July 15, 1947. J. H. MOORE 2,423,944

WELL FLOW CONTROL

Filed Aug. 22, 1944 2 Sheets-Sheet 1

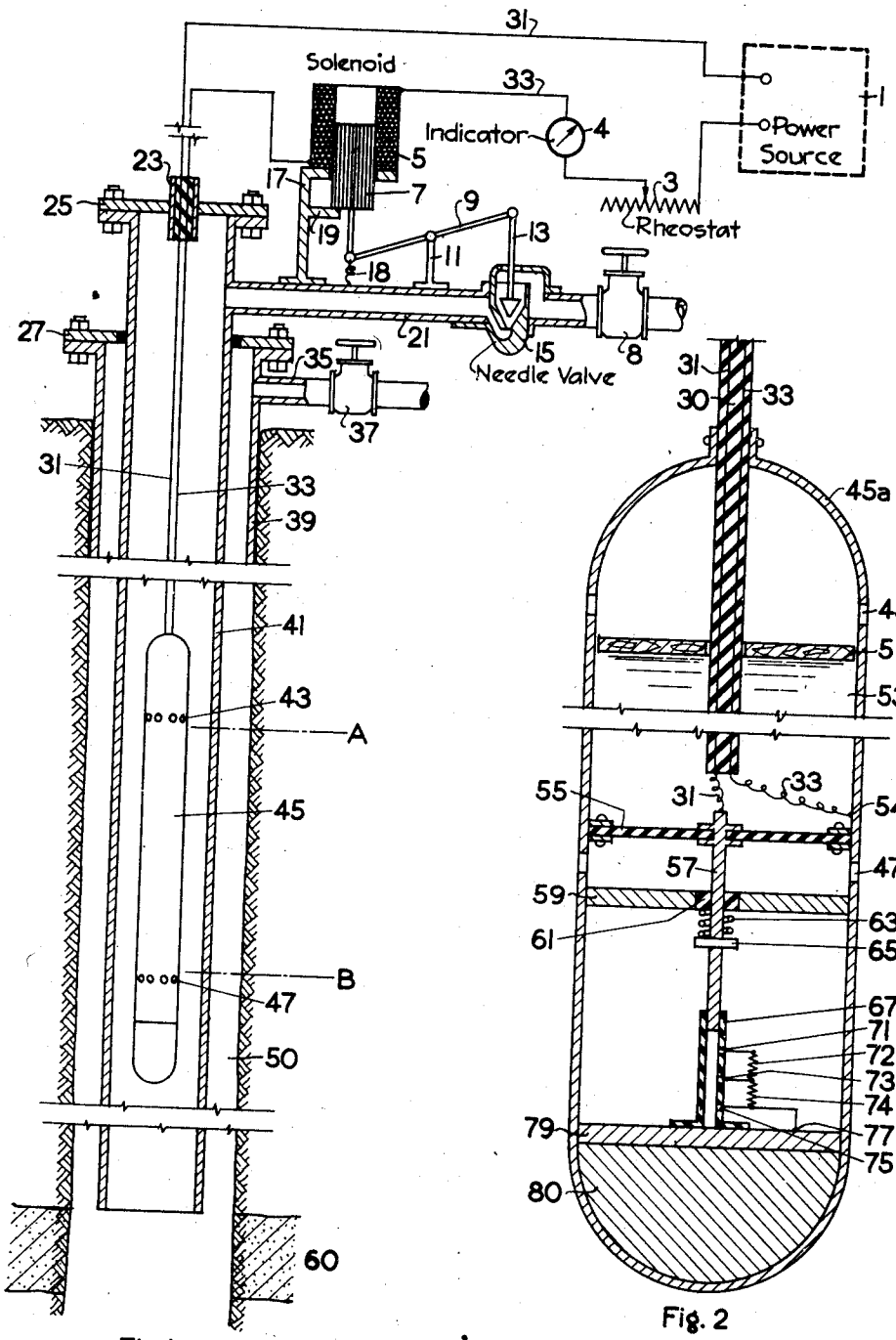


Fig. 1

Fig. 2

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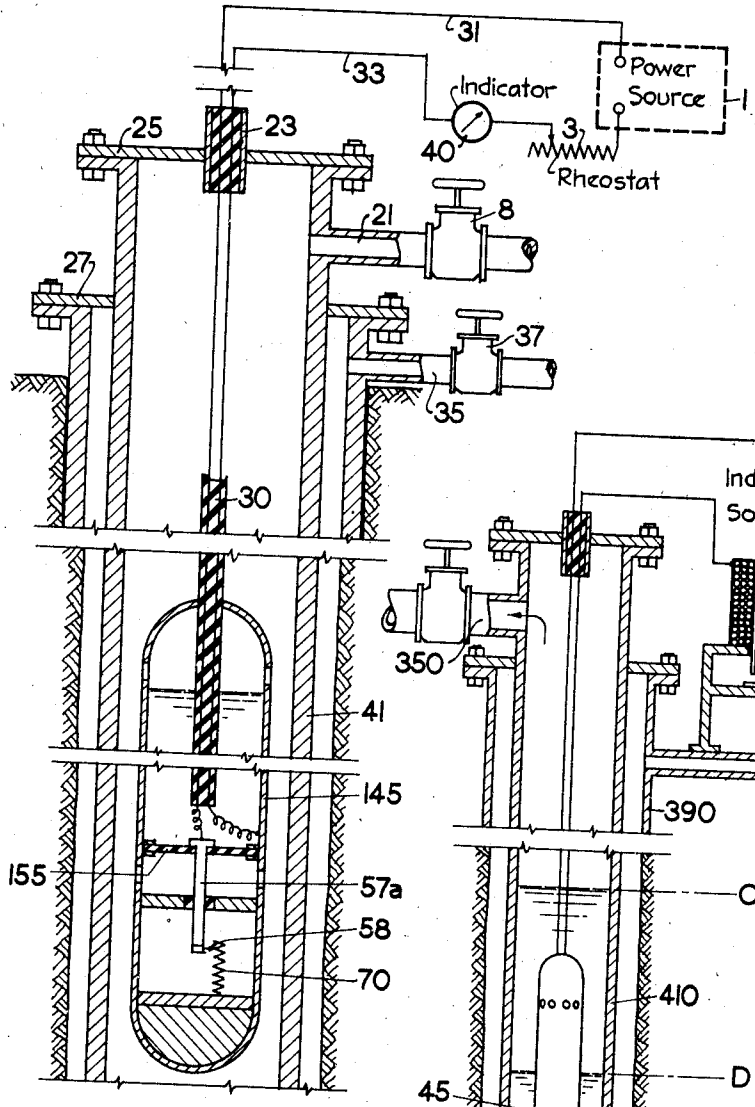


Fig. 3

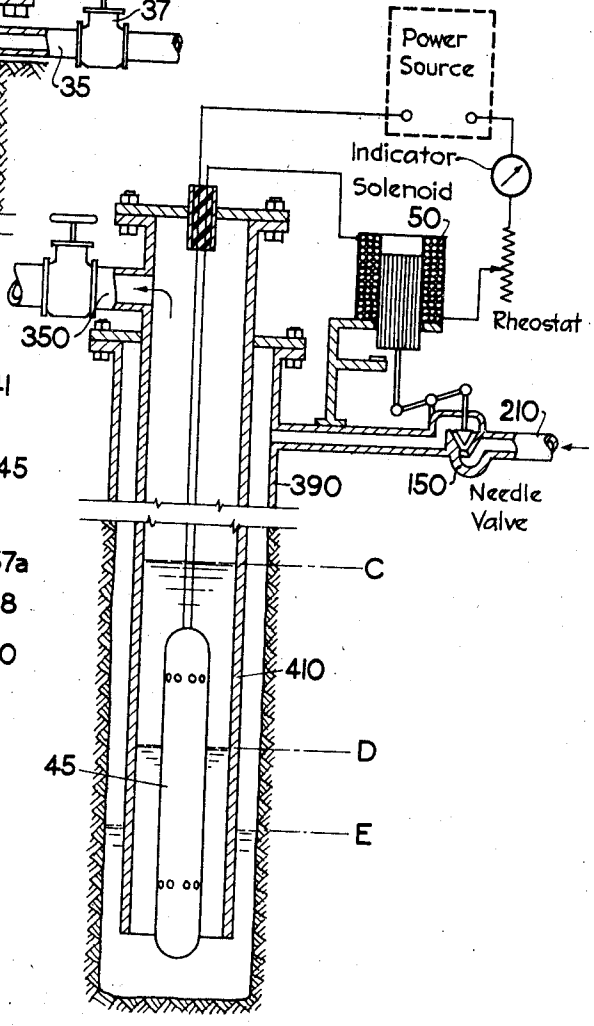


Fig. 4

Inventor: Joe Hiram Moore

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UNITED STATES PATENT OFFICE

2,423,944

WELL FLOW CONTROL

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3 Claims. (Cl. 166—2)

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This invention relates to apparatus for controlling the flow of fluids from oil and gas wells, and relates more particularly to a system whereby such flow can be controlled to give the most effective and most economic flow rate.

In producing oil from flowing wells, an optimum set of conditions obtains when the gas produced with the oil remains in solution in said oil until after the formation fluid has passed from the formation into the borehole. In order to approximate and to maintain such conditions, wells are often produced at low flow rates to prevent building up, between the formation and the borehole, a pressure differential sufficiently high for the dissolved gas to be liberated from the oil within the formation itself.

However, in producing a well in this manner, the operators have no direct means of determining whether the well is actually produced at the optimum or maximum permissible flow rate, or of ascertaining the probable changes in conditions which may occur when the flow rate is modified, and especially increased. They have, therefore, no means for immediately applying proper control measures to correct undesirable conditions or changes in conditions. It is therefore an object of this invention to provide a system for controlling the fluid flow from a well in such a manner as to maintain the fluid in a saturated condition at the face of the producing formation traversed by the well.

It is an object of this invention to provide a system for establishing and maintaining an optimum or maximum permissible rate of flow from a well without loss of reservoir energy or possible loss of recoverable oil due to premature gas liberation within the producing formation.

It is also an object of this invention to provide a system of well flow control wherein the hydrostatic head of a column of well fluid is balanced within the well against the hydrostatic head of a column of a fluid of predetermined density, and the pressure differential between said heads is used for electrically energizing an indicating or actuating flow control circuit at the surface.

These and other objects of this invention will be understood from the following description taken with reference to the attached drawings, wherein:

Figure 1 is a diagrammatic view of an embodiment of the present automatic control system in application to a flowing well;

Figure 2 is a cross section view of the controller forming a part of the present system;

Figure 3 is another diagrammatic view of a control system according to the present invention; and

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Figure 4 is a diagrammatic view of an embodiment of the present invention in application to wells operated by pressure gas injection.

Referring to Figure 1, a well **50** is shown provided with a casing string **39**, extending into the well to any desired level and closed at the surface by means of a casing head **27** provided with a conduit **35**, closed by a valve **37**. A tubing string **41** is positioned within the casing and extends likewise to any desired level, for example that of the producing formation **60**. The tubing **41** is closed at the top by means of a head **25** provided with a lubricator **23**.

The tubing **41** is used for raising to the surface the fluid entering the well from the producing formation **60**, and is provided at the surface with a conduit **21**, which may be in communication with a storage tank, not shown. The rate of flow in conduit **21**, and therefore in tubing **41**, is controlled by means of an automatic valve, such as a choke or needle valve schematically shown at **15**. A valve such as a gate valve **8** may likewise be provided in conduit **21**.

The valve **15** is electrically operated by means comprising a controller **45** which may be installed within the tubing **41**, or may be lowered thereinto on a cable **30**, passing through the lubricator **23** and comprising one or more insulated electrical conductors, as shown at **31** and **33**.

Besides the controller **45** and conductors **31** and **33**, the control circuit of the automatic valve **15** may comprise a source of electrical energy **1**, a rheostat **3**, an indicator **4**, and means responsive to the controller **45** for actuating the valve **15** to an open, closed or intermediate position such, for example, as an electric motor or a relay or solenoid **5** linked to the stem **13** of valve **15** by means such as a pivoted lever **9**, as shown in the drawing for purposes of illustration.

The controller **45**, as shown in greater detail in Figure 2, comprises an elongated, fluid-tight housing **45***a*, preferably made of metal, and supported on the insulated cable **30**, by means of which it is lowered into the well.

The housing **45***a* is provided in its upper part with an upper port or ports **43**, whereby fluid communication is established between the well and a chamber **53** within the controller. The chamber **53** is closed preferably at the bottom by means of a transverse resilient or flexible fluid-tight diaphragm **55**, and is adapted to be filled with a desired fluid. A float or plug **51** may, if desired, be provided to minimize intermixing be-

tween the fluid in chamber 53 and the well fluid which may enter the chamber 53 through ports 43. The chamber 53 should preferably have a considerable axial or vertical length, such for example as about 20 feet.

A metallic stem 57 is fixedly carried by the diaphragm 55, and is electrically connected to one of the leads 31—33, the other lead being grounded to the housing as shown at 54. The stem 57 passes through a bushing 61 of a guide plate 59, and may be provided with a spring 63, carried between or attached to said plate and a ring or plate 65, affixed to the stem 57. The spring 63 is adapted to dampen small or non-significant pulsations of the diaphragm 55.

A lower port or ports 47 through the housing 45a are in communication between the well and the space below the diaphragm 55.

The lower end of the stem 57 is adapted to engage electrical contacts, of which three are shown, for purposes of illustration, at 71, 73 and 75, although any desired number of such contacts may obviously be used. Resistances 72 and 74 are connected in series with each other between contacts 71, 73 and 75, in such a manner that a gradual downward motion of the stem 57 results in gradually cutting out said resistances, the lowermost contact and the outer end of the last resistance being grounded to the housing at 77. The contacts may be conveniently mounted on an insulating hollow mandrel 67, adapted to receive and to guide the lower end of the stem 57 as it moves downward in response to a downward deflection of the diaphragm 55. The lower portion of the housing 45a is adapted to receive a weight or weighting bar 80.

In operation, the chamber 53 of the controller 45 is filled, approximately to the level of the ports 43, with a liquid having a desired density, for example a mineral oil having approximately the same specific gravity as the fluid produced by the formation 60.

The controller 45 is then lowered within the tubing to a level such, for example, as from 50 to 300 feet above the producing formation 60, the cable 30 unrolling from a reel arrangement, not shown, and passing into the well through the lubricator 23.

When the controller is at the proper level, the valve 8 being open, oil is produced from the formation through tubing 41 and conduit 21 at a rate determined by the opening of valve 8.

It will be noted that the hydrostatic head applied under those conditions to the upper face of diaphragm 55 will consist of the head of the fluid column within the chamber 53 (substantially between the levels A and B of Figure 1) plus the head of the well fluid in the tubing 41, for example from level A to the surface, as applied through the ports 43. The hydrostatic head applied at the same time to the lower face of diaphragm 55 will consist of the head of the well fluid in the outside annular space around the controller 45 in the tubing 41 (substantially between the levels A and B, as applied through the ports 47) plus the head of the well fluid in the tubing 41 from level A to the surface.

As long, therefore, as the fluid flow is maintained at a proper rate by a suitable adjustment of the valve 8, so that a proper back pressure is maintained on the well, and no separation or liberation of gas from the oil takes place at the face of the formation 61 to cut with gas the column of oil within tubing 41 and around the controller 45, the hydrostatic heads applied to both sides of diaphragm 55 will be substantially

equal. The diaphragm will therefore be in an unstressed or undeflected condition, except for small haphazard pulsations which will be smoothed out by the effect of the spring 63. The lower end of the conductor stem 57 will therefore be out of engagement with the contacts 71, 73 and 75, thus maintaining the electrical control circuit of Figure 1 open. The solenoid 5 will at that time be de-energized, the core 7, for example, assuming a lowermost position, by gravity and/or by the effect of a calibrated spring 18, with the result that the stem 13 of valve 15 will be maintained in a wide-open position by the pivoted lever linkage 9. If, however, for any reason, gas is liberated at the face of the producing formation and starts to cut the oil column within the tubing 41, as usually is the case when the flow rate is too high, the annular fluid column outside of the controller between levels A and B, being gas cut, will have a lesser density than the fluid column between the same levels within the chamber 53, which is not subject to gas cutting.

The hydrostatic head applied to the diaphragm 55 from above will therefore be larger than that applied from below, and the pressure differential thus developed will deflect said diaphragm downwards, forcing the stem 57 consecutively against the contacts 71, 73 and 75 to an extent depending on the value of said pressure differential.

With the control circuit thus closed, the solenoid 5 will be energized, pulling the core 7 upwards against the force of gravity and of the calibrated spring 18, thus lowering the stem 13 and tending to restrict the flow through the valve 15. It is obvious that the degree of closure of the valve 15 will thus be determined by the intensity of the current energizing the solenoid 5, which in turn depends on the value of the resistances 72 and 74 cut out of the circuit by the downward motion of the stem 57, which is further dependent on the value of the pressure differential due to a particular gas-cutting condition. The present system will therefore be able to control any undesirable gas-cutting condition arising in the well, and to adjust the opening of the valve 15 in a manner adapted to eliminate or to correct said undesirable condition while giving an optimum or maximum permissible rate of flow.

It will therefore be seen that the present system is applicable both as a positive and automatic control means adapted to prevent reservoir energy loss due to flowing wells at excessive rates, and as a means for determining the maximum permissible or effective rates at which wells may be produced. In the first case, the system may be installed as a permanent control for wells, while in the second case it may be used for testing wells at intervals for which purpose the readily removable and portable controller 45 is especially well adapted.

In the second case, the automatic valve 15 and the control motor for solenoid 5 may be dispensed with, and flow control effected manually by means of the hand operated valve 8, in accordance with the readings of the indicator 4, which may be properly calibrated for this purpose. Such an installation is shown in Figure 3, and is similar to that of Figure 1. The controller 145 may in such cases be provided with a stem 57a, affixed to the diaphragm 155 and provided with a contact point 58, adapted to slide over a resistance 70, whereby the calibrated indicator 40 will indicate the pressure differential due to the difference of densities of the fluid in the controller and in the

annular tubing space surrounding the controller. Any gas cutting effect arising during the flowing of the well may thus be immediately detected, measured and corrected by an adjustment of the manual valve **8**. It is obvious that the sliding contact arrangement of Figure 3 may likewise be used with the device of Figure 2 instead of the contacts **71**, **73** and **75** shown therein.

The present system is likewise applicable for wells operated by intermittent gas injection, as shown in Figure 4. In this case, a gas may be intermittently forced from a time-controlled pressure gas source, not shown, into the conduit **210**, provided with an automatic valve **150**, and thence into the casing **390** of the well, wherein the liquid may stand, for example, to a level E. The gas pressure forces the well liquid up the tubing **410** and out through a conduit **350** to a storage tank, not shown. The controller **45** of the present invention is positioned at a desired level within the tubing, and is connected to a motor or solenoid **50**, adapted to operate the valve **150** in the gas injection conduit in the same manner as described with regard to Figure 1. As long as the liquid column within the tubing **410** extends to the surface, or to any level C above the upper ports of the controller, the automatic valve **150** remains open and does not interfere with the injection of the pressure gas from the source of supply, which may be time controlled, as described, for example, in United States Letters Patent No. 2,326,442. When, however, due to a rate of exhaustion of the well fluid more rapid than the rate of inflow of said fluid into the borehole, the fluid within the tubing is depressed to a level such as D, below the upper ports of the controller, the closing of the electrical contacts in the controller by the pressure differential thus developed within the controller causes the motor or solenoid **50** to close the valve **150** independently of the intermitter controls or gas supply source, thus permitting a further accumulation of the fluid of the well without unnecessary waste of the pressure gas.

I claim as my invention:

1. For use in a well installation comprising electrical circuit means for the control of fluid flow at the well head, a housing adapted to be positioned in a well, an elongated chamber in said housing adapted to be filled with a fluid of predetermined density, a movable fluid-tight partition forming a portion of the walls in the lower portion of said chamber, one side of said partition being in contact with the well fluid and exposed to the hydrostatic pressure of the well fluid standing above said partition, the other side of said partition being in contact with the fluid of predetermined density in said chamber, port means through the walls of the upper portion of said chamber opening to the well substantially above said partition, whereby said other side of the partition is exposed to the superimposed hydrostatic pressure of the fluid in said chamber and of the well fluid standing thereabove, said partition being normally maintained stationary by the balance of the hydrostatic pressures applied to the two sides thereof, switch means associated with said partition and adapted to be closed by a fluid pressure-responsive displacement of said partition, and means comprising conductor means connected to said switch means and to said control circuit at the surface for energizing said circuit in response to the closure of said switch means.

2. For use in a well installation comprising electrical circuit means for the control of fluid flow at the well head, a housing adapted to be positioned in a well, an elongated chamber in said housing adapted to be filled with a fluid of predetermined density, a movable fluid-tight partition forming a portion of the walls in the lower portion of said chamber, one side of said partition being in contact with the well fluid and exposed to the hydrostatic pressure of the well fluid standing above said partition, the other side of said partition being in contact with the fluid of predetermined density in said chamber, port means through the walls of the upper portion of said chamber opening to the well substantially above said partition, whereby said other side of the partition is exposed to the superimposed hydrostatic pressure of the fluid in said chamber and of the well fluid standing thereabove, said partition being normally maintained stationary by the balance of the hydrostatic pressures applied to the two sides thereof, switch means associated with said partition and adapted to be closed by a fluid pressure-responsive displacement of said partition, and means comprising conductor means connected to said switch means and to said control circuit at the surface for energizing said circuit in response to the closure of said switch means.

3. For use in a well installation comprising electrical circuit means for the control of fluid flow at the well head, a housing adapted to be positioned in a well, an elongated chamber in said housing adapted to be filled with a fluid of predetermined density, a movable fluid-tight partition forming a portion of the walls of the lower portion of said chamber, one side of said partition being in contact with the well fluid and exposed to the hydrostatic pressure of the well fluid standing above said partition, the other side of said partition being in contact with the fluid of predetermined density in said chamber, port means through the walls of the upper portion of said chamber opening to the well substantially above said partition, whereby said other side of the partition is exposed to the superimposed hydrostatic pressure of the fluid in said chamber and of the well fluid standing thereabove, said partition being normally maintained stationary by the balance of the hydrostatic pressures applied to the two sides thereof, resistor means in said housing, contact means affixed to said partition and adapted for a sliding engagement with said resistor means upon a fluid pressure responsive displacement of said partition, and means comprising conductor means electrically connecting said resistor and contact means to said control circuit at the surface for energizing said circuit in response to the engagement of said contact means with said resistor means.

JOE HIRAM MOORE.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,198,351	Thielers et al.	Apr. 23, 1940
2,251,244	Stanley	July 29, 1941
2,322,453	Kaveler	June 22, 1943