

April 23, 1957

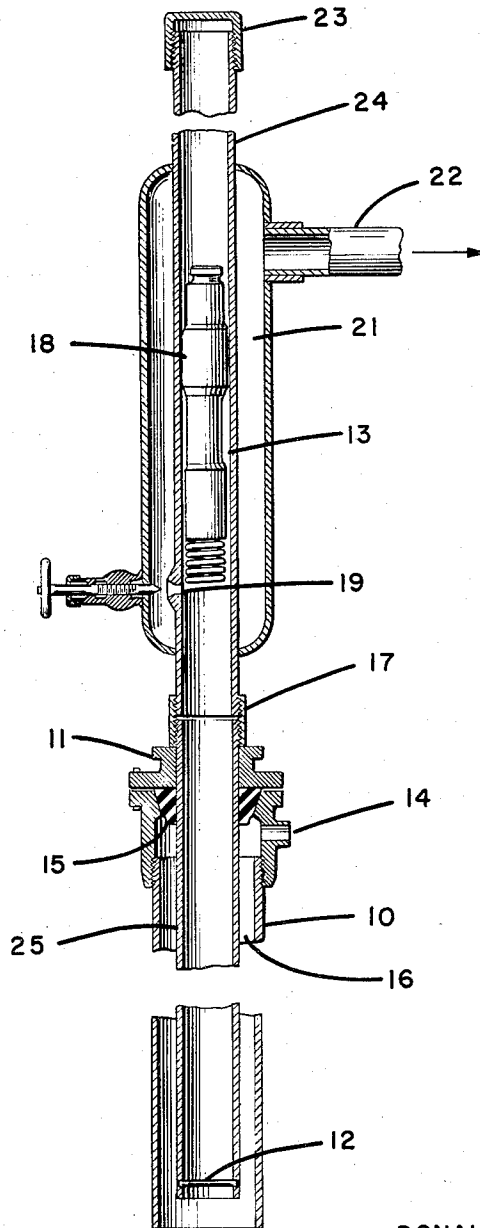
D. D. CURNUTT ET AL

2,789,645

TEMPERATURE-ACTUATED FREE PISTON APPARATUS

Filed Nov. 9, 1953

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

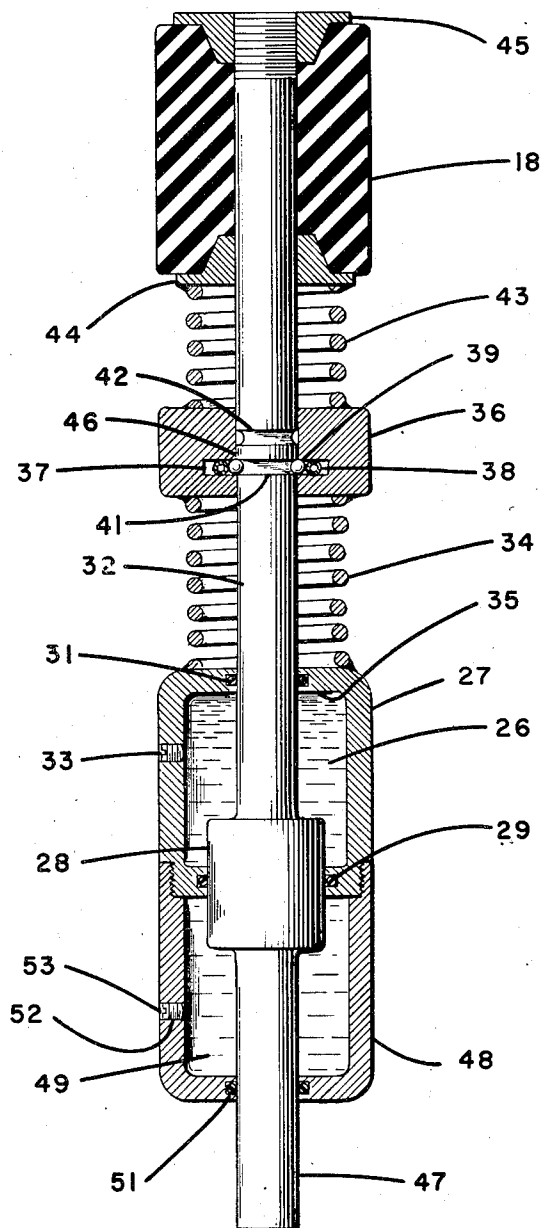


FIG. 2

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4 Sheets-Sheet 3

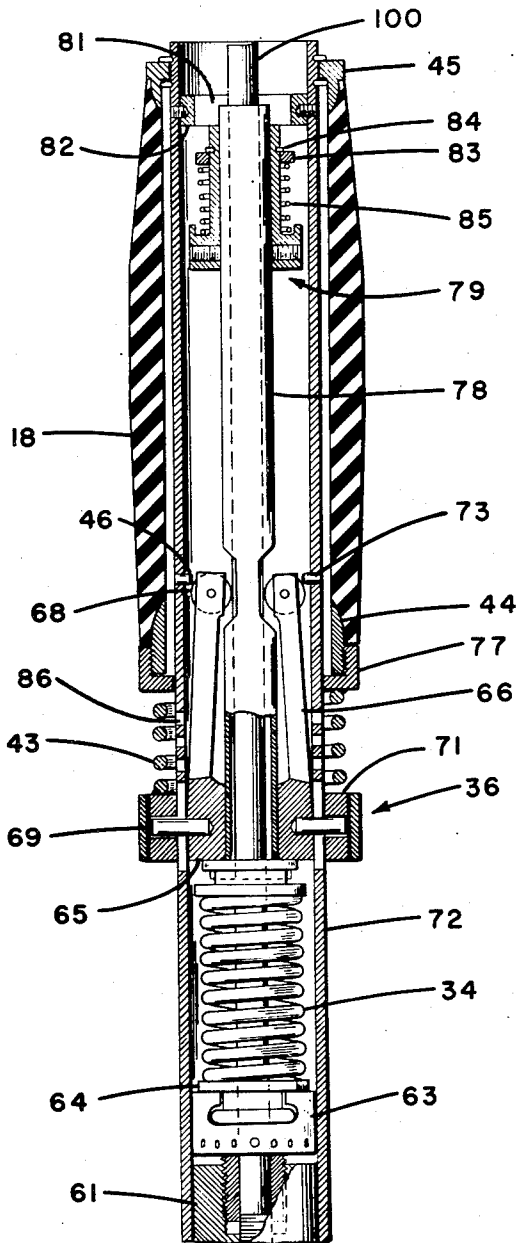


FIG. 3

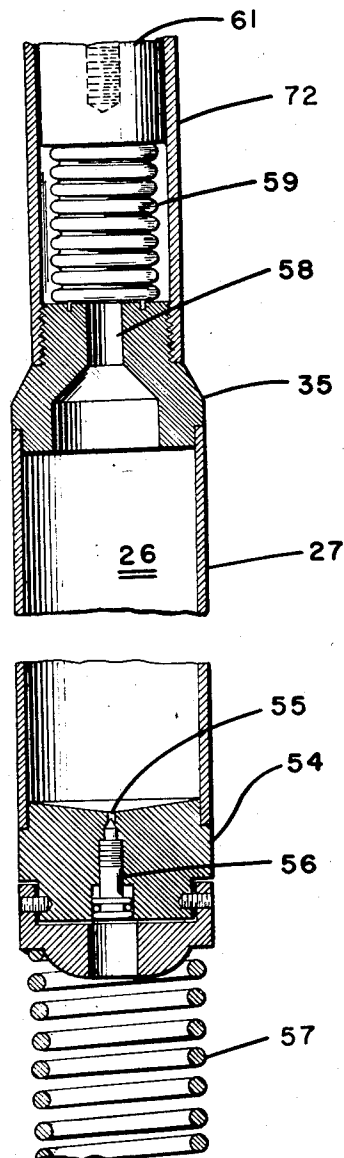


FIG. 4

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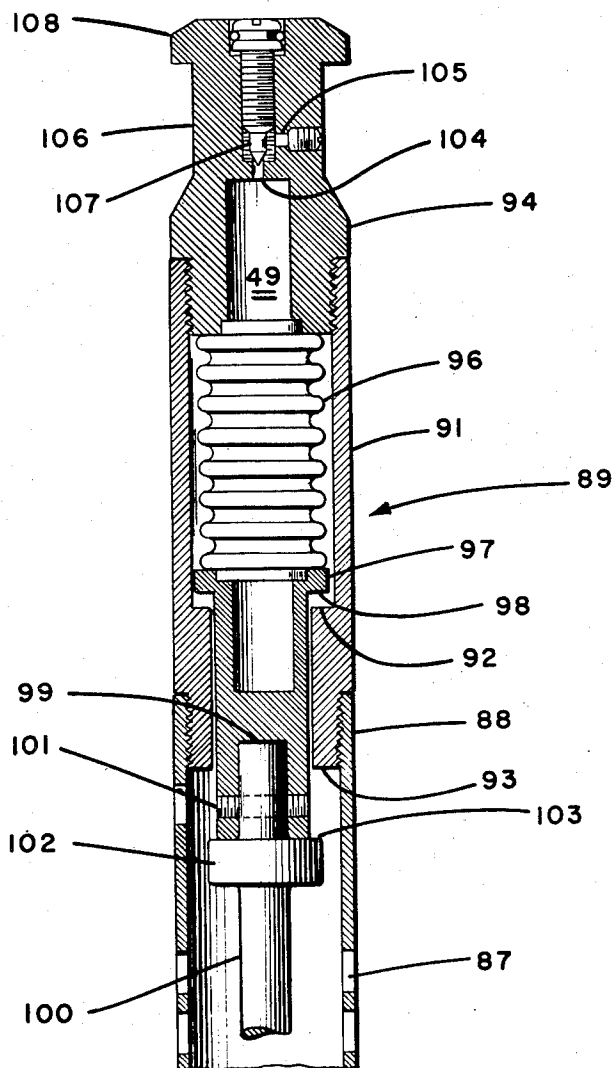


FIG. 5

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2,789,645

TEMPERATURE-ACTUATED FREE PISTON APPARATUS

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Application November 9, 1953, Serial No. 390,849

18 Claims. (Cl. 166—170)

This invention relates to a free piston which automatically reciprocates in a vertical tubing string. More particularly, this invention relates to a temperature-actuated free piston which reciprocates in a vertical well tubing to produce a well or to remove deposits such as paraffin from the inside tubing walls.

In the producing of oil wells, various types of free pistons, or plungers as they are sometimes called, have been used as a divider or packer between the lifting gas and the produced liquids whereby the well may be produced with a reduced gas/oil ratio. These free pistons also have been used in flowing and gas lift wells for the purpose of preventing the accumulation of thick deposits on the tubing wall and for removing deposits from such tubing walls once they have been produced. These include the non-automatic rabbit or tubing cutter which is dropped into a well tubing when the well is not flowing, is allowed to drop to the bottom of the tubing, and is then driven to the surface by flowing the well. Occasional passage of such cutters through the tubing generally keeps deposits from accumulating on the tubing walls. This non-automatic type, however, requires considerable attention, and if the rabbit is not run at proper intervals and the deposit becomes too thick, the scraper will not fall and other and more expensive means have to be provided for removing the thick tubing deposit. For this reason, the non-automatic type of scrapers have been replaced, to some extent, by the automatic type scrapers which reciprocate periodically in the tubing without any care or attention from the operator. One automatic type of free piston is disclosed in copending application Serial Number 197,048, now Patent No. 2,704,980. The apparatus therein disclosed has been found to operate satisfactorily both as a pumping apparatus and as a paraffin scraper, but in some cases minor modifications are desirable.

It is, therefore, an object of this invention to provide an improved free piston. It is a more specific object of this invention to provide a temperature-sensitive free piston which is not responsive to pressure variations and which is so constructed as to accumulate energy in a resilient member such as a spring to operate the packing or scraping element in both directions of operation and then to provide a positive snap action which releases the accumulated energy to expand or contract the scraping element forcibly with a quick action. These and other objects of this invention will become apparent from the following description in which various embodiments of the invention are shown and described for the purpose of illustrating the invention. In this description, reference will be made to the accompanying drawings wherein like numbers refer to corresponding parts and in which:

Figure 1 is a cross-sectional view of a well apparatus in which the free piston operates;

Figure 2 is a cross-sectional view of an embodiment of our improved free piston showing particularly the elements of such a free piston in simplified form;

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Figures 3 and 4 are cross-sectional views of a preferred embodiment of the free piston apparatus; and

Figure 5 is a cross-sectional view of an apparatus used to modify the apparatus shown in Figures 3 and 4.

This invention in brief comprises a temperature-actuated free piston apparatus which may be used for pumping a well or for scraping deposits from well tubing, and more particularly, it comprises an improved temperature-actuated free piston wherein the packing or scraping element is expanded at the lower end of its stroke with a snap action and is contracted at the upper end of its stroke with a similar snap action. Referring now to the drawings and specifically to Figure 1 of the drawings, a cased well 10 is shown with a tubing head 11 attached to the upper end of the casing. The tubing is equipped at the bottom with a crosspin 12 which permits well fluids to flow through the tubing but prevents the free piston 13 from falling out the bottom of the tubing into the open well. The tubing head has a lateral connection 14 into which gas may be injected. Packing 15 is also provided in the tubing head to seal around the tubing so that compressed gas can be injected into the annular space 16 for lifting the well fluids through the tubing. The tubing may be hung in the well heads by the use of slips or by collar 17, as is well known in the art.

A cooling device for the free piston as disclosed in copending application Serial Number 375,341 may be provided at the upper end of the tubing and connected to the tubing by collar 17. Inasmuch as the free piston 13 is temperature actuated, i. e., caused to reciprocate by the difference in temperature between the bottom of the well and the top of the well, and inasmuch as this difference in temperature may be very small, for example in the range 5–15° F., it is sometimes desirable to cool the free piston at the surface so that the scraping element or packer 18 will be contracted and the free piston can fall through the well fluids which are flowing upwardly in the tubing. This cooling may be accomplished by natural or artificial means such as artificial refrigeration. A preferred embodiment consists of utilizing the energy of the well fluids which are expanded adiabatically through the adjustable orifice or choke 19. These cooled expanded fluids circulate up through the cooling chamber 21 in indirect heat exchange with the free piston 13 and flow out of storage and service connections through flow line 22.

In the case of a flowing well, cap 23 is removed from the tubing extension 24 and the free piston is cooled and dropped into the tubing. This free piston being cool, the scraper is contracted so it falls through the tubing until it strikes the bottom stop, crosspin 12, or until the temperature of the free piston is high enough to actuate the scraper expanding mechanism. When the scraper is expanded, the piston can no longer fall freely through the upwardly flowing well fluids, and the piston is lifted by the well fluids to a position above adjustable choke 19. In this position, the free piston is cooled until the temperature-actuating mechanism contracts the scraper 18 and allows the free piston to fall again through the tubing.

In some cases, the free piston is used as a pumping mechanism as well as a paraffin scraping apparatus in a gas lift well. In this embodiment, the operation is substantially similar to the operation in a flowing well as above described. After the piston is dropped into the well and has been allowed to fall through the tubing to the bottom stop and after a suitable lapse of time in which the temperature of the free piston rises and expands the scraper, gas is injected into the annular space 16 through lateral connection 14. This gas may be injected from annular space 16 into the tubing 25 through gas lift valves

(not shown) or it may be displaced around the lower end of the tubing. The scraper 18 having been expanded, the piston is lifted by the gas, displacing the well fluids ahead of the free piston up the tubing. Since the gas is thus prevented by the free piston from bypassing the well fluids, the gas/oil ratio is maintained very low. Gas injection into the annular space may be discontinued when sufficient gas has been injected to displace the free piston up the tubing to the well head above adjustable choke 19. After injection of gas has been discontinued and the gas pressure has been dissipated, well fluids enter the tubing as the free piston is cooling and falling through the tubing. When the free piston has reached the bottom stop and its temperature has been increased by heat exchange with the well fluids, gas injection is commenced again on another cycle.

The elements of a temperature-actuated quick-acting free piston are shown schematically in Figure 2. In the temperature-sensitive quick-acting free piston, a liquid having a high coefficient of cubical expansion and low compressibility is used as the motivating force for expanding and contracting the scraping element 18. Suitable liquids comprise, for example, petroleum oils having a cubical expansion coefficient in the order of 0.0005 cubic inch per cubic inch per degree F., ether having a coefficient of 0.00092, and the lower alcohols such as methanol which has a coefficient of 0.0008. This liquid is placed in chamber 26 within variable volume container 27. This container, which is metallic and typically steel, has a coefficient of cubical expansion substantially lower than the coefficient for the liquid. A step piston 28 is disposed within the chamber and provides a movable wall in the container 27. Fluid seals 29 and 31 are provided respectively between the step piston and the container at the lower end and between the piston rod 32 and the container 27 at the other end of the chamber. The temperature-sensitive liquid is placed in the chamber through an opening in the wall which is closed by a plug 33. A helical spring 34 is affixed as by welding to the upper head 35 of container 27. The upper end of this helical spring is attached as by welding to a floating collar 36. This floating collar has a bore equal to the diameter of piston rod 32 so that the floating collar can be reciprocated axially on the piston rod. This collar also contains an annular recess 37 which contains a toroidal spring 38 and a number of balls 39. The toroidal spring is placed in the recess in tension so that the balls 39 are urged radially inward into recesses 41 and 42 in piston rod 32. A second helical spring 43 is attached to the upper end of floating collar 36 as by welding. The upper end of helical spring 43 is attached to and actuates the lower end of the scraping element. The upper end of the scraping element is attached to piston rod 32. In practice, the scraping element may be a metallic expandable element as shown, for example, in depending application Serial Number 151,139, now U. S. Patent 2,674,951 or it may be a resilient element as, for example, a rubber sleeve. In the case of a rubber scraping element, metallic ends 44 and 45 are affixed respectively to the lower and upper ends of the rubber sleeve by vulcanization or by mechanical means such as clamps or threads. The upper metallic element 45 may be threaded internally to receive the threaded end of piston rod 32. The lower metallic end 44 has a smooth bore adapted to slide on piston rod 32.

In operation, the floating collar is placed in the lower position with balls 39 in recess 41, and the chamber 26 is filled with the temperature-sensitive liquid by removing plug 33. This liquid may be injected into the chamber displacing step piston 28 downwardly and expanding the chamber until the pressure in the chamber is at a mean well pressure, i. e., a pressure less than the maximum well pressure but above the minimum well pressure. The correct pressure is generally calculated or determined experimentally. This pressure of the temperature-sensitive liquid in the chamber places helical spring 34 in compres-

sion which tends to but does not cause the floating collar 36 to be displaced upwardly on piston rod 32. The floating head being in the lower position, helical spring 43 is in tension. Since this spring is attached to the lower metallic end 44 and since the upper metallic end 45 is attached to the piston rod, the scraper 18 is also in tension axially causing the cross-sectional area and the outside diameter to be contracted. The piston apparatus is placed in the well in this condition, i. e., with the scraping element contracted. As it falls through the tubing in which the well fluids may be flowing upwardly, the well fluids pass around the container 27 and the scraper 18. This contact with the well fluids eventually warms and expands the temperature-sensitive liquid in chamber 26 causing the liquid in the chamber to expand at a more rapid rate than the container is expanded. This expansion of the liquid displaces step piston 28 downwardly in the chamber and at the same time moves piston rod 32 and floating collar 36 in the same direction, placing additional energy in and further compressing helical spring 34. When sufficient energy is stored in the helical spring 34 to expand the scraping element, the snap-action or quick-acting mechanism in the floating collar is actuated. (As used herein with regard to the scraper, "expand" and "contract" refer to the cross-sectional area radially and to the outside diameter.) That is, the balls 39 are forced outwardly against the force of toroidal spring 38 causing them to jump over the shoulder 46 and fall into upper recess 42. This movement of the floating collar compresses helical spring 43 which in turn expands the scraper 18 by exerting a compressive force on the lower end that is counteracted by the tension in piston rod 32. The free piston is then lifted through the tubing by the flow of the well fluids until the piston is cooled at the surface as by artificial cooling as above described. As the temperature of the temperature-sensitive liquid is reduced, helical spring 34 is placed in tension and when cooling has proceeded to a predetermined amount, the quick-acting mechanism causes the floating collar to be moved substantially instantaneously from the upper position in which the balls 39 are in recess 42 down to the lower position in which the balls are in lower recess 41. The downward movement of the floating collar then places helical spring 43 in tension which in turn contracts scraper 18 and thus allows the well fluids to bypass the free piston so that it can fall relatively freely through the tubing to commence another cycle.

In some cases, particularly in wells where the pressure differential between the bottom and top of the well is high, it is desirable to counteract the effect of well pressure on the expansion and contraction of the chamber 26. This may be accomplished by balancing the forces on the ends of the step piston 28 and the piston rod 32. A piston rod extension 47 which has a cross-sectional area substantially equal to the cross-sectional area of the piston rod is connected to the lower end of the step piston 28. A secondary container 48 is then connected to the lower end of container 27 forming a gas chamber 49. A fluid seal 51 is placed between the container and the piston rod extension so that the chamber 49 is sealed. Gas, which may be predominantly nitrogen or some other preferably inert gas such as nitrogen, is injected into chamber 49 through opening 52 which is sealed with a plug 53. This gas may have a temperature coefficient of cubical expansion equal to or even greater than the coefficient of cubical expansion of the liquid in chamber 26. However, being a gas, it is substantially more compressible than the liquid in chamber 26, and, therefore, when the temperature of both is raised, the expansion of the liquid in chamber 26 forces step piston 28 into chamber 49 against the force of the gas which is also tending to expand. Thus, the cross-sectional area of the piston rod and the piston rod extension being substantially equal where they emerge from the two chambers 26 and 49 respectively, any external pressure or variation in pressure

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has no effect upon the forces exerted by the temperature-sensitive liquid to expand or contract the scraper 18.

A preferred embodiment of the temperature-actuated quick-acting free piston is shown in Figures 3 and 4. In this embodiment, the lower head 54 of chamber 26 has a filling port 55 which may contain a valve 56 for filling the chamber with liquid and for sealing the filled chamber. A resilient bumper such as a cylinder of rubber or a helical spring 57 is attached to the lower end of head 54. This bumper substantially reduces the shock when the free piston is dropped into a dry string of tubing and falls to the bottom stop without being cushioned by liquid in the tubing. The upper head 35 of container 27 has a fluid passage 58 leading into a bellows 59 which is used as a flexible fluid seal to provide movement of the cross head 61 when the temperature-sensitive liquid in chamber 26 is expanded and contracted due to temperature changes. The movement of the cross head is transmitted to helical spring 34 through a spring adjusting screw 63 which is threadably connected for axial adjustment to the cross head and to the lower spring connector 64. The lower spring connector is attached to the lower end of spring 34 so that the spring may be placed in tension as well as in compression. The upper end of helical spring 34 is affixed to floating collar 36 which consists of an inner forked member 65 having two or more cantilever springs 66. Each spring has a roller or follower 68 at the outer or free end. The forked member 65 is connected by pins 69 to an outer sleeve 71 which floats on the piston rod or tubular body 72. The force from helical spring 34 is thus transmitted through the forked member 65 and pins 69 to the outer sleeve 71 and thence to the helical spring 43. This spring is attached at the bottom to the outer sleeve 71 and at the top to the lower end of scraper 18. Pins 73 are affixed to the tubular body 72 and project inwardly from the inside surface providing shoulders or cams 46 over which the followers 68 pass as the floating collar moves up and down relative to the body. The cantilever spring 66 in an unstressed condition hold the outer surfaces of followers 68 at a spacing greater than the spacing between the cams 46 so that considerable force is required to cause the followers to pass axially from one side of the cams to the other. The amount of force required to cause these followers to jump over cams 46 and actuate the quick-acting mechanism may vary from about fifty to several hundred pounds. Typically, an axial force of about 100 pounds is used when the scraper is a rubber sleeve.

Inasmuch as the scraper 18 is typically synthetic rubber or some other resilient material, it is attached as by vulcanizing at the ends to lower and upper metallic sleeves 44 and 45 respectively. Lower sleeve 44 is then connected as by threads to a nut 77 which is connected to the upper end of helical spring 43. The upper end of scraper 18 is then connected through the upper metallic sleeve 45 to the piston rod or tubular body 72 so that this upper end will be fixed relative to the chamber via the body and so that the connection to the lower end of the scraper element can be moved up and down relative to the connection to its upper end to expand and contract the scraper diametrically.

The axial movement of floating collar 36 relative to the body is transmitted through a tube 78 to a valve 79 which closes the fluid passage 81 through the tubular body 72. The valve consists of a valve seat 82 which is connected to the body and of a valve member 83. In the open position, this valve member is urged against a stop 84 by a helical compression spring 85. As the floating collar 36 and tube 78 are moved up by the expansion of the temperature-sensitive liquid in chamber 26, the helical compression spring 85 urges the valve member against the valve seat completely closing the fluid passage through the inside of body 72. The tubular body has a number of openings or perforations 86 below the lower end of the scraper 18 so that when the floating collar 36 is in its

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lower position and the valve is open, fluid may bypass the packer both on the outside between the tubing and the scraper and through the inside of the body.

In some cases, as indicated above, it is desirable to compensate this apparatus for the influence of pressure so that the movement of the cross head, floating collar, and scraper is not affected by the well pressure or changes in the well pressure. Referring now to Figure 5, the piston rod or tubular body 72 may be extended above the scraper 18. The tubular body contains a multiplicity of perforations 87 above the scraper to provide a fluid passage or exhaust ports for well fluids flowing around the inside of scraper 18 as the piston is lowered through the tubing, i. e., when valve 79 is open. The body is threaded at the upper end 88 to receive a pressure-compensating attachment 89. This pressure-compensating attachment consists of a case 91 which is threadably attached at the lower end to the upper end of body 88. It is internally upset at the lower end to provide an upper shoulder 92 and a lower shoulder 93. At the upper end, the case is threadably attached to a variable volume gas container 94 which has an internal gas chamber 49. This container has as a movable wall a bellows 96 which is attached at the upper end to the gas container 94 and which is sealed at the other end to a coupling 97 so that the inside of bellows 96 constitutes a part of the hermetically-sealed gas chamber 49. The cross-sectional area of bellows 96 is desirably equal to the cross-sectional area of bellows 59 so that the movement of each, being connected together, will be independent of variations in external pressure. The coupling 97 has an upper shoulder 98 which is adapted to strike shoulder 92 on the upset of case 91. This limits the lengthening of the bellows so that when it is filled with a gas before it is attached to the body, the bellows will not be distorted or destroyed. The lower end of the coupling 97 is drilled to provide an opening 99 which receives the upper end of a connecting rod 100. This connecting rod is threadably attached at the lower end to the cross head 61 and extends up through an axial bore in the floating collar 36, through tube 78, and valve 79 connecting directly the liquid bellows 59 and the gas bellows 96 so that the external forces on the two chambers 26 and 49 are balanced or compensated. Connecting rod 100 is attached at the upper end to coupling 97 with a pin 101. The connecting rod has an upset 102 near the upper end which provides a shoulder 103. This shoulder is adapted to co-act with shoulder 93 on the upset of case 91 and together with shoulders 92 and 98 to provide a limit or stop for the axial movement of the connecting rod and the floating ends of the two bellows so that neither will be destroyed due to extreme variations in temperature or the like. The gas chamber 49 is filled through ports 104 and 105 in the upper head 106. A valve member 107 is provided for closing the port 104 when the chamber has been filled with gas. A fishing or retrieving head 108 may be provided on the upper end of the piston so that it can be fished out of the well in case of an emergency.

In a typical apparatus for scraping paraffin from a two-inch tubing, it has been found that the scraper can be constructed of a rubber sleeve having a wall thickness of about $\frac{1}{2}$ inch and a length of about 6 inches. About $\frac{3}{8}$ inch of axial travel at one end provides adequate expansion and contraction of the outside diameter of this scraper so that on the upstroke there is sufficient pressure on the tubing wall to remove the deposit and on the downstroke there is sufficient clearance to allow the piston to fall freely through the tubing. In order to obtain about $\frac{3}{8}$ inch of travel at one end of the scraper, it has been found that with methyl alcohol as the temperature-sensitive liquid, the lower chamber 26 should have a total volume of about 42 cubic inches when a differential temperature of 15° is available between the upper and lower ends of the travel path. It has been found that with a gas chamber volume having about 4 cubic inches capacity filled with nitrogen to an intermediate pressure, typically about 500

p. s. i., the motivating force available for actuating the quick-acting mechanism is greater than 100 pounds over a displacement range of $\frac{3}{8}$ inch. Under these conditions, it can readily be seen that the helical spring 34 should provide a force of about 300 pounds per inch of displacement. The helical spring 43 is desirably weaker than helical spring 34 and is generally selected empirically depending upon the cross-sectional area of the scraper element, its hardness, and the like. Other design constants can be readily ascertained depending upon the temperature difference available for actuating the piston, the tubing size, and the like.

From the foregoing, it can be seen that any type of packing or scraping element can be employed. While the description has been based generally upon the use of a rubber element, it has also been found that metallic elements of various designs can be substituted for the element described. Metallic elements are preferred in some cases as, for example, where there are burrs on the tubing which would destroy softer scraper elements. After the burrs are removed, rubber or fibrous elements may be substituted for the metallic scrapers. Also, it will be apparent that while only one packing or scraping element has been disclosed, two or more such elements properly spaced can be employed to advantage in some cases to provide a better fluid seal with the inside surface of the tubing and to prevent fluid bypass around the packing element when that element crosses a tubing coupling or the like. Thus, it can be seen that this invention is capable of substantial modifications and is, therefore, not to be construed to be limited to the embodiments specifically described. The invention should instead be construed to be limited only by the scope of the appended claims.

We claim:

1. A well apparatus for automatic reciprocating in a vertical tubing comprising an enclosed variable volume container, a liquid in said container, the thermal coefficients of cubical expansion of said liquid and said container being substantially different, said container including a fixed wall and a movable wall, said movable wall being moved by the difference in cubical expansion of said liquid and said container when subjected to a change in temperature, a packer outwardly expansible to engage the wall of said tubing, said packer having a connection at one end to said fixed wall and a connection at the other end to said movable wall, one of said connections being resilient, and a quick-action mechanism between said connections, whereby energy is stored in said resilient connection when said apparatus is undergoing a change in temperature and said energy is released substantially instantaneously to actuate said packer.

2. An apparatus according to claim 1 including a gas-filled container affixed to said variable volume container and having a movable wall, said movable wall in said liquid container and said movable wall in said gas-filled container having substantially equal areas exposed to external pressure, and a connection between said movable wall in said gas-filled container and said movable wall in said liquid container to balance the external forces on said variable volume container due to changes in external pressure.

3. In a well apparatus including an enclosed variable volume container, a liquid in said container, the thermal coefficient of cubical expansion of said liquid and said container being substantially different, a wall in said container which is moved by the difference in cubical expansion of said liquid and said container when subjected to a change in temperature, and a packer outwardly expansible to engage the wall of said tubing, said packer having a connection at one end to said container and a connection at the other end to said movable wall, one of said connections being resilient, the improvement comprising a quick-action mechanism between said connections, whereby energy is stored in said resilient connection when said apparatus is undergoing a change in temperature and said

energy is released substantially instantaneously to actuate said packer.

4. An apparatus according to claim 3 including a gas-filled container, a movable wall in said gas-filled container, and means connecting said wall in said variable volume container and said movable wall in said gas-filled container to balance the external forces on said variable volume container due to changes in external pressure.

5. A scraper for automatic reciprocation in a vertical well tubing comprising an enclosed variable volume container, a liquid in said container, the thermal coefficient of cubical expansion of said liquid being substantially greater than the thermal coefficient of cubical expansion of said container, a wall in said container which is moved by the cubical expansion of said liquid in said container, a scraping element outwardly expansible to engage the wall of said tubing, said scraping element having a connection at one end to said container and a connection at the other end to said wall, one of said connections being rigid, the other of said connections being resilient, and a quick-action mechanism between said connections, whereby energy is stored in said resilient connection when said apparatus is undergoing a change in temperature and said energy is released substantially instantaneously to actuate said scraping element.

6. A scraper for automatic reciprocation in a vertical well tubing comprising an enclosed variable volume container, a movable wall in said container, a scraping element outwardly expansible to engage the wall of said tubing, said scraping element being connected to both said container and said movable wall, one of the connections being resilient to store energy from the movement of said movable wall, and a quick-action mechanism between said connections, whereby the energy stored in said resilient connection is released substantially instantaneously to actuate said expansible scraping element.

7. A scraper according to claim 6 including means to balance the external forces on said variable volume container due to changes in external pressure.

8. A scraper according to claim 6 including a second container, said variable volume container and said second container being rigidly connected, a movable wall in said second container, the cross-sectional area of both said movable walls being substantially equal, said movable walls being mechanically connected in opposition to compensate for variations in external pressure on said movable walls.

9. A scraper for automatic reciprocation in a vertical well tubing comprising an enclosed variable volume container, a scraping element outwardly expansible to engage the wall of said tubing, said scraping element having a connection to said container, a movable wall in said container, means including a spring connected at one end to said movable wall to actuate said expansible scraping element, and a quick-action mechanism operatively connecting the other end of said spring with said scraping element, whereby the energy stored in said resilient connection by variations in the volume of said container is released substantially instantaneously to actuate said expansible scraping element.

10. A scraper according to claim 9 wherein said expansible scraping element comprises a resilient sleeve and wherein said connection to said container is at one end of said scraping element and the other end of said scraping element is resiliently connected to said quick-action mechanism.

11. A scraper according to claim 10 including a gas-filled container, a movable wall in said gas-filled container, and means connecting said wall in said variable volume container and said movable wall in said gas-filled container to balance the external forces on said variable volume container due to changes in external pressure.

12. A scraper according to claim 9 including a liquid in said container, said liquid having a thermal coefficient

of cubical expansion substantially greater than the thermal coefficient of cubical expansion of said container.

13. A scraper according to claim 12 in which said container is steel and said liquid is a lower alcohol.

14. A thermally-actuated well apparatus for automatic reciprocation in a vertical well tubing comprising an enclosed variable volume container, a liquid in said container, the thermal coefficient of cubical expansion of said liquid being substantially greater than the thermal coefficient of cubical expansion of said container, a bellows connected at one end to said container and forming at the other end a movable wall in said enclosed variable volume container, a packing element expandable to engage the wall of said tubing, a perforated tubular body extending through and connecting one end of said packing element to said container, a spring connected at one end to said bellows and at the other end to a resilient follower, a cam on said tubular body constructed and arranged to cooperate with said resilient follower to produce a quick action axially in both directions as said spring is placed in tension and compression by the movement of said movable wall, means connecting said other end of said spring to the other end of said expandable packing element, said spring being compressed and said packing element being expanded by the movement of said movable wall when the temperature of said liquid is increased, a fluid passage through said tubular body, a valve in said passage and means connecting said valve to said other end of said spring to close said passage when said packing element is expanded.

15. An apparatus according to claim 14 including a

second variable volume container, substantially inflexible means connecting said second variable volume container to said tubular body, a gas in said second variable volume container, a second bellows connected at one end to said second variable volume container and forming at the other end a movable wall in said second variable volume container, said movable walls in both of said variable volume containers being of substantially equal cross-sectional areas and being mechanically connected in opposition to compensate for variations in external pressure on said movable walls.

16. An apparatus according to claim 15 including stop means to limit the axial movement of said movable walls.

17. An apparatus according to claim 16 wherein said liquid is a lower alcohol and said gas is predominantly nitrogen.

18. An apparatus according to claim 15 wherein said means connecting said other end of said spring to the other end of said expandable packing element comprises a spring whereby when said packing element is in a diametrically expanded position, said other end of said expandable packing element can move axially to compensate for minor variations in the internal diameter of said well tubing.

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