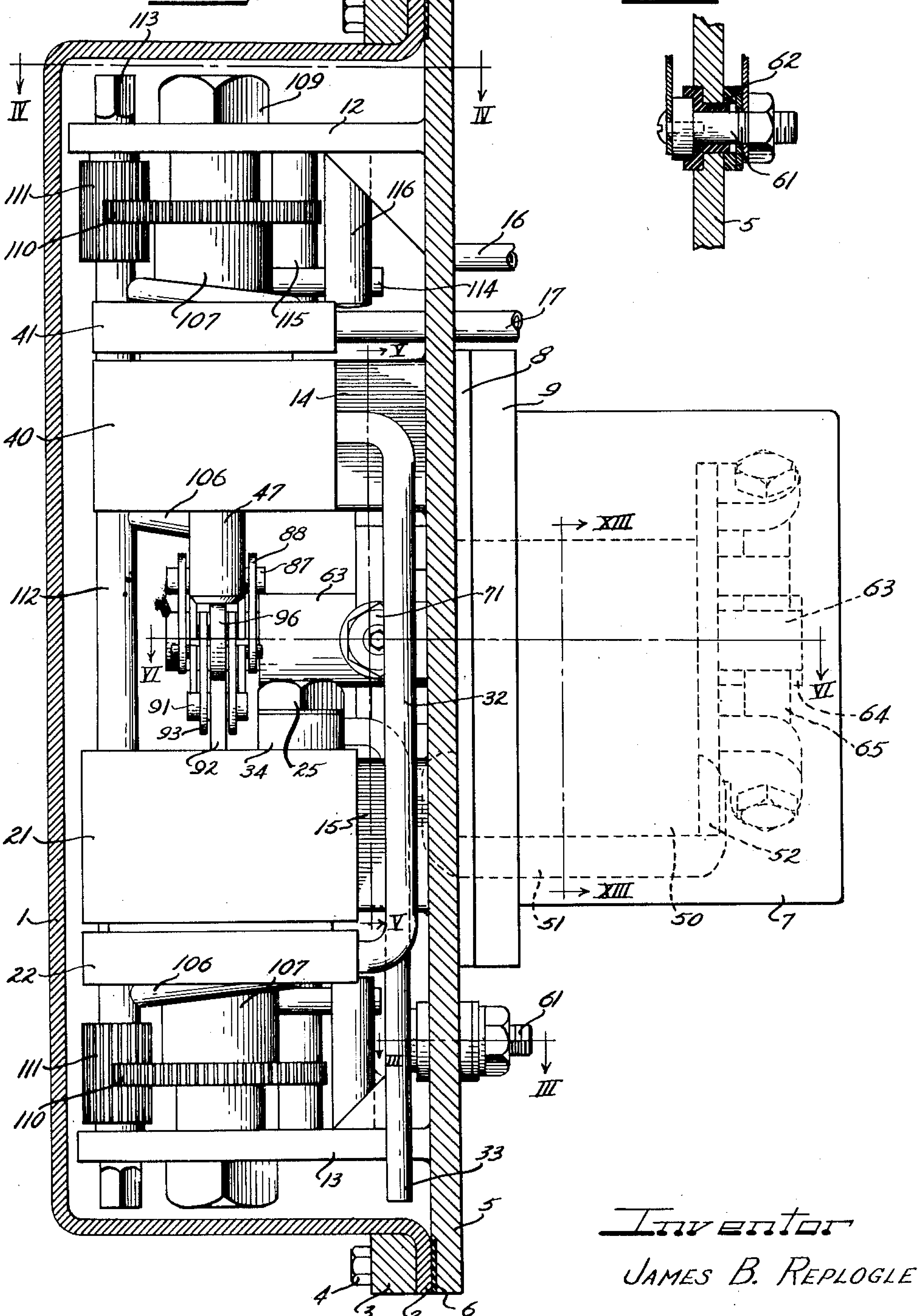

Fig. 3

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OSCILLATING ELECTRICAL COMPRESSOR

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Fig. 4

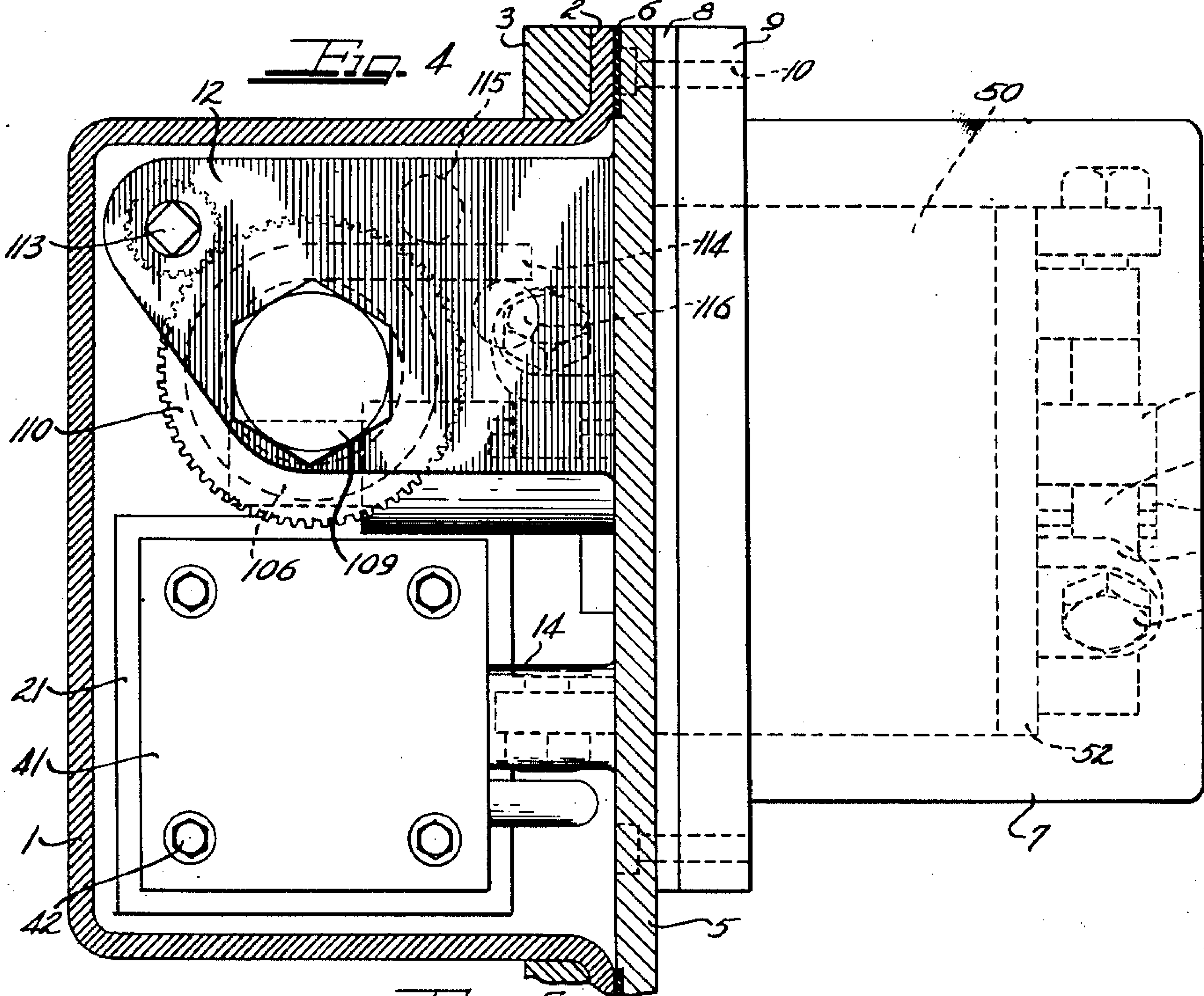

Fig. 5

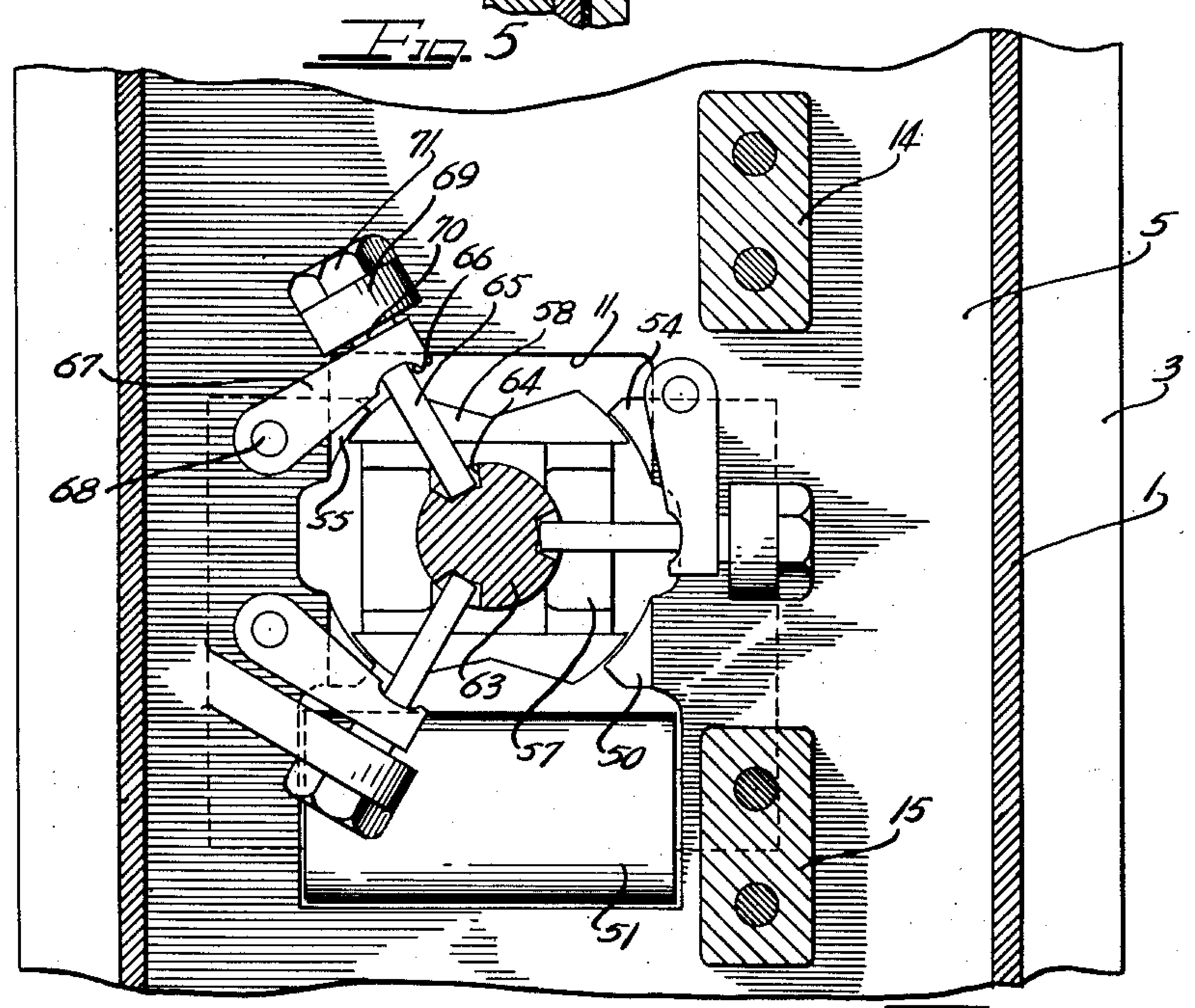

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Fig. 6

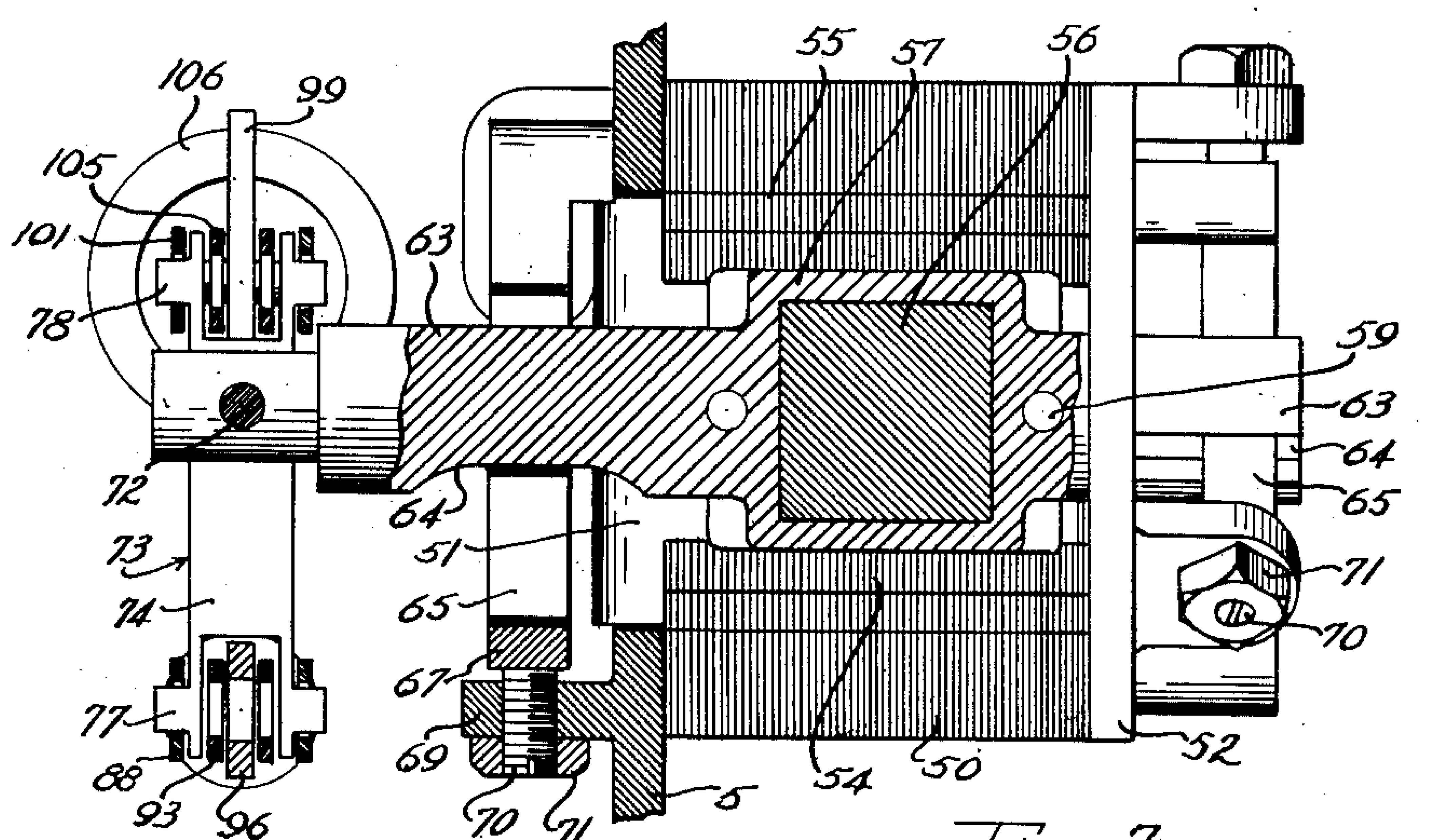

Fig. 7

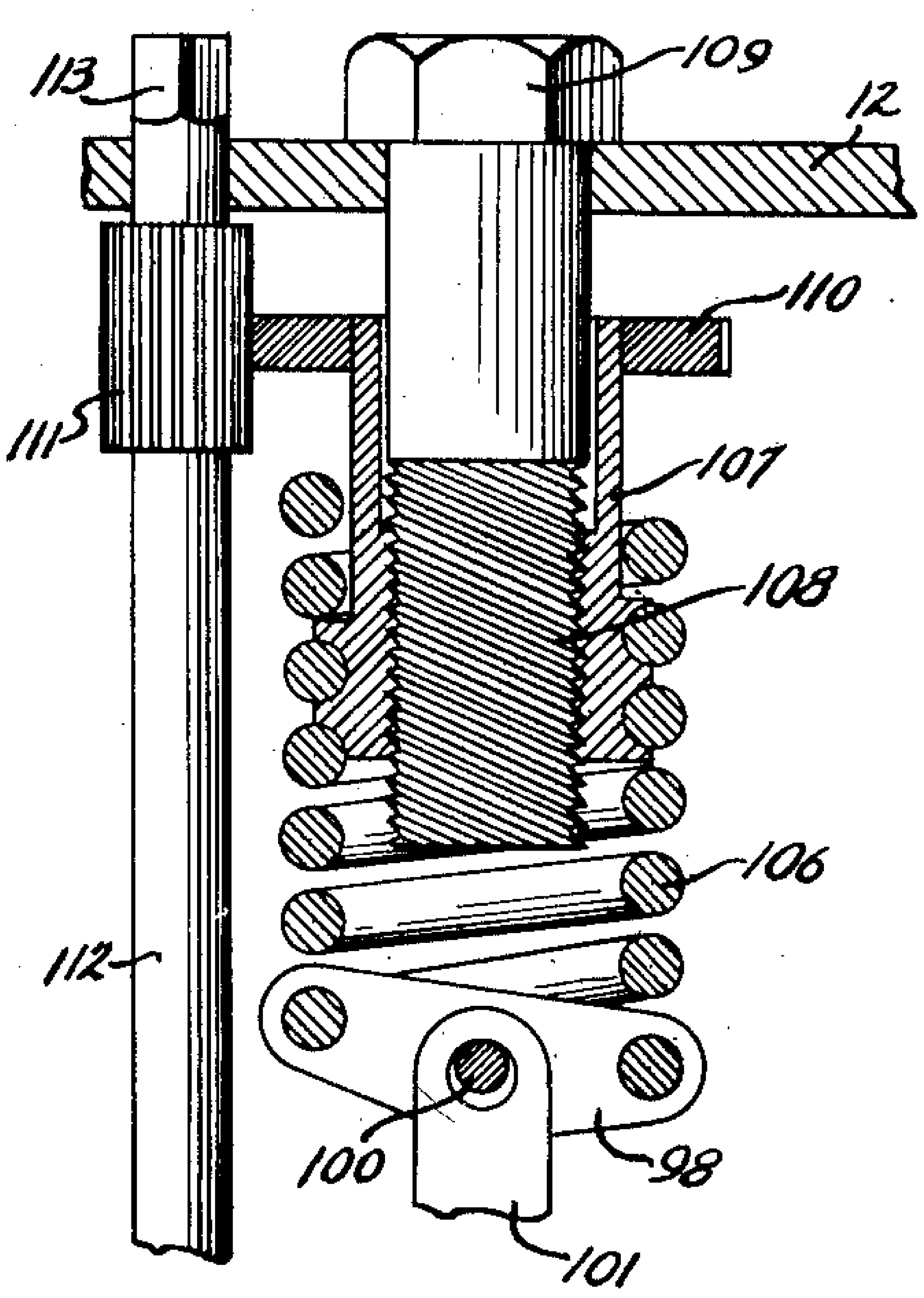

Fig. 8

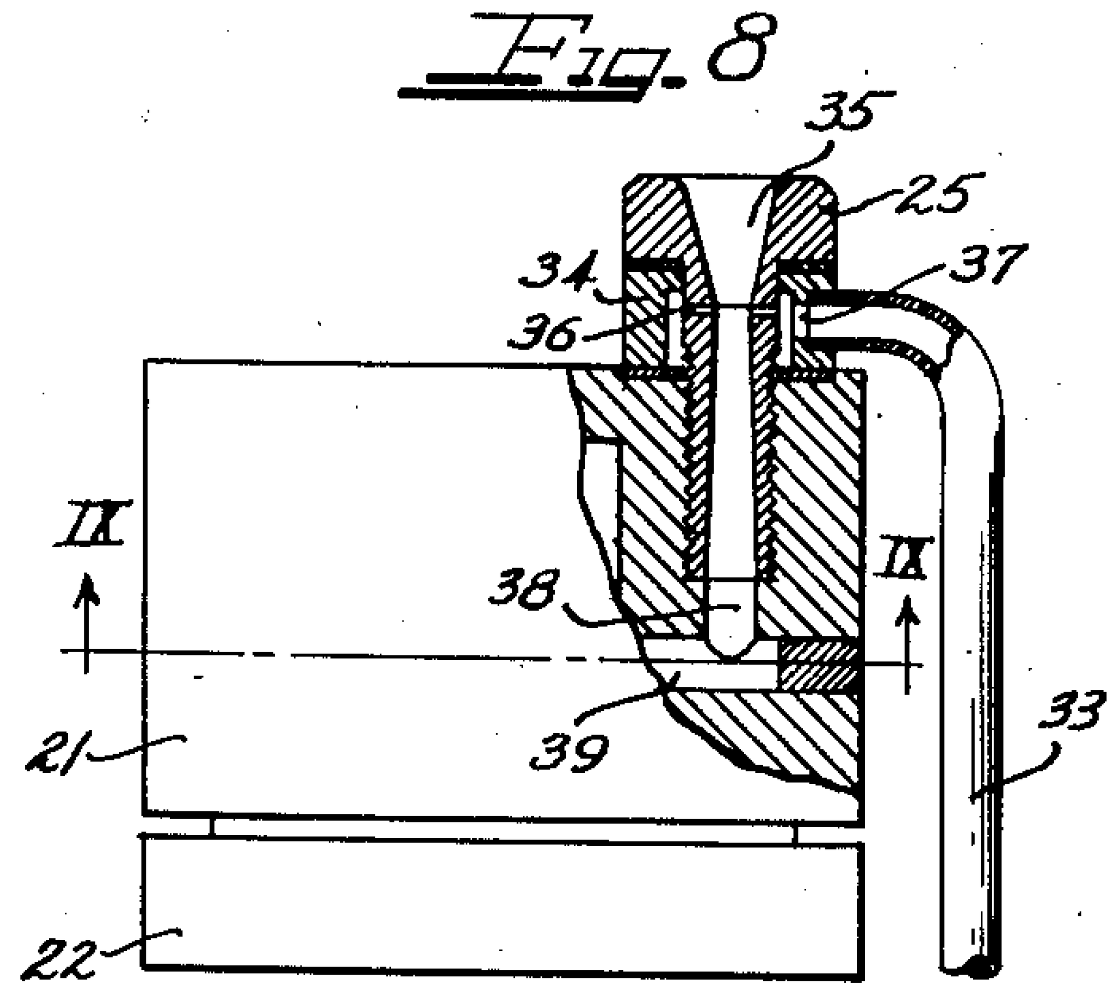

Fig. 9

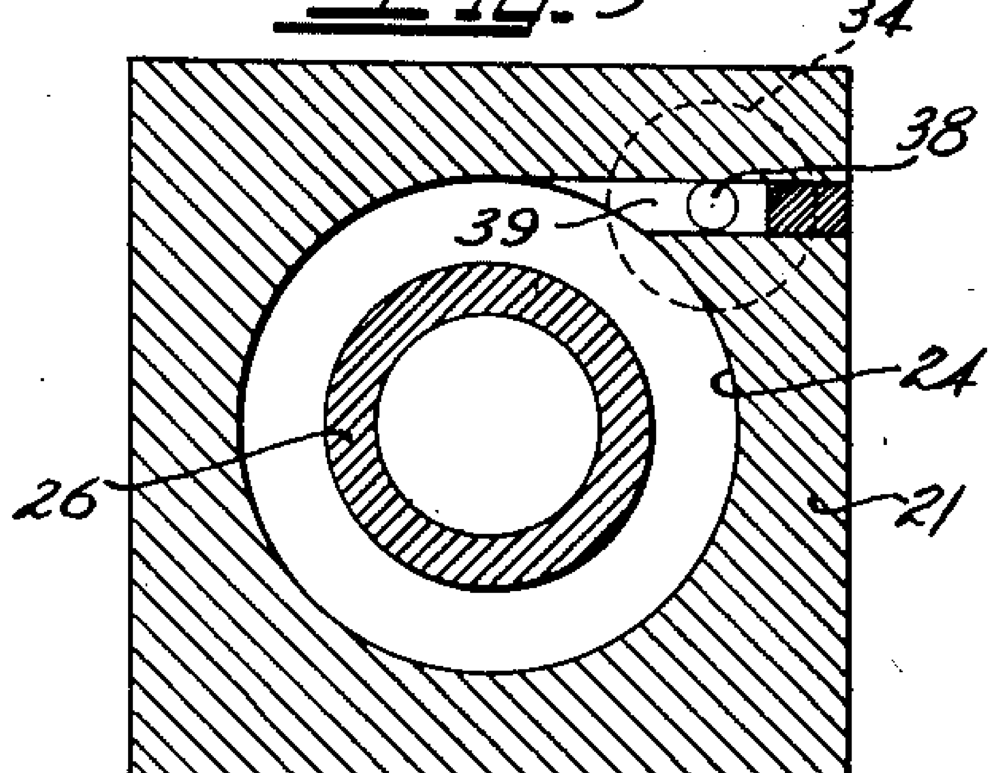

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Fig. 10

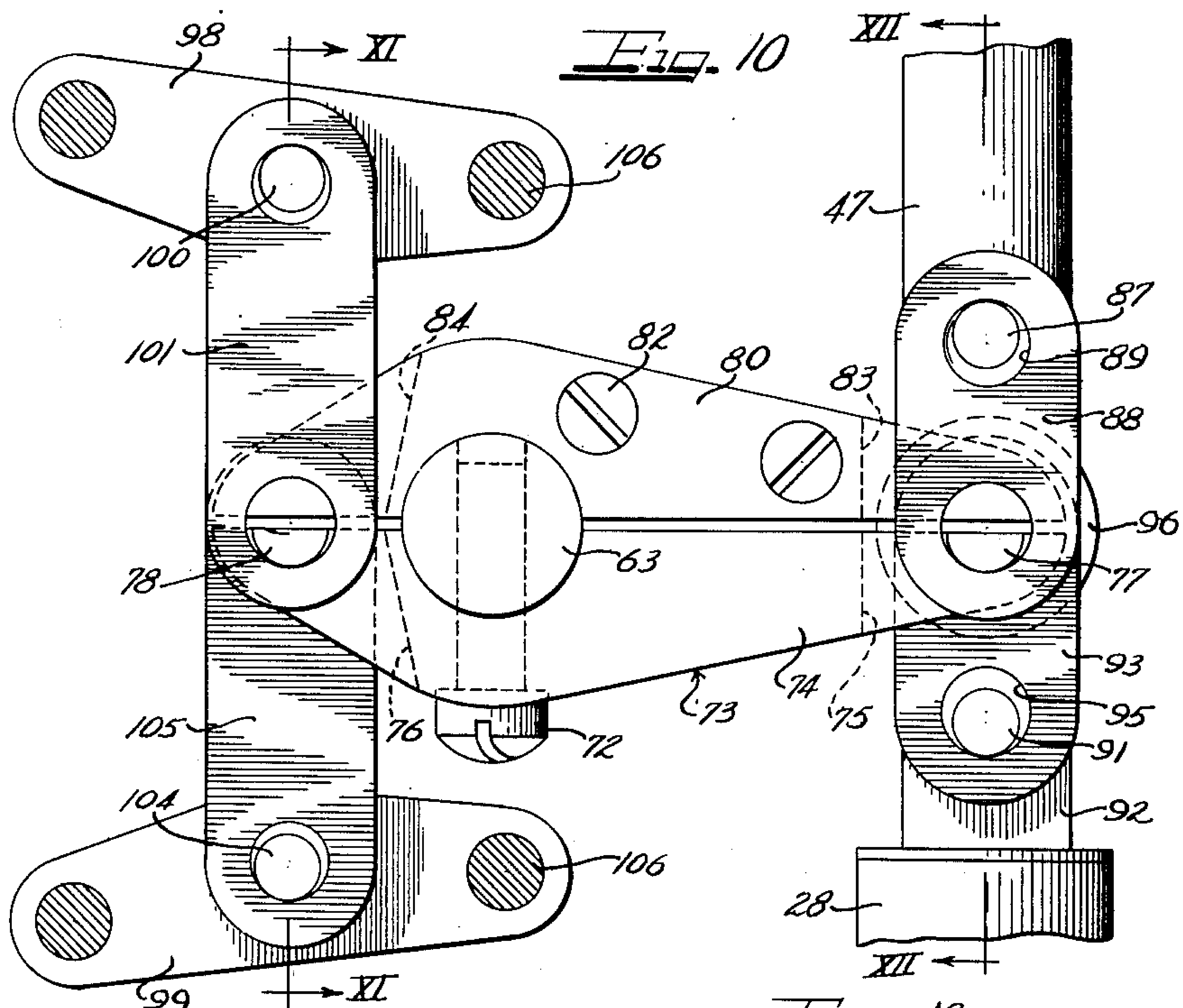

Fig. 11

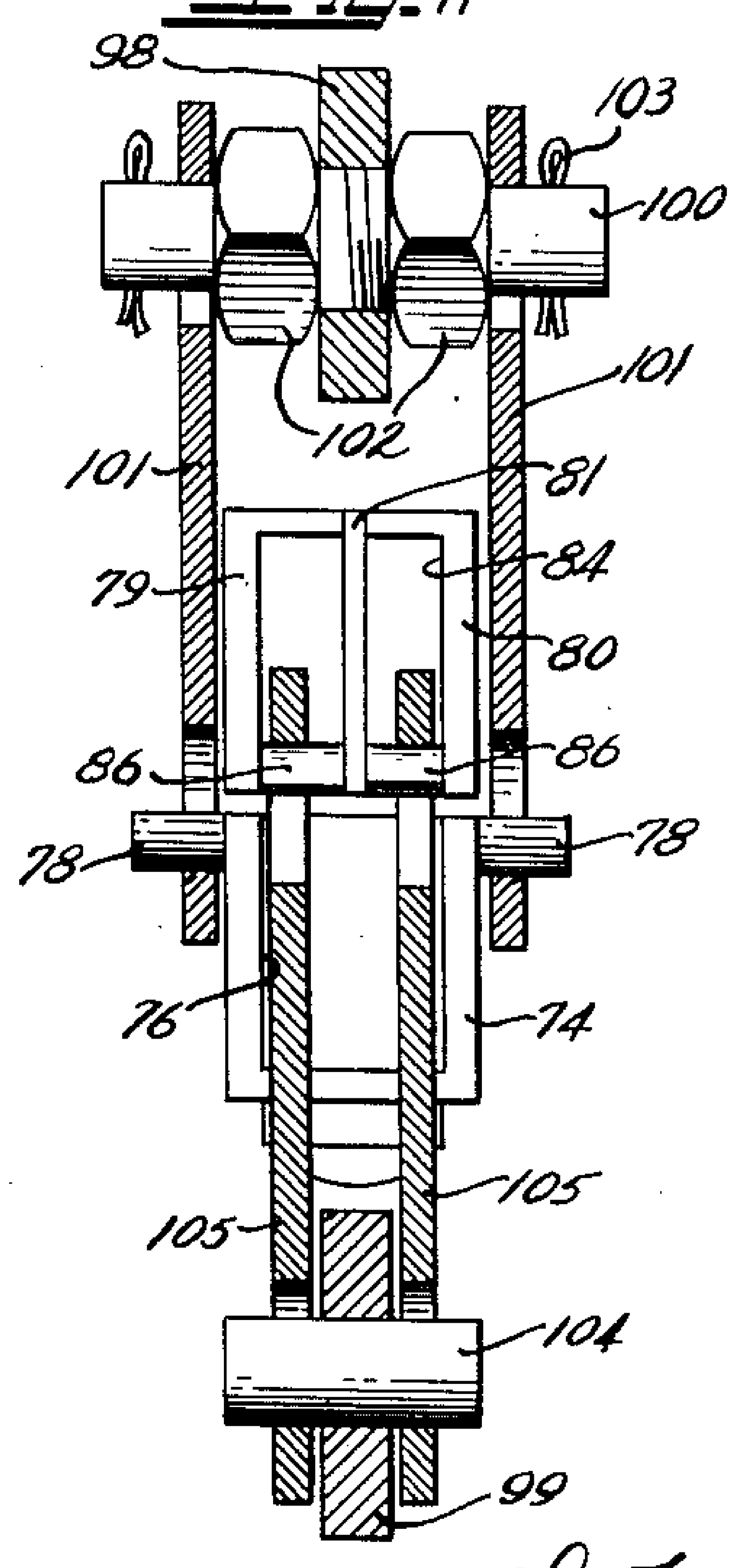

Fig. 12

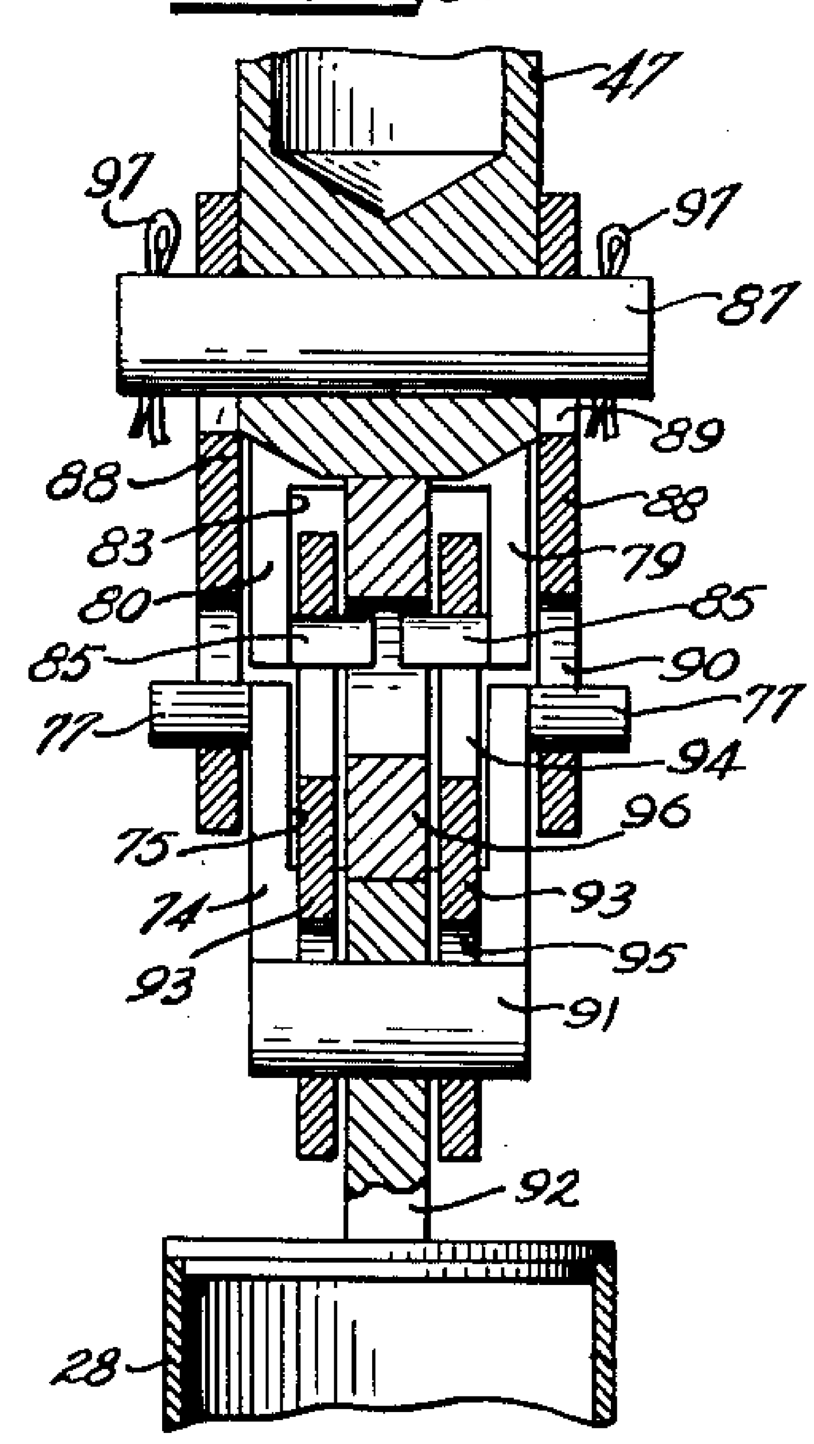

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Fig. 13

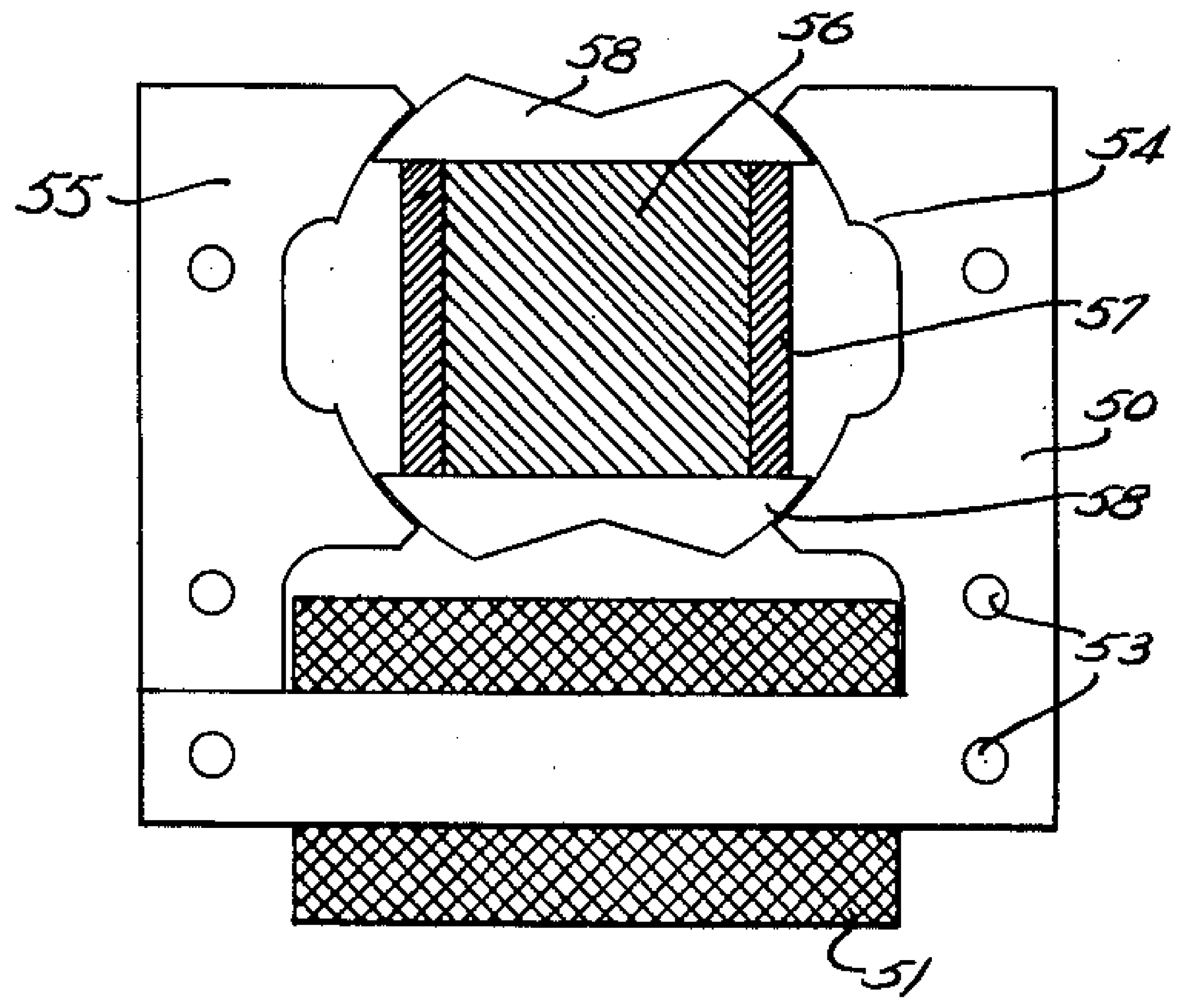


Fig. 14

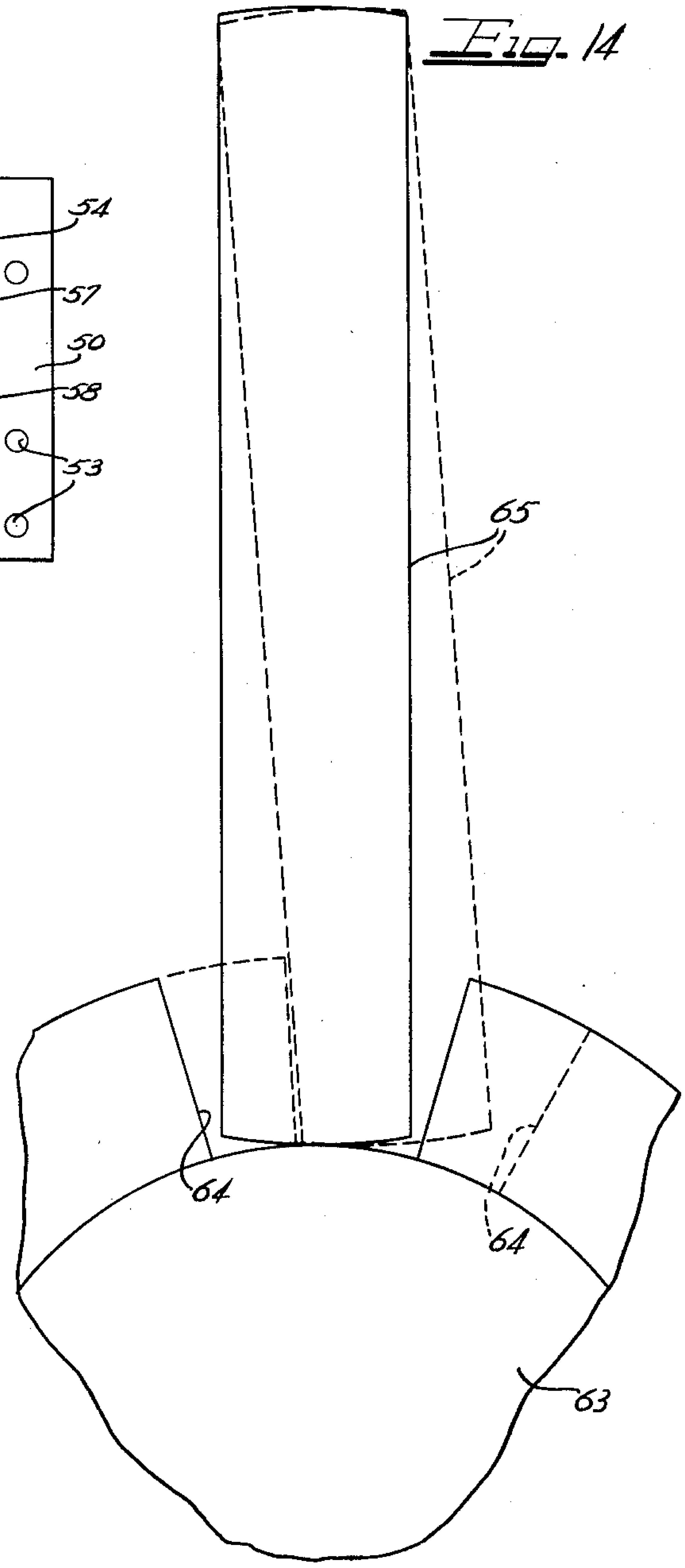
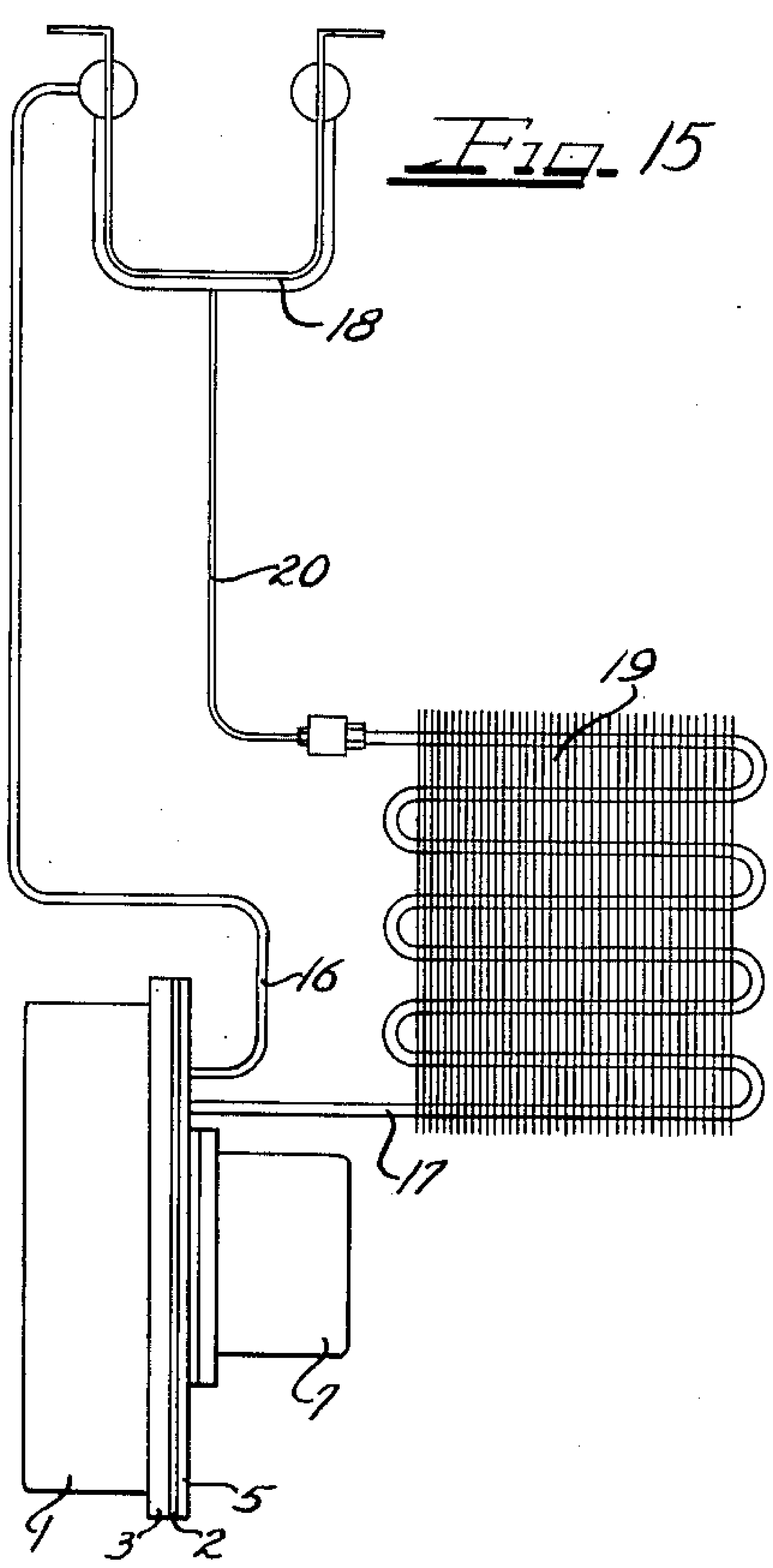


Fig. 15



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Patented Feb. 24, 1953 2,629,538

UNITED STATES PATENT OFFICE

2,629,538

OSCILLATING ELECTRICAL COMPRESSOR

James B. Replogle, Waukegan, Ill.

Application May 6, 1948, Serial No. 25,423

10 Claims. (Cl. 230—48)

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This invention relates to improvements in an oscillating electrical compressor; more broadly to a machine having an oscillating element that is electrically actuated, with means to utilize the motion of that oscillating element to perform work; and more specifically to a compressor embodying such oscillating element with means associated therewith to effect fluid compression as a result of the oscillating movement of the element, such compressor being highly desirable for use in connection with refrigerating systems for compressing the fluid refrigerant, although the invention will have other uses and purposes as will be apparent to one skilled in the art.

By way of presenting the instant invention in a specific practical example, the invention will be disclosed and described herein mainly as involved in a refrigeration compressor, although many features of the invention may well be employed with other types of apparatus.

In the art of compressors, especially those used in refrigeration systems, a compressor was formerly actuated by an electric motor on the outside of the compressor from which a shaft extended into the compressor requiring a highly efficient packing and sealing arrangement about that shaft, and rotary motion, or complete rotation of parts in the compressor were used to compress the refrigerant. More recently, the general trend has been to have the electric motor contained within the compressor case to eliminate the expensive packing around the shaft and to eliminate possibilities of leakage. When a single phase alternating current motor was used in this arrangement the form of motor was limited since it would be substantially impossible to utilize commutators and brushes, or to have any form of mechanism wherein a contact is made and broken within the oil charged atmosphere inside the compressor housing. Therefore the motor was either of the split phase or capacitor type. The split phase type of motor is inherently weak with respect to the starting torque and in most cases could only be used with a relatively inefficient compression system because of that fact. The capacitor type motor has proven fairly successful, but is objectionably expensive and therefore in many cases its use is prohibited. The operating power factor of either the split phase or the capacitor motor is relatively low and that results in the flow of heavier current of electricity within the machine, increasing heat losses.

With these thoughts in mind, it is an important object of the instant invention to provide an electrically driven compressor in which the power element is enclosed within the compressor casing, but wherein that power element is not subject to the deficiencies of the split phase or capacitor motor, or other devices heretofore used for the same purpose, and wherein the compressor is exceedingly small in size, economically operated, highly durable, and requires practically no servicing.

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Also an object of this invention is the provision of a machine of the character set forth herein wherein the prime mover is actuated both electrically and magnetically to provide an oscillatory movement of a drive member as distinguished from a rotary movement, with means to utilize that oscillatory motion to perform work.

Still another object of this invention is the provision of a device in which relative oscillatory movement is created between a unidirectionally magnetized member and an alternatingly magnetized member, with power takeoff means connected to the oscillating member.

It is also a feature of this invention to provide an electrically operated prime mover including an element permanently magnetized unidirectionally, and another element is alternatingly magnetized by the application of alternating current resulting in an oscillatory movement of a power delivery member connected with one of the aforesaid elements, and wherein the oscillating member can be adjusted to a resonant relationship with the alternating current while the device is in operation.

The instant invention also contemplates the provision of an electrical prime mover embodying a unidirectionally magnetized member, an alternatingly magnetized member, and a power delivery element connected to one of said members which by virtue of the relationship of the magnetization of the members will be caused to oscillate, with resilient means for bringing the oscillating mass into resonance with the alternating current, such resilient means being adjustable so that with proper selection of the amount of magnetic force in the unidirectionally magnetized element and the impressed voltage on the current supply to the alternatingly magnetized member, the power factor of the entire unit is brought very close to unity.

A further feature of this invention resides in the provision of a compressor for fluids, electrically driven, and in which all power transmitting parts have a rocking or oscillating motion as distinguished from a rotary motion.

Another feature of the invention is the provision of a compressor, which may be a single or multiple stage compressor, and in which no rotor is embodied, but in which the piston or pistons may be actuated by an oscillating mass.

Still another object of the invention is the provision of a fluid compressor in which the alternating factor of alternating current is utilized to produce mechanical power in the form of an oscillating motion, and resilient means may be utilized to insure proper reversals of the oscillating motion without any injurious lag.

The invention also seeks the provision of a compressor in which various linkages are utilized to transmit power from a source to a piston or pistons, as the case may be, with all lost motion and rattle eliminated between the various connections.

Another feature of the invention resides in the provision of a compressor utilizing linkages so arranged that relative motion between connected parts is of a rolling character rather than a sliding character, and lost motion is eliminated.

It is also a feature of the invention to provide a compressor involving a piston or pistons that are automatically lubricated positively while operating and by virtue of their reciprocatory movement within a cylinder or cylinders.

Still another feature of the invention resides in the provision of a compressor having opposed cylinders with the pistons actuated by an oscillating mass disposed therebetween, and with opposed spring means balancing said oscillating mass from the opposite side of the pivot point from the pistons, such spring means being so arranged that all parts of the spring means are exerting a pull on the mass regardless of the movement of the mass. In other words, no portion of the spring means is ever permitted to become relaxed.

Briefly, the instant invention contemplates a power source including a peranent unidirectionally magnetized member disposed within a laminated core energized by a coil through which alternating current flows, so that the reversals of the alternating current causes a relative oscillatory movement of the permanently magnetized member. A power delivery member is connected to the permanently magnetized member to oscillate therewith. By means of springs of adjustable resiliency, the power delivery member is tuned to a natural frequency of oscillation corresponding to the frequency of the alternating current. The springs are so designed that there is an absence of reversed stresses within the springs and the ultimate stress in the spring fibers is held to a relatively small percentage of the stresses that would result in spring failure. Further, it will be understood that all parts, including such springs, are preferably made of a material such as beryllium copper which has great resistance to fatigue, so as to insure continued and long lived operation of the device. Suitable linkage connections from the power delivery member are provided to pistons operating in cylinders to effect a compression of fluid. Where the device is used as a refrigerant compressor, the entire mechanism is contained within a housing into which the refrigerant to be compressed is freely admitted, so that the entire mechanism is constantly bathed in the refrigerant it is acting upon.

While some of the more salient features, characteristics and advantages of the instant invention have been above pointed out, others will become apparent from the following disclosures, taken in conjunction with the accompanying drawings, in which—

Figure 1 is a front elevational view of a compressor embodying principles of the instant invention, a section being taken through the casing alone, and certain portions of the apparatus being disclosed in section to better illustrate the structure;

Figure 2 is a side elevational view of the compressor, again with a part of the casing shown in section, and taken from the right hand side of Fig. 1;

Figure 3 is a fragmentary detail sectional view, with parts shown in elevation, taken substantially as indicated by the line III—III of Fig. 2, looking in the direction of the arrows;

Figure 4 is a plan sectional view taken through the casing only, substantially as indicated by the line IV—IV of Fig. 2, to provide in effect a plan view of the compressor structure;

Figure 5 is a fragmentary vertical sectional view illustrating an interior portion of the apparatus and taken substantially as indicated by the line V—V of Fig. 2;

Figure 6 is a fragmentary plan sectional view taken substantially as indicated by the line VI—VI of Fig. 2;

Figure 7 is a fragmentary, part sectional and part elevational view, of the structure seen in the upper left hand corner of Fig. 1, illustrating the adjustment of the spring means;

Figure 8 is a substantially diagrammatic view of the first stage compression cylinder, in the position the same as seen in the lower central portion of Fig. 2, with the automatic lubricating arrangement shown in section;

Figure 9 is a bottom plan sectional view of the structure of Fig. 8 taken substantially as indicated by the line IX—IX of Fig. 8;

Figure 10 is an enlarged fragmentary front elevational view of the power delivery oscillating member and the linkage connections associated therewith, such structure being seen in the central portion of Fig. 1, with the springs shown in section;

Figure 11 is a fragmentary vertical sectional view taken substantially as indicated by the line XI—XI of Fig. 10;

Figure 12 is a fragmentary vertical sectional view taken substantially as indicated by the line XII—XII of Fig. 10;

Figure 13 is a vertical sectional view through the prime moving element, taken substantially as indicated by the line XIII—XIII of Fig. 2, with the casing and other parts omitted;

Figure 14 is a greatly enlarged fragmentary diagrammatic view illustrating the operation of one of the bearing parts seen in Fig. 5; and

Figure 15 is a diagrammatic view of a refrigerating system embodying the compressor of this invention.

As shown on the drawings:

With reference first more particularly to Figs. 1 and 2 of the drawings, it will be seen that the illustrated embodiment of the instant invention includes a substantially rectangular relatively deep dished style of casing **1** having an outwardly disposed flange **2** at the open side thereof with an external reinforcing band **3** brazed, welded, or equivalently secured to the casing and flange. Through the reinforcing and flange, bolts **4** may pass to hold a cover in the form of a plate **5** on the casing. Obviously, where adjacent portions of the entire casing assembly are connected together, such as the plate **5** and the casing **1**, suitable gasket means, as indicated at 6, are employed to effect a fluid tight seal between all such connections.

Enclosing the power unit of the device is another casing 7, similar in shape to the casing 1 but of considerably smaller size, which smaller casing is provided with a flange 8 and a reinforcing band 9 and is secured to the opposite side of the plate 5 in an intermediate portion thereof by means of bolts 10 or the equivalent as seen best in Fig. 4. With reference to Fig. 5 it will be seen that there is an irregularly shaped opening 11 in the plate 5 to establish the necessary communication between the interior of the casing 1 and the casing 7.

All of the operating structure contained within the above described casing assembly is carried by the plate 5. As seen in Figs. 1, 2 and 3 anchor plates 12 and 13 extend outwardly from the plate 5, at right angles thereto, to support the drive mechanism and spring balancing means while the compressor cylinders are secured to a pair of bosses 14 and 15, also integral with the plate 5. As indicated in Fig. 6, the stator of the prime mover is carried by the opposite side of the plate 5.

Refrigerant to be compressed may enter the casing through a fluid line 16 and compressed fluid is discharged from the casing through a fluid line 17 (Figs. 2 and 15). When the device is installed in a refrigerating system as indicated diagrammatically in Fig. 15, evaporated refrigerant will leave the evaporator 18 through the line 16 into the inside of the casing assembly, and after compression fluid is discharged through the line 17 into a condenser 19 from which the then liquid refrigerant may travel through a line 20 back to the evaporator, completing the circuit. The fluid refrigerant may freely dispose itself throughout the interior of the compressor casing assembly.

The illustrated embodiment of the invention is in the form of a two stage compressor including a first stage compression cylinder, and a second stage and smaller compression cylinder that provides the final and higher compression for the refrigerant fluid.

With reference now more particularly to Figs. 1, 2, 4, 8 and 9, it will be seen that the first stage compression means include a substantially square shaped cylinder housing 21 secured in any desired manner to the aforesaid boss 15 on the plate 5. This housing is preferably made in two parts including a body portion and a cover portion 22 bolted to the body portion at the respective corners, a suitable gasket 23 being employed at the fluid discharge end to effect the proper seal. Inside the housing 21 is a chamber 24 into which the fluid may pass from the interior of the casing through a fitting 25. This chamber is preferably circular in configuration, and surrounds a cylindrical compression cylinder 26 having opposed ports 27 in the side wall thereof as seen best in Fig. 1. A piston 28 reciprocates within the cylinder 26, and as seen in Fig. 12, the piston is preferably hollow to reduce weight.

As the piston 28 moves outwardly through one end of the cylinder 26 and the inner end of the piston passes the ports 27, fluid is drawn in through the ports and when the piston passes the ports in the opposite direction or upon its inward stroke, that fluid is compressed to a predetermined extent against a valve 29 spring biased as indicated at 30 to seat against the open end of the cylinder. When the compression reaches a degree determined by the spring 30, the valve will be forced off its seat, and the compressed fluid forced down the cylinder into a chamber 31 from which it passes through a pipe or conduit 32, Fig. 2, to the second stage compressor. The valve 29 may be made of a suitable plastic material, and the spring 30 is preferably in the form of a coil spring of conical shape with its apical portion fixedly secured to the valve, and with its base portion securely seated in a suitable recess in the housing head 22.

Means are provided in the instant invention for the automatic lubrication of the piston 28, and as will more fully later appear herein, such means also effect a positive lubrication of the other piston operating in the second stage compression cylinder. The lubricating means are best seen in Figs. 8 and 9. It is to be understood that a quantity of lubricant is mixed with the refrigerant itself. While some of this lubricant will undoubtedly stay mixed with the refrigerant in a substantially vaporous condition, a quantity of the lubricant will accumulate in the bottom of the casing by virtue of its higher specific gravity. With that though in mind, a lubricant pipe 33 is provided which, as seen in Figs. 1 and 2, has its lower open end adjacent the bottom of the casing. The upper end of this lubricant pipe 33 enters through the side of a sleeve 34 clamped between the head of the fitting 25 and the cylinder housing 21. From the disclosure in Fig. 8 it will be noted that the fitting 25 is provided interiorly with a Venturi passage 35 having one or more ports 36 to establish communication between the throat of the passage 35 and the inside of the sleeve 34, said sleeve having an opening 37 therein in communication with the pipe 33. As refrigerant is drawn through the Venturi opening 35 by the action of the piston 28, lubricant will be aspirated or educed through the ports 36 and mixed with the refrigerant. The refrigerant with its charge of lubricant then descends through a vertical passage 38 to a horizontal passage 39 leading into the chamber 24 from which both the refrigerant and the lubricant contained therein may enter the cylinder through the ports 27. Of course, a portion of this lubricant is forced out of the first stage compression cylinder along with the compressed refrigerant and carried through the pipe 32 into the second stage compression cylinder so that the piston acting therein is also automatically lubricated.

From the showing in Figs. 1, 2 and 4, it will be seen that the second stage compression arrangement also embodies a square shaped cylinder housing 40 to which a cover portion 41 is bolted over the discharge end as indicated at 42 in Fig. 4. Inside the housing 40 is a refrigerant chamber 43, and a cylinder 44 having ports 45 in the side wall thereof. The structure is very similar to the structure of the first stage compression arrangement, with the exception that it is smaller in size, and the fact that an extra gasket 46 must be employed between the cylinder and the housing at the inner end of the housing, owing to the fact that the fluid entering the chamber 43 has already undergone one stage of compression. Operating within the cylinder 44 is a piston 47 which compresses the fluid against a valve 48 spring biased as at 49 and of the same construction as the valve and spring arrangement 29—30 above discussed. Due to the action of the piston 47, which is also preferably hollow for lightness as seen in Fig. 12, the fluid is discharged under its final stage of compression through the conduit or line 17 to the condenser of the refrigerating system.

The pistons 28 and 47 are moved simultaneously in the same direction; i. e., they reciprocate in unison so as to alternately provide a compression stroke in the cylinders 26 and 44. The pistons are so actuated through a system of linkages, in turn actuated by what may be termed an oscillating mass connected to the power source, now about to be described.

With reference now to Figs. 5, 6 and 13, it will be seen that the power source includes a stator or core 50 made up of a plurality of laminations so assembled as to provide a cross leg extending through a coil 51. The core is secured to the plate 5, and carries a plate 52 at the opposite end by means of bolts extending through suitable apertures 53 (Fig. 13) in the laminations. This laminated core is alternatingly magnetized by means of an alternating electric current passing through the coil 51. As seen clearly in Fig. 13, the core is shaped to provide poles 54 and 55 which will be of opposite polarity at all times, but which will reverse in polarity in keeping with the alternations of the current passing through the coil 51.

Between the poles 54 and 55 a permanently magnetized member 56 is disposed. In the illustrated instance this member is in the form of a cubical block, and four sides of the member are enclosed in a shroud 57, preferably of material such as cast beryllium copper having the qualities of being non-magnetic, relatively highly conductive, and possessing great strength and hardness. It should be especially noted that the member 56 is magnetized unidirectionally and that direction is toward the open ends of the member where the shroud 57 does not cover it. The member 56 is preferably made of a highly retentive material, such as the type of material described in Mashima Patents 2,027,994, to 2,208,000, inclusive, and Ruder Patents 1,947,274 and 1,968,569, or in some instances it may be convenient to employ a sintered form of the same magnetic material produced in accordance with Howe Patent 2,192,744. It is also preferable that the grain of the metal forming the block 56 runs in substantially a straight line from one end of the block to the other in the direction of the magnetization. On each open end of the block 56 a soft iron pole piece 58 is secured and these pole pieces are in effect both mechanically and magnetically attached to the permanent magnet 56. The pole pieces may be bolted to the shroud by way of the bolt holes 59 seen in Fig. 6.

The coil 51 may be energized from any suitable source of alternating curent. Terminals of the coil will be connected in a known manner to binding posts 60 and 61 (Fig. 1) which extend through the plate 5 as seen more clearly in Figs. 2 and 3. With reference now to Fig. 3 it will be seen that each of these binding posts is insulated from the casing as indicated at 62 and leads from these posts exteriorly of the casing may be connected to any suitable convenient outlet socket.

With reference again to Figs. 5 and 6, it will be noted that the shroud 57 surrounding the permanent magnet 56 is an integral enlarged intermediate portion of a shaft 63 extending both directions from the shroud portion. Each end of the shaft 63 obviously must be journaled in proper bearings. Roller bearings would be much preferred, but a full roller bearing arrangement at each end of the shaft would provide more than a desirable amount of weight. Therefore special bearing means have been provided, one on the outside face of the plate 52, and one on the inside face of the plate 5. These bearing arrangements are identical and each gives the complete effect of a full roller bearing assembly but each is designed in a skeleton form so as to reduce weight.

In the illustrated instance three bearing members are provided for each end of the shaft 63. The shaft is provided with a recess 64 having diverging side walls and a curvate bottom for each of these bearing members. The curvate bottom is a portion of an arc with its center coinciding with the center of the shaft. A bearing member 65 has one end seated in the recess 64 and the other end seated in an arcuate recess 66 in the free end of an arm 67 pivoted as at 68 near its opposite end. The bearing member 65 is a diametral section of a roller bearing and the arcuate ends of the member both have the same center on the central axis of the member. Immediately outside the arm 67 a lug 69 extends inwardly from the plate 5. Through this lug a bolt 70 is threaded so that the inner end of the bolt will bear against the free end of the arm 67 and thus hold that arm in proper contact with the respective bearing member 65. A lock nut 71 anchors the bolt 70 in a desired position of adjustment.

The shaft 63, of course, never completes a revolution, but only oscillates through a relatively small arc. By way of example, it may be mentioned that a satisfactory oscillation of this shaft may be less than 15° to each side of center or neutral position. The oscillation of the shaft 63, of course, is in response to the changes in polarity of the poles 54 and 55 on the core 50 due to the alternations of the current passing through the coil 51. The pole pieces 58—58 on the permanent magnet 56 will be of opposite polarity, but the polarity of each pole piece will remain constant. Referring to Fig. 13, let it be assumed that the uppermost pole piece 58 is north and the lower pole piece 58 is south. Let it further be assumed that at a single instance the pole piece 54 is north and the pole piece 55 is south. The pole 55 will attract the upper pole 58 and the pole 54 will repel the upper pole 58. At the same time, the lower portion of the pole 54 will attract the lower pole 58 and it will be repelled by the corresponding portion of the pole 55. Thus, the permanent magnet 56 will move counterclockwise. But a small fraction of a second later, the poles 54 and 55 will reverse their polarity, and the permanent magnet 56 will be caused to move clockwise back to the neutral position illustrated in this figure and an equal distance farther.

The bearing system for the shaft 63 above described therefore provides an effective roller bearing arrangement for the oscillatory movement of the shaft. This is diagrammatically illustrated in an enlarged manner in Fig. 14. In this figure the full line showing indicates neutral position on the bearing member 65 and the shaft 63, corresponding to the position of the permanent magnet 56 in Fig. 13. The dotted line position shows the shaft 63 oscillated clockwise, and the bearing member 65 has pivoted along with the movement of the shaft to the dotted line position, the arcuate inner end of the bearing member in effect rolling along the arcuate bottom of the recess 64 in the shaft. At the same time, with reference again to Fig. 5, the outer arcuate end of the bearing member rolls in the arcuate recess 66 of the arm 67. That recess in the arm has its center coinciding with the center of the shaft 63, and the pivot point 68 of the arm is on a tangent to the outer arcuate edge of the bearing member 65. Therefore, there can be no locking of the bearing member, and free rolling action is provided at each end of that bearing member without any relative slipping of any of the parts, so that friction is reduced to a minimum.

With reference more particularly to Figs. 1, 10, 11 and 12, it will be seen that a reduced inner end portion of the shaft 63 is locked by means of a bolt 72 to an oscillating drive member generally indicated by numeral 73, which in reality is an assembly of several different parts, and which taken with the shaft 63 and the permanent magnet 56 may be considered an oscillating mass. At one end thereof the member 73 is connected by suitable linkages to the aforesaid pistons 28 and 47, and on the other side of the shaft 63 this driving member is connected through suitable linkages to spring biasing means which as will more fully later appear herein place the oscillating mass in a condition of resonance with respect to the alternating current flowing through the coil 51 and also aid in eliminating lost motion.

As seen in Figs. 10, 11 and 12, the driving member 73 includes a lower member 74 that is milled out at one end as indicated at 75 to provide a recess for the accommodation of linkages, and is milled out at the other end as indicated at 76 to provide a similar recess. Between the milled recesses the member is solid. At the end having the recess 75 therein the member is provided with a pair of substantially half-pins 77—77 projecting outwardly from each side wing of the milled end of the member. On the opposite end thereof, adjacent the recess 76, the member is provided with a pair of similar outwardly extending half-pins 78—78. For convenience in manufacture, the upper part of the driving member 73 is formed of three pieces, including right and left members 79 and 80 with a spacer element 81 therebetween. These members are held together by bolts 82 (Fig. 10), or in an equivalent manner. At one end thereof, the members are milled as indicated at 83 to provide a recess forming in effect a continuation of the recess 75 in the lower member, and at the other end these members are milled as indicated at 84 to provide a recess forming in effect a continuation of the recess 76 in the lower member. At the end having the recess 83, the wings at the sides of the recess are provided with inwardly extending half-pins 85—85, and at the other end thereof, the member is similarly provided with inwardly extending half-pins 86—86.

Connection between the driving member 73 and the piston 47 is established by means of a cross pin 87 press fitted through the inner end of the piston. A pair of like links 88—88 each engage over a projecting end of the cross pin and one of the half-pins 77 on each side of the piston. It will be noted that the openings 89 and 90 in each of these links 88—88 are of considerably greater size than the pin and half-pins they receive respectively. Consequently all relative movement will be of a rolling character between the pin or half-pin and the links and not of a sliding character, thus prolonging the life of the parts against wear, and lessening friction.

Connection is made with the other piston 28 by way of a cross pin 91 press fitted in an extension 92 of the piston. A pair of like inside links 93—93 engage the cross pin 91 on each side of the extension 92, and also engage the aforesaid inwardly extending pins 85—85. The holes 94 and 95 in each of these links 93—93 are also considerably larger than the pin or half-pin extending through them. In order to maintain the respective pins and half-pins in proper association with the links, and eliminate lost motion, a centrally apertured pressure disk or wheel 96 is disposed between the smooth end of the piston 47 and the smooth end of the extension 92 on the piston 28 so that the pistons are constantly maintained a fixed distance apart. Thus, when the pistons move downwardly as viewed in Figs. 10 and 12, the piston 47 is pulled by the links 88—88 being acted upon by the half-pins 77—77 at one end and acting upon the piston pin 87 at the other ends. The pressure wheel 96 pushes the piston 28 during that movement. When the pistons move in the reverse direction, the piston 47 is pushed by the pressure wheel, and the piston 28 is pulled by the inner links 93—93, each pulling on the piston pin 91 at one end, and being pulled by the half-pin 85 at the other end.

Cotter pins 97—97 may be provided through the opposite end of the piston pin 87 to eliminate any possibility of the links 88—88 sliding out of position.

On the opposite side of the shaft 63, the driving element 73 is connected through linkages to a pair of like spring connectors 98 and 99. The connector 98 carries a fixed transverse pin 100 engaged by a pair of outside links 101—101 which links also engage the aforesaid outwardly projecting half-pins 78—78 on the lower part of the driving member 73. A pair of nuts 102 may be threaded on the pin 100 on opposite sides of the connector 98 to provide adequate spacing between the links 101—101, and these links may be retained in position by suitable cotter pins 103 passing through the pin 100. The connector 99 is also provided with a cross pin 104 fixed therein, and this pin is engaged on opposite sides of the connector by links 105—105 which also engage over the aforesaid inwardly extending half-pins 86—86 carried by the upper portion of the oscillating driving member 73. As in the previously described arrangement at the opposite end of the driving member, all links are provided with apertures greatly exceeding the size of the pin or half-pin extending therethrough.

A coiled tension spring is connected at one end to each of the spring connectors 98 and 99. These springs 106—106 are similar, and the adjustment arrangement associated with each spring is similar to the corresponding arrangement associated with the other spring at the opposite end of the casing. One of the spring adjustment assemblies is secured to the anchor plate 12 extending inwardly from the casing plate 5 and the other spring adjustment assembly is secured to the similar anchor plate 13.

With reference now more particularly to Fig. 7, it will be seen that the outer end of the spring connected to the connector 98 is threaded on the outer portion of an adjusting sleeve 107, which sleeve is also internally threaded for engagement with the threaded inner end 108 of a bolt 109 having a smooth shank extending through the anchor plate 12. In this instance, the spring threads on the outside of the sleeve 107, the inside threads of the sleeve and the bolt threads are all preferably left hand. Further, the inside threading of the sleeve and the bolt threads are preferably quadruple to provide a pitch substantially the same as the pitch of the spring threads on the outside of the sleeve. The outside end of the sleeve 107 fixedly carries a spur gear 110 which is in mesh with a pinion 111 on a shaft 112, which shaft also extends through the anchor plate 12 and terminates in a polygonal head 113 to facilitate rotating the shaft. As is seen best in Figs. 2 and 4, the spring terminates in a straight end 114 disposed between a pair of fixed studs 115 and 116 secured to the plate 12, to prevent any rotation of the spring itself.

As disclosed clearly in Fig. 2, the pinion shaft 112 extends substantially the full length of the structure and carries a similar pinion 111 at the opposite end thereof for the adjustment assembly of the other spring. The adjustment assemblies are identical, with the exception of the opposite winding of the spring, and the fact that the outside and inside threading of the adjusting sleeve 107 and the outside threading of the bolt 109 connected with the anchor plate 13 are right hand rather than left hand. Thus, when the pinion shaft 112 is rotated from either end, the adjusting sleeves 107—107 are caused to move toward or away from each other depending upon the direction of rotation.

When the structure is assembled, the bolts 109—109 are adjusted to place the proper amount of tension on the respective springs to effect the proper neutral position of the oscillating driving element 73 and provide a centering of the pistons 28 and 47. This will place approximately the proper amount of tension on the springs. Then the pinion shaft 112 is actuated to move the adjusting sleeves 107 toward or away from each other and thus increase or decrease the number of turns of each spring on its respective adjusting sleeve thus varying the number of active or effective turns of each spring. This, of course, affects the resiliency of the springs and makes it possible to bring the oscillating mass into resonance with the alternating current. Experiment has demonstrated that if the free natural period of oscillation of the mass is made very slightly higher in cycles per second than the alternating current, when the structure is supplied with a load as when actively compressing the refrigerant, the conditions of resonance will be so complete that the power factor of the electrical circuit becomes substantially unity.

With the present invention, it is desirable to set the adjusting bolts 109—109 in such position that there will always be a residual tension on the springs during the entire amplitude of oscillation in either direction. Neither spring ever becomes relaxed. Thus, the entire oscillating mass is in effect resiliently positioned. Therefore, each compressor as manufactured, may be individually adjusted to the proper degree notwithstanding variations in size, shape, weight, etc. of the various parts of the apparatus owing to tolerances allowed in mass production.

Notwithstanding those mass production variations, the adjustment of the springs is quite effective to very quickly bring the association of the mass and the resiliency into its natural period of vibration, which remains fixed so long as there is no change in the vibrating mass or the amount of resiliency. Therefore, when the springs are adjusted once to the proper degree of tension and to the proper number of active spring coils, there is no need for further adjustment of the apparatus.

It should further be especially noted that while the connections between the various linkages and pins or half-pins engaged therewith are deliberately made very loose to produce a rolling instead of a sliding action between the parts, the opposed action of the springs eliminates or takes up any lost motion so that the movement of the pistons is accurate, and no rattling can ever result.

It should also be noted that the first and second stage compression cylinders 26 and 44 are made removable from their blocks or housings so as to permit superfinish of the inside cylindrical surfaces and respective valve seats, thus furnishing a high quality product with a low manufacturing cost.

The pressure disk or wheel 96 interposed between the pistons effectively eliminates strain by compensating for any misalignment of the pistons that might arise due to an accumulation of minute errors in manufacture.

It might also be mentioned that when the instant compressor is used with refrigerants of more than common volatility, such as propane, monochlorodifluoromethane in order to operate at relatively low temperature there may be a rather high ratio of the absolute pressure within the high pressure chamber 31 as compared with the pressure within the annular chamber 24. This might be detrimental in that it would tend to carbonize the lubricant oil and close the passages with the finely divided carbon. Under such circumstances, the pipe or conduit 32 between the two compression stages may be taken through an interstage cooler and a sufficient amount of heat removed from the gas therein to prevent overheating in the high pressure chamber, always staying under a carbonizing temperature.

The operation of the instant invention is believed to be sufficiently apparent from the foregoing to warrant only a further brief discussion. Immediately upon the energization of the coil 51 with alternating current, the oscillating structure including the shaft 63 and the driving element 73 will start oscillating immediately without the interposition of any special starting equipment such as required for a single phase motor. There is no need to provide means such as unloading devices to hold back the compression load until the mechanism is operating at full amplitude.

The oscillations of course actuate the pistons 28 and 47 simultaneously, and refrigerant under ambient pressure is drawn from within the casing into the first stage cylinder, compressed, advanced to the second stage compression cylinder, compressed to the final degree and discharged to the condenser through the line 17. During this operation, by virtue of the venturi 35 through which the refrigerant enters, lubricating oil is drawn into the first cylinder to lubricate the piston, and that oil remains in the refrigerant when it is passed to the second cylinder to lubricate the piston there as well.

The springs 106—106, each of which is always under tension, maintain the oscillating mass in resonance with respect to the alternating current, and also eliminate lost motion. There is another important function of these springs, namely to insure a vigorous and positive operation of the moving parts and especially the pistons. The oscillations of the permanent magnet 56 and the structure connected thereto, hereinbefore termed the oscillating mass, would be relatively feeble because a great proportion of the energy of the alternating current would be expended in reversing the oscillations were those oscillations not reversed by the action of the springs. Thus, the entire apparatus is positive and highly efficient in its operation.

It should also be borne in mind that the high conductivity of the shroud protects the permanent magnet because currents induced in the shroud by any incipient change in magnetism in the element 56 as a result of the alternating current are inhibited from assuming a magnitude that would effect a definite change in the permanent magnetism.

It will, of course, be understood that various details of construction may be varied through a wide range without departing from the principles of this invention and it is, therefore, not the purpose to limit the patent granted hereon otherwise than necessitated by the scope of the appended claims.

I claim as my invention:

1. In combination, a permanently and unidirectionally magnetized element, another element magnetized by alternating current, said elements being disposed adjacent each other so that one will oscillate relatively to the other, means connected to the oscillating element to perform work, and resilient means arranged to exert continuous tension on opposite sides of the oscillating element and its load sufficient to vary the free natural period of the oscillating mass slightly from the frequency of the alternating current and bring the power factor substantially to unity.

2. In combination, a permanently and unidirectionally magnetized element, another element magnetized by alternating current, said elements being disposed adjacent each other so that one will oscillate relatively to the other, means connected to the oscillating element to perform work, and resilient means acting upon the oscillating element and its load in a manner to vary the natural period of oscillation thereof slightly from the frequency of the alternating current and bring the power factor substantially to unity.

3. In a machine of the character described, a unidirectionally magnetized element, an alternatingly magnetized element, said elements being sufficiently closely associated for one to oscillate relatively to the other in keeping with reversals of magnetism in the second said element, a driving member connected at an intermediate point to the oscillating element, a load connected to one end of said driving member, and opposed spring means connected to the other end of said driving member to maintain the oscillating member and load in resonance with the alternations of magnetism in the second said element.

4. In a compressor, a pair of opposed compression cylinders, pistons operating in said cylinders, means connecting said pistons to cause them to operate in unison, a pivoted drive member connected to said means to actuate the same, electromagnetic means connected with said drive member to oscillate the latter about its pivot point, and opposed spring means pulling in opposite directions on said drive member on the opposite side of the pivot point thereof, said spring means being adjusted so that each is always under tension regardless of the movement of said drive member.

5. In a compressor, a pair of opposed compression cylinders, pistons operating in said cylinders, means connecting said pistons to cause them to operate in unison, a pivoted drive member connected to said means to actuate the same, electromagnetic means connected with said drive member to oscillate the latter about its pivot point, opposed springs pulling on said drive member on the opposite side of the pivot point thereof, means to adjust the tension of said springs so neither will ever become relaxed, means to adjust the effective turns of said springs, and both said adjustment means being operable while said drive member is oscillating.

6. In combination, a permanently and unidirectionally magnetized element, another element magnetized by alternating current, said elements being disposed adjacent each other so that one will oscillate relatively to the other, a drive member connected to the oscillating element at an intermediate point to move therewith, work performing means connected to one end of the drive member, opposed resilient means connected to the other end of the drive member, and adjustment means to act on said resilient means to bring said drive member and its load into resonance with the alternating current, said adjustment means being variable while said drive member oscillates.

7. In a two-stage compressor, a pair of opposed compression cylinders, a pair of opposed pistons movable in said cylinders, an oscillatable shaft, a drive member on said shaft, link and pin connections between said member and said pistons, the openings in said links being exaggerated with respect to the pins received therein to insure relative rolling action at connection points, and a pressure wheel between said pistons.

8. In a two-stage compressor, a pair of opposed compression cylinders, a pair of opposed pistons movable in said cylinders, an oscillatable shaft, a drive member connected at an intermediate point to said shaft, a pair of opposed tension springs on the opposite side of said shaft from said pistons, link and pin connections between said drive member and said pistons, and link and pin connections between said drive member and said springs, the openings in said links being exaggerated with respect to the pins received therein to insure relative rolling action at connection points, said springs eliminating lost motion.

9. In combination, a permanently and unidirectionally magnetized element, another element magnetized by alternating current, said elements being in juxtaposed arrangement so that one will oscillate relatively to the other in keeping with the reversals in alternating current, a shroud of highly conductive material encasing said permanently magnetized element except for the poles thereof, a shaft formed integral with said shroud, a drive member on said shaft, a pair of compression cylinders, a pair of opposed pistons movable in said cylinders, means connecting an end of said drive member to said pistons to actuate the same in unison, and opposed spring means acting on the other end of said drive member to maintain the oscillating mass in a condition of resonance with the alternating current.

10. In a compressor, opposed cylinders, opposed pistons movable therein, a drive member, means to oscillate said drive member about an intermediate pivot point, means connecting an end of said drive member to said pistons to actuate the same, opposed springs each having an end connected to the other end of said drive member, a support for the other end of each said spring, a bolt through each said support, a sleeve threaded on each said bolt, and the other end of a spring threaded on the respective sleeve, each spring being locked against rotation, said bolts

being adjustable to vary the tension of the springs, and means connecting said sleeves to rotate the same in unison to vary the effective turns of said springs.

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