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PRESSURE CONTROL MECHANISM

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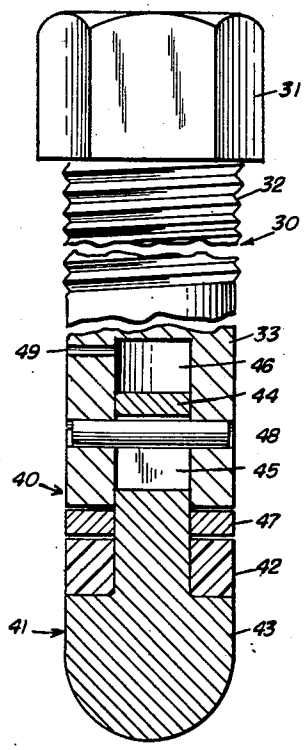
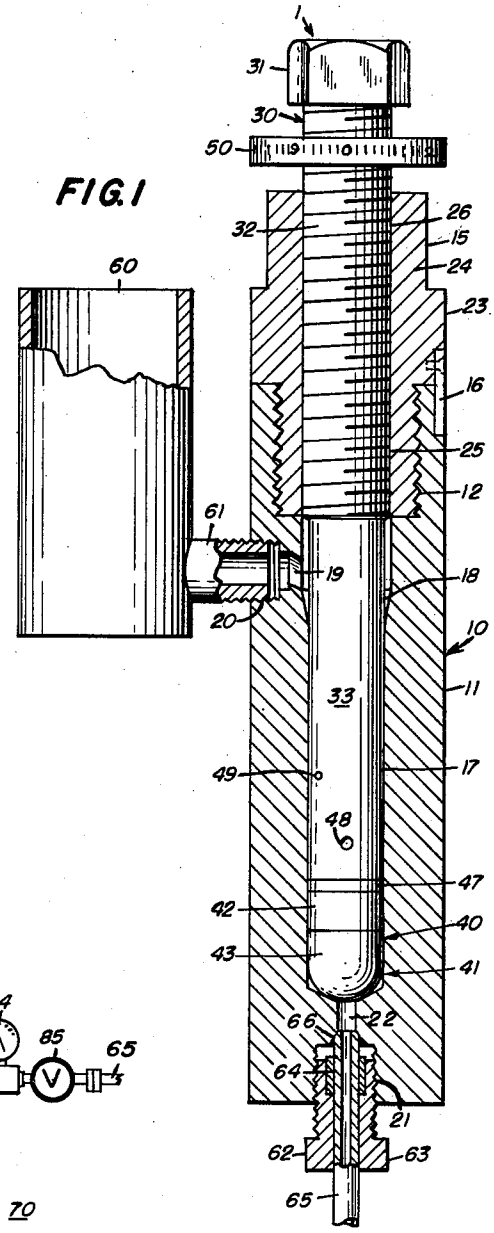


FIG. 2

FIG. 1



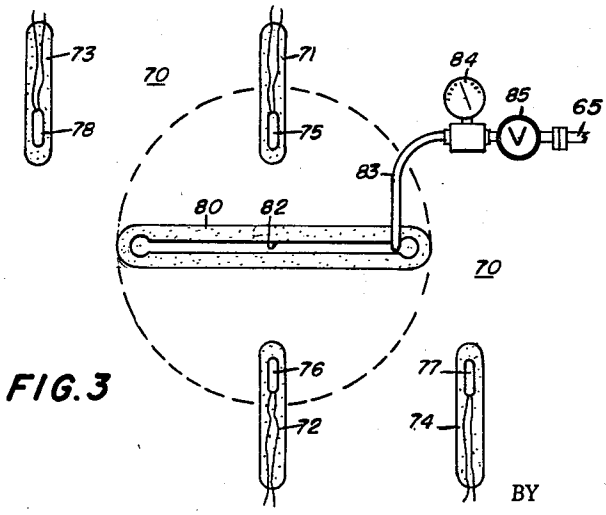


FIG. 3

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PRESSURE CONTROL MECHANISM

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The invention herein described and claimed may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of royalties thereon or therefor.

This invention relates to a portable hand-operated mechanical device for pumping fluids under high pressure and simultaneously metering the volume of fluid pumped. It has particular utility as a means to control the raising or lowering of pressure in various types of hydraulic pressure cells which may be installed in concrete portions of structures, or in rock or other geologic materials in mines, quarries and tunnels, to measure or to study the pressure or load existing in the concrete or rock. The data and other information made available by such measurements and studies are important for devising improved methods of designing structures, controlling and supporting "ground" in the vicinity of excavations in the earth's crust, for excavating, and the sequencing thereof, and for guiding construction and mining operations. Pressure cells as controlled by the present invention, provide continuous indications of the magnitude and changes of ground pressure as well as forewarning of dangerous ground conditions.

A typical utilization of the present invention is in the control of rock displacement in a mine. Pressure data provided by means of the invention is significant to the determination of the character and extent of the rock load, and the possible rock displacement or deformation. The effect of excessive pressure may be rockburst if the rock is strong, or it may be a plastic flow as in "squeezing ground" if the rock is "soft." Previously, the evaluation of steps taken to control rock pressure was based largely on the occurrence or non-occurrence of excessive rock displacement. Since the magnitude of displacement and deformation depend on the mechanical properties of the rock as well as the rock pressure, the variability of rock properties tended to obscure the influence of pressure on the deformation at different locations within the mine. Moreover, as the control of rock displacement depends ultimately on controlling the pressure that creates the displacement, knowledge of the direction and magnitude of the rock pressure is likely to be much more meaningful than knowledge of the direction and magnitude of the rock displacement and deformation. In addition, since the magnitude of rock deformation particularly flow and fracture, depends on the duration of loading as well as on the applied pressure, an earlier indication of the ground control situation is obtained by measurement of rock pressure than by measurement of rock deformation. In an operating situation this amounts to an advance warning, permitting appropriate corrective action to be initiated perhaps by changing the sequence or rate of extraction in the effected area so as to decrease the rock pressure before it causes excessive deformation which might otherwise lead to the crushing of supports by squeezing ground.

It is an object of the present invention to provide a mechanism for controlling very high pressures by means of an easily displaceable hand-operated piston of the mechanism.

A further object of the present invention is to provide in a pressure control mechanism a screw type hydraulic pressure applying piston having a highly effective sealing arrangement for hydraulic fluid, including a displaceable part.

A still further object of the present invention is a pressure control mechanism having means for accurately metering fluid pumped by a pressure applying piston therein.

These and other objects and advantages of the invention will be more clearly understood from the following description of a preferred embodiment of the invention, considered together with the accompanying drawing wherein:

FIG. 1 is an elevational view of the assembled pressure regulator shown partly in section taken axially through the apparatus;

FIG. 2 is a cross-sectional view taken axially through the assembled piston part of the apparatus shown in FIG. 1, and

FIG. 3 is a schematic representation of a hydraulic pressure cell in a pressure measurement array.

A housing **10** and a screw piston **30** constitute the major cooperating components of the pressure control mechanism, according to the present invention. Housing **10** consists of a stainless steel piston block **11**, having for the greater part of its length a square cross-section and is topped by a short cylindrical portion. Through the upper flat surface of the cylindrical portion there is provided a relatively wide internally threaded opening **12** into which is tightly screwed a cap-like bearing sleeve **15**, also of stainless steel. Key means **16** fitted into an elongated socket having matching parts on the block **11** and sleeve **15**, and secured to the latter by a small screw, prevents any relative movement between these housing parts.

Centrally drilled through the bottom of opening **12**, and directed axially into the block **11** for the greater part of its length, is a cylindrical well **17**, the bottom of which is tapered downward at a small angle towards its center. A short length of the upper part of well **17**, which is of slightly greater diameter than the lower part thereof, is joined to this lower part by a short tapered portion **18**. Into one of the flat sides of block **11** is a threaded recess **20**, communicating with a short passage **19** downwardly inclined towards, and opening into well **17** near the top of the tapered portion **18**. A further short threaded recess **21** in the base surface of block **11** is bottomed with a short central taper and communicates through an opening therein with a relatively small diameter passage **22**, joining recess **21** to an axial opening in the bottom taper of well **17**.

Sleeve **15** capping the block **11**, is formed with a cylindrical mid-section **23**, matching the upper cylindrical portion of the block, an upper hexagonal nut-like portion **24**, and a turned down lower portion **25** of appropriate length and externally threaded to allow this sleeve portion to substantially fill the opening **12** of the block when it is screwed down therein. A central hole **26**, axially through the sleeve **15**, and matching in diameter the enlarged upper part of well **17**, is finely threaded along its full length. Although housing **10** has been described as formed by joining two individual sections, it will be readily appreciated that this construction is for convenience in fabrication, and the housing may be made as a unitary element.

Screw piston **30** is basically formed from a stainless steel rod which has been machined to provide a hexagonal head **31**, a threaded portion **32**, and a finger-like plunger **33**. Portion **32** is of a proper diameter, and provided with appropriate fine thread to be precisely accommodated for threaded engagement in hole **26** of the sleeve **15**. The diameter of plunger **33** is turned down from

that of portion 32 to permit the greater length of well 17 to receive the plunger in a sliding fit. Attached on the far end of the plunger 33, for relative displacement therewith is a high pressure sealing mechanism 40, including a stainless steel mushroom tip 41, and a disk seal 42. With reference to FIG. 2, there is seen in cross-section the actual configuration of the mushroom shaped tip 41, which includes a hemispherical head 43, at the end of a cylindrical stem 44, the latter having an elongated slot 45 cut through the upper half thereof. The diameter of tip head 43 exceeds that of the plunger 33 by a very slight amount, whereby it obtains a snug fit in the well 17 of the housing, instead of a sliding fit. Slidably retained on stem 44, and normally seated on a shoulder defined by the under surface of head 43 and the cylindrical surface of stem 44, is the disk seal 42, whose outside diameter equals that of the tip head 43. This disk seal is made of a relatively wide ring of Teflon, a plastic consisting of tetrafluoroethylene polymer, a polyethylene or other similar material.

To facilitate the assembly of the sealing mechanism 40, on the plunger 33, the end of the latter is provided with a relatively deep socket 46 which receives within it the cylindrical tip stem 44. Socket 46 is sufficiently deeper than the length of stem 44, to allow the tip and the disk seal fitted thereon to have movement relatively to the plunger. A narrow stainless steel retainer ring 47 corresponding to the form of the bottom surface of the plunger, is slipped over the stem 44, and provides contacting surfaces between the disk seal and the plunger as the stem slides in the socket 46. So that such sliding may be maintained within limits, a small hole through the cylindrical surfaces of the plunger, and in alignment with a middle portion of slot 45 when parts 43, 42, 47 and 33 are fully compacted, as shown in FIG. 1, receives a rod-like pin 48 passing through the slot 45. In its most extended position, the tip 41 brings the upper end of slot 45 into contact with pin 48. A small passage 49 from the socket 46, opens through the cylindrical wall of the plunger, and provides a conventional fluid exhaust port for the socket.

Screwed high up on the threaded portion 32 of the piston 30, is a relatively thick, and wide collar-like calibrated disk 50. When this disk is preset in position on the piston 30, each complete and partial revolution of the threads on portion 32, raising or lowering the piston, will also rotate the disk to the same extent past a conventional index marker and the numerals 0 to 9, and the graduations therebetween will indicate the turns to the nearest $\frac{1}{100}$ of a revolution.

Fluid such as mercury, glycerine, or oil, upon which piston 30 acts, is supplied to the housing 10 from a reservoir 60, connected to the housing by means of a short pipe 61. Threads are provided on both ends of this pipe which is screwed into a threaded hole at the lower part of reservoir 60, and into the threaded recess 20 of housing 10, to form a conduit with passage 19, from the reservoir to housing well 17. The flow of fluid under pressure is through a conventional coupling nipple 62, screwed into recess 21 of housing 10, by means of a hexagonal head gland nut 63 on the nipple. A tubing constituting a pipe 65, having threaded onto one end thereof, a collar 64 which is seated within the coupling nipple 62, is coupled to the block 11 by turning nut 63 of the coupling to force a cone shaped end 66 of the pipe into a conical receiving portion at the bottom of recess 21. The path for the fluid flow is completed through the passage 22, and the pipe 65 coupled by the nipple 62 to connect a hydraulic pressure receiving device to the pressure regulator.

Before applying the present invention for operation, the pressure receiving device and the connecting line between it and the pressure regulator, including piping equipped with a pressure gage and a valve, are completely filled with fluid, and the valve is closed. With piston 30 removed, fluid is poured into the reservoir 60 until the fluid level in the well 17 rises above the fluid inlet opening from passage 19. Piston 30 is then inserted into the housing 10,

submerging the plunger 33 in the fluid, and piston portion 32 and sleeve 15, are brought into threaded engagement. By advancing the piston 30 excess fluid in the well 17 is forced back through passage 19 and out into the reservoir 60. The slightly enlarged upper end tapered portion 18 in the bore of well 17 are provided so that excessive fluid pressure does not develop until the disk seal 42 on the piston 30 has passed below the fluid inlet opening out of passage 19. It becomes evident from this arrangement that the tapered portion 18 in conjunction with the location of the fluid inlet passage 19, makes a check valve unnecessary when fluid is being pumped into the receiving device, and makes a by-pass valve unnecessary when fluid is permitted to leave the receiving device in excess of the capacity of well 17.

When fluid pressure develops in the well 17 against the advance of the piston, as indicated by a sudden increase of the torque required to turn the screw of the piston, the valve in the piping connecting the receiving device, is opened. By thereafter setting calibrated disk 50 to an index mark, and counting therefrom the turns of the screw piston 30 as it advances beyond the point of increased torque, the volume of fluid pumped into the receiving device may be calculated from the following relationship:

$$\text{(Cubic inches of fluid)} = \frac{\text{(number of turns of screw piston)}}{\text{(number of threads per inch on screw piston)}} \times \text{(square inches of cross-sectional area of the well bore)}$$

When the full travel of the screw piston has been reached by reason of the tip head 43 seating in the tapered end of well 17, another charge may then be conveniently pumped to the receiving device. For this purpose, the valve in the connecting line is again closed to retain the fluid previously pumped into the receiving device. Retraction of the piston 30 is begun and continued until the plunger tip 41 clears the inlet opening out of passage 19, which is indicated by a sudden lowering of the fluid level in the reservoir 60. It is evident from this function that the reservoir should be replenished at intervals and never allowed to become empty. When after a short time the flow of fluid from the reservoir into the well 17 ceases, the piston is again advanced until fluid pressure develops. In the manner previously set forth, the valve in the line of the receiving device is opened, and the turns of the screw piston beyond this point are counted by means of the again reset calibrated disk 50, to measure the volume of fluid pumped. This pumping and metering cycle may be repeated any number of times.

Volume metering in the manner described is dependable in that entrapment of air is prevented by the filling with fluid of all elements coupled to the pressure control mechanism, and by the sealing action of the advancing piston tip 41 of plunger 33. However, of more significance in this respect is the highly effective sealing action of the disk seal 42 at the end of plunger 33, which prevents fluid leakage past the piston irrespective of the fluid pressures produced. Fluid pressure against the head 43 of the mushroom tip, causes it to compress the disk seal 42 against the retainer ring 47, whereby the disk seal expands upon the wall of well 17, and the tight fit achieved thereby prevents fluid from leaking or escaping around the plunger 33. Since the stem 44 may slide in socket 46, and hence allow tip 41 to be displaceable relative to the end of the plunger 33, the disk seal 42 on the tip can be compressed in proportion to the fluid pressure. To avoid any possible impediment to this cooperation by reason of fluid gradually working its way into the bottom of socket 46, the relief port 49 is provided to permit the escape of any such fluid from socket 46. By means of this construction, the higher the fluid pressure the greater is the sealing pressure exerted by the disk seal 42. When the piston under this state of high pressure is turned to retract it in the well, plunger

pin 48 acts upon the upper end of slots 45 to assist in withdrawing the parts 41, 42, and 47.

The pressure control mechanism of the present invention is uniquely suited for applying and controlling the pressure in an arrangement of apparatus such as shown in FIG. 3 which is used to measure total existing rock pressure in mines, for purposes hereinbefore explained. In the figure, a vertical section 70 of a rib of rock in which the pressure is to be measured, is shown with four vertical slots 71, 72, 73, and 74, cut therein by drilling a series of overlapping holes with an airleg drill. Into each of the respective slots at a suitable depth indicated below, are cemented commercially available electric resistance strain gages 75, 76, 77, and 78. Initial gage readings G*i* are noted, which are indicative of the initial vertical rock pressure *pi*. Thereafter a horizontal slot 80 is cut into the rib, which results in partly relieving the vertical rock pressure within a zone roughly cylindrical in shape and centered about the slot as shown in FIG. 3 by dashed line 81. This causes the reading G*i* of the gages 75, 76, to change to an average value of G*r*, corresponding to the relieved state. By considering the readings from a pair of strain gages the influence of rock variability is averaged out. A flat steel hydraulic pressure cell 82, shown by FIG. 3 in vertical cross-section, and usually measuring 12 x 12 inches to 16 x 16 inches, as seen in plan view, is then cemented in the horizontal slot 80. The location of the pressure cell center in its emplacement provides the suitable measure of depth into the rib for the strain gages, since when so placed they respond to changes inside the rib rather than to surface changes.

Extending out of the unitary structure of cell 82 is a pipe 83 having inserted along its conduit path a pressure gage 84, and a valve 85, and which through its coupling to pipe 65 completes a path for fluid flow between the cell and the pressure control mechanism shown in FIG. 1. In the manner previously described, fluid is supplied to fill the pressure cell 82, and the connecting elements including pipes 65 and 83, gage 84, and open valve 85. Thereafter valve 85 is closed, and a buildup of pressure in pressure control mechanism 1 is followed by opening the valve to permit the build up of pressure in the pressure cell 82. Merely turning the screw piston 30 by applying a hand wrench to its hexagonal head 31, pressures up to 10,000 pounds per square inch may be built up by pumping repeated charges of fluid to the pressure cell, and the volume of fluid pumped can be metered as the fluid is pumped. In the operation for the arrangement of FIG. 3, the control mechanism 1 raises the pressure within the cell 82 until the average reading of gages 75 and 76 returns to the initial value G*i*. When this occurs, the pressure within the cell is presumed to be equal to *pi*, the vertical pressure that was formerly carried by the rock within the horizontal slot. The rock pressure is thus obtained by direct measurement rather than being determined by measuring deformation which is then converted to pressure through a stress-strain relationship. Once the cell pressure is made equal to the rock pressure, and the valve 85 is closed, the fluid pressure read on gage 84 will rise and fall with the rock pressure, remaining always equal to it, if the hydraulic pressure cell and the slot-filling mortar together possess an effective modulus of elasticity, E not too different from that of the rock. In view of the difficulty of accurately determining the effective E of the cell and mortar, there is available the further arrangement of FIG. 3, including the outer pair of strain gages 77 and 78, which may be operated independently of the knowledge of E. These outer gages are installed a selected distance away from the pressure cell so that their readings cannot be influenced by the pressure relief effect due to making slot 80, or to the pressure exerted by pumping fluid into cell 82. When, owing to the effects of mining in the vicinity, the rock pressure changes from the initial value *pi* to some new value *px*, the new rock pressure is found as (and is equal to) the

fluid pressure required to bring the average reading of the gages 75, and 76, to G*x*, rather than to G*i*, as before, because G*i* corresponds only to the initial rock pressure *pi*. On the other hand, G*x* is determined from the average reading of the outer strain gages 77, and 78 at the new rock pressure *px*, and is the average reading that the gages 75, and 76 should exhibit if the pressure cell 82 and slot 80 were not present.

Mechanical properties of the rock can be deduced from the relationship between the fluid pressure and the accurately-metered volume of fluid pumped into the fluid pressure cell. For this application of the pressure control mechanism the fluid pressure cell may have different shapes such as cylindrical, instead of being flat like that shown for pressure cell 82.

While one embodiment of the invention and a practical application thereof have been described more or less in detail with specific reference to the drawings, it will be obvious that changes in detail may be made without departing from the spirit of the invention, and that the invention has utility in many other sructural arrangements requiring the build up and control of high pressure in an enclosure. In a possible modification of the FIG. 1 arrangement, the coupling means 62 for the pipe 65 joining the control mechanism 1 to a pressure receiving device, would be in the side of housing 10 near the lower end of well 17, rather than in the bottom of the housing. The control mechanism 1 which is usually operated in the vertical position may also be operated with its axis inclined or horizontal, in which case it may be convenient to modify the reservoir 60 such that its attaching pipe 61 extends from the bottom of the reservoir.

From the foregoing description it will be apparent that the invention provides a novel pressure control mechanism which is simple in construction and highly efficient in use.

We claim:

1. Apparatus for controlling pressure, comprising a housing having a passage therethrough, opening fully at one end of the housing and constrictively at the other end thereof, said passage having means adjacent said full opening for receiving and maintaining in displaceable engagement therewith a piston means, a first conduit passage in said housing communicating the said passage at a point between said openings therein, with means outside said housing, a second conduit passage in said housing communicating the said constructive opening in the passage with further means outside the housing, a piston means for engagement in the said full opening comprising a plunger element made operable when displaced along said passage between points adjacent the said first conduit passage and said constrictive opening, bearing means fixedly secured within said piston means and passing through said plunger element whereby the latter is free to be displaced relative to said bearing means, and a deformable means supported at one end of said plunger element and displaceable thereon relative to said piston means, for sealing off any communication between the said means and further means outside said housing through the said first and second conduit passages by way of said passage.

2. The pressure control apparatus of claim 1, wherein said means for receiving and maintaining said piston means in said full opening of the passage, comprises means formed along a portion of said passage for guiding said piston for rotative movement and linear displacement along said passage.

3. The pressure control apparatus of claim 1, wherein the said passage is cylindrical, and a portion thereof adjacent the said first conduit passage is tapered to join an elongated uniform diameter portion of the passage with a shorter portion thereof having a greater uniform diameter.

4. The pressure control apparatus of claim 1, wherein the means outside said housing comprises a container

having an opening therein, and a pipe means fastened in said opening and in said first conduit passage to provide a conduit path between the container and the passage in said housing.

5. The pressure control apparatus of claim 2, wherein complementary guide means on said piston means operatively cooperates wtih said means formed along a portion of said passage, to obtain the said rotative and linear displacement of the piston means, and a calibrated indicia element positionable on said complementary guiding means and operable to rotate with said piston means to indicate the number of rotations made by said piston means.

6. Apparatus for controlling pressure, comprising a housing and a piston rotatively and linearly displaceable therein, an elongated cylindrical portion of said piston sliding within a hollow conforming cylindrical portion of the housing, a fluid storage element and conduit means for conducting fluid from said storage element to said hollow portion of the housing, driven means on said piston operative to rotate and linearly displace the piston in said housing, a piston tip arrangement comprising a terminal hemispherical fluid contacting element and a cylindrical stem extending from the base thereof having an elongated slot therethrough, a socket in the end of the said cylindrical portion of the piston receiving said tip stem for sliding movement therein, a pin supported in said socket and passing through said slot whereby the movement of the tip arrangement relative to the piston is limited, a retainer ring and a deformable sealing element supported on said tip stem, said element being operable to contact the base of said hemispherical element and said ring, and to deform in contact with the surface defining said hollow portion of the housing, under pressure produced in fluid confined in said hollow portion, by the linear movement of the piston.

7. The pressure controlling apparatus of claim 6, wherein the material constituting the sealing element is Teflon.

8. The pressure controlling apparatus of claim 6, wherein the sealing element is made of polyethylene.

9. A pressure control apparatus having a fluid storage element and means for conducting fluid from said storage element, and at high pressures through said apparatus, including means for precisely metering the volume of fluid conducted through said apparatus comprising a housing and a piston mechanism rotatively and linearly displaceable therein, an elongated cylindrical portion of said piston mechanism sliding within a hollow conforming cylindrical portion of the housing, driven means on one end of said piston mechanism operative to rotate and linearly displace the piston in said housing, a fluid sealing arrangement on an end of said piston opposite to the said one end, said arrangement comprising a deformable sealing element supported on a means movable relative to the said elongated cylindrical portion of the said piston mechanism, said sealing element being operative to deform in contact wtih the surface defining said hollow portion of the housing, under pressure produced in fluid confined in said hollow portion by the linear movement of the piston, and a calibrated indicia element positionable on said driven means and operable to rotate with said piston mechanism to indicate the volume of fluid conducted in accordance with the number of rotations made by said piston mechanism.

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