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Dec. 14, 1948. G. A. SMITH 2,456,456

OIL WELL PUMP CONTROL SYSTEM

Filed Jan. 4, 1946 2 Sheets-Sheet 1

Timer controls the duration of a pumping and non pumping cycle although load on the motor will have the affect of closing down pumping if no oil is being pumped in spite of time left in the timer for the pumping cycle. Adjustments in the time durations made by tests

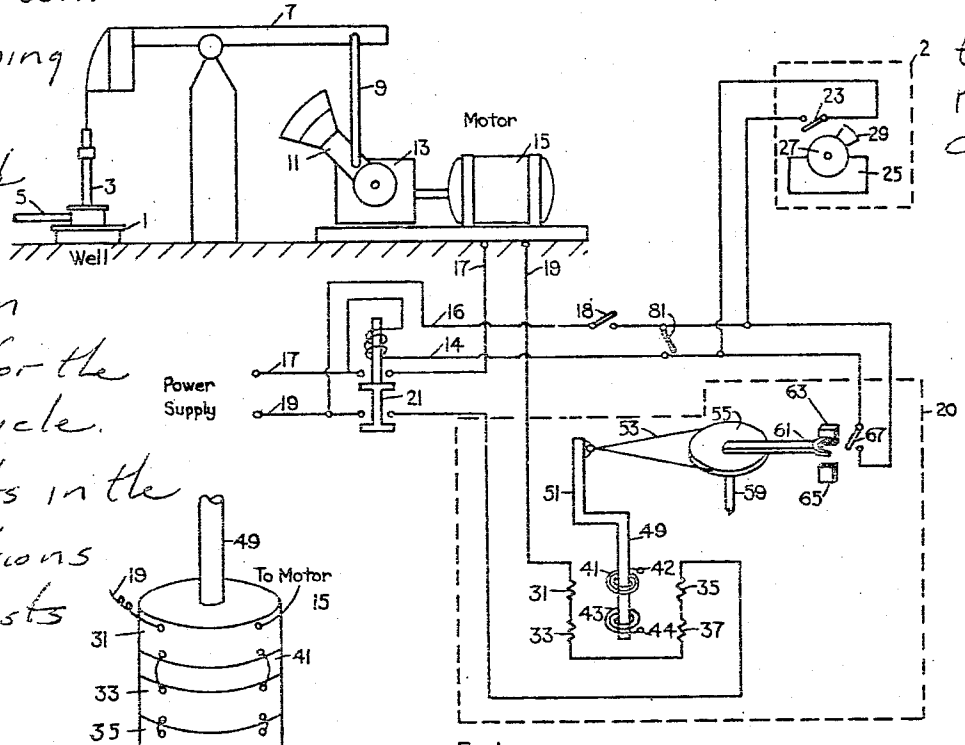


Fig. 1

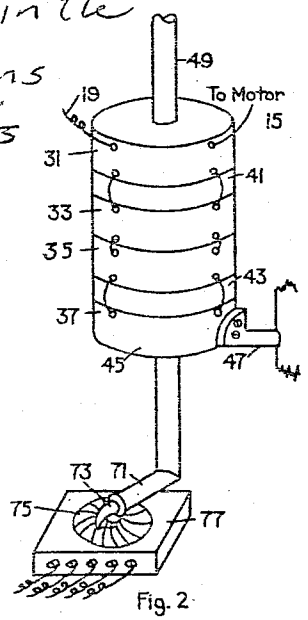


Fig. 2

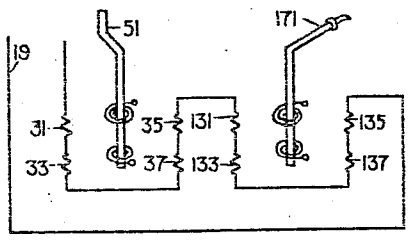


Fig. 3

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By his Attorney: [illegible]

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OIL WELL PUMP CONTROL SYSTEM

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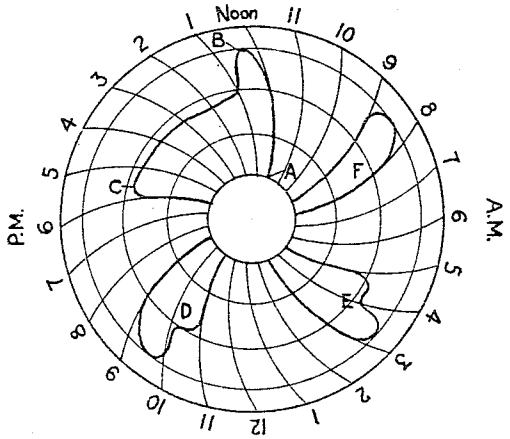


Fig. 4

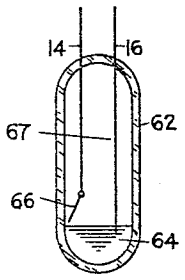


Fig. 6

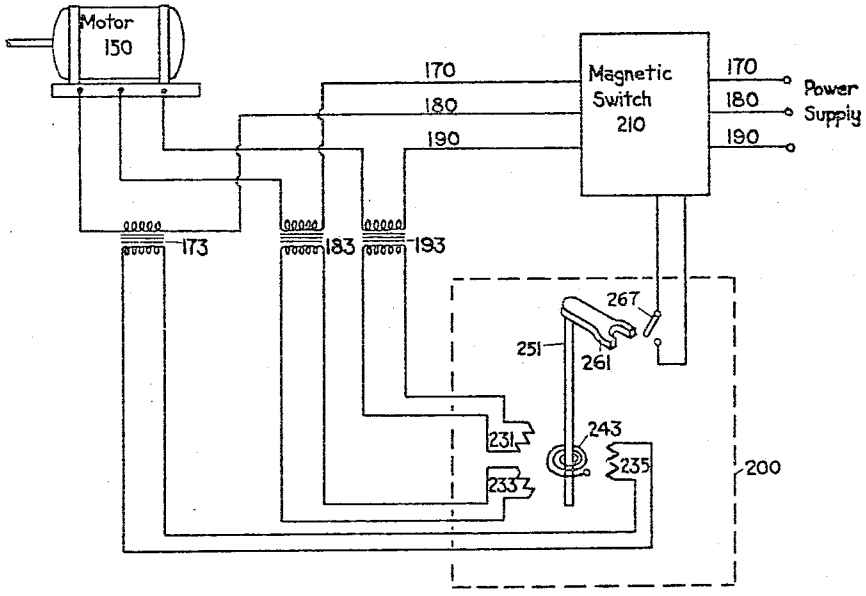


Fig. 5

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UNITED STATES PATENT OFFICE

2,456,456

OIL WELL PUMP CONTROL SYSTEM

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Application January 4, 1946, Serial No. 639,117

5 Claims. (Cl. 103—25)

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This invention pertains to a system for recording and/or controlling the operation of oil well pumps, and relates more particularly to an automatic system for the control of electrically driven pumps in wells producing small quantities of fluid.

In many wells, especially during the later stages of their exploitation, the quantity of fluid entering the borehole from the formation is often less than that which can be readily handled by the pumping equipment, that is, the volumetric capacity of the pumping equipment installed at the well is such that a sustained operation thereof results in pumping the well "off" or dry. Under these conditions, it is usual to produce such wells by intermittent pumping, so that the fluid is permitted to accumulate in the borehole during pump shut-down periods, and is exhausted from the well during alternate pump operation periods.

Such intermittent operation of the well pumping equipment may be controlled either manually, whereby the pump is started and stopped by hand for each operating period, or automatically, whereby the pump is started and stopped at predetermined set intervals by a time-responsive mechanism, such as an electrically or spring driven clock.

The disadvantages of manual pump control methods, involving the hazards of the human element, are obvious. The disadvantages of automatic time-responsive methods of control are as follows. The length of each particular time period during which a well must be shut down to permit the proper amount of oil to accumulate therein, and the ratio of this time period to that during which the pump is operated to effect a complete depletion of the well, depends in each case on the particular characteristics and potential of the well, which are sometimes variable, and on the volumetric capacity of the pumping equipment. Since the operator has usually no means for measuring or determining these factors, the arbitrary setting of the time-responsive pump control mechanism often results in incorrect time periods being selected, whereby the over-all efficiency of the pumping operations is greatly lowered.

Thus, a well which was pumped daily in two periods of four hours each produced 7.42 barrels of oil per day, giving a pump efficiency of 26%. When the pumping operations were changed, according to the present invention, to four periods of one hour each, the well produced 9.12 barrels of oil per day, whereby the pump efficiency was raised to 64.4%.

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It is therefore an object of this invention to provide a well-pumping system wherein the duration of the pumping and shut-down period may be correctly set according to indications secured and recorded in operating said system.

It is also an object of this invention to provide a well-pumping system wherein the operation of the pump is automatically stopped when the fluid in the borehole is depleted.

It is another object of this invention to provide a system wherein each pumping period is started by an automatic time-responsive device, and is terminated by an automatic device responsive to well conditions.

It is another object of this invention to provide a system wherein the operation of the pump may be automatically stopped at any time when abnormal conditions develop in the pumping installation.

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

Fig. 1 is a diagrammatic sketch showing the general arrangement of the component parts of the present system;

Fig. 2 is a perspective diagrammatic view of the controller and recorder elements of the present system;

Fig. 3 shows an alternative arrangement of the circuit of the controller 20 of Fig. 2;

Fig. 4 illustrates a type of circular record chart obtained by means of the present system;

Fig. 5 is a three-phase circuit diagram of another embodiment of the circuit of the present invention;

Fig. 6 is a detail view of a magnetic mercury switch used at 67 in Fig. 1.

Referring to the drawings, the present system is described by way of illustration with regard to an electrically driven reciprocating pump, although it obviously can be used in installations comprising pumps of the centrifugal or other types.

As shown in Fig. 1, a pump located in a well 1 is actuated by means of a sucker rod string 3, the fluid lifted to the surface being directed to storage through a pipe 5. The sucker rod string 3 is reciprocated in the well by the oscillating motion of the walking beam 7, which is driven, through a pitman 9, crank 11 and reducing mechanism 13, by an electric motor 15, receiving its power through lines 17 and 19. Although the

present system is described for simplicity with regard to a single phase power supply, it is understood that the following description applies equally well to three-phase systems.

The operation of the motor 15 is started by the closing of the normally open magnetic switch 21, whose electrical circuit is energized from the lines 17 and 19, connected to the electric power supply, and comprises lines 14 and 16 and a hand-operated switch 18, such as a single pole switch, whereby said circuit may be closed through either or both of two branch circuits connected thereto in parallel: the time-responsive control circuit 2, and the work-responsive control circuit 20.

The control circuit 2 comprises a normally open switch 23, adapted to be closed by a time-responsive device such as an electric or spring driven clock mechanism 25 of any desired type. For simplicity, this mechanism is shown in Fig. 1 as comprising a rotating wheel or disk 27 provided with a segment 29 adapted to close the switch 23 by contact therewith. It will be seen that the time at which the switch 23 is closed and opened can be accurately pre-set or controlled by suitably adjusting the speed of rotation of the disk 27 and the size of the segment 29.

The control circuit 20 comprises any desired number of resistances connected in series in one of the lines supplying power to the motor 15, for example, line 19. For purposes of illustration, four such resistors are shown at 31, 33, 35 and 37. These resistors are preferably made in the form of flat coils and are placed adjacent to a desired number of spirally wound bi-metallic strips or coils such as shown at 41 and 43, said bi-metallic elements being electrically insulated from the resistors. A preferred physical arrangement of these elements is illustrated in Fig. 2, wherein they are shown encased in a housing 45 rigidly attached by a bracket 47 to a suitable fixed member of a supporting structure. The outer ends 42 and 44 of the bi-metallic coils 41 and 43 are attached to any desired fixed points, for example to the fixed housing 45. The inner ends of the strips 41 and 43 are attached to a rotatable shaft 49 passing through the center of said coils. The shaft 49 carries an arm 51 adapted to describe an arc upon the rotation of the shaft 49. Attached to the arm 51 is a friction belt or string 53, passing over a pulley 55 rotatable about a shaft or bearing 59. Fixedly carried by the pulley 55 is a magnet 61 adapted to rotate together with the pulley between stops 63 and 65. Arranged in the proximity of one of these stops, for example, stop 63, is a switch 67, such for example a small mercury switch diagrammatically shown in Fig. 6 and comprising a glass envelope 62, a body of mercury 64 and a magnetically movable pivoted element 66, the switch being adapted to open when the magnet 61 rests against the stop 63 and pulls the element 66 out of contact with the mercury. The switch 67 serves to open or to close that branch of the circuit of the magnetic switch 21 which forms part of the controller 20.

As shown in Fig. 2, the rotatable shaft 49 may have attached thereto, in addition to the arm 51, a second arm 71 carrying a pen 73, whereby the motion of the shaft 49 may be recorded on a strip or disk type chart 75, for purposes to be described hereinbelow, said chart being actuated by an electrically or spring driven clock mechanism 77.

It is understood that instead of being connected to the same shaft 49, the arm 51 and the pen-arm 71 may be connected to separate shafts, each responsive to a separate set of bi-metallic coils and resistors connected in series into the circuit of the motor 15, as shown in Fig. 3 with regard to pen arm 171, shaft 149 and elements 131—137, 141 and 143.

With the above organization of the present system in mind, its operation is as follows:

The speed of the clock-work mechanism 25 is regulated so as to start pumping periods at desired predetermined time intervals. For example, if the pump is capable of depleting the well in three hours, and the well then requires another four hours to accumulate sufficient fluid for the next pumping period, the timing mechanism is adjusted for a time interval of seven hours between the starting of two consecutive pumping periods. For example, the wheel 27 is adjusted to make one complete revolution in seven hours.

With the hand operated switch 18 closed, the switch 23 is closed by the timing mechanism, which energizes the circuit of the magnetic switch 21 and closes said switch, thereby starting the motor 15 and the pumping operations.

The switch 67, which may be selected as a normally closed switch, that is, a switch tending to remain closed unless specifically controlled, is open at that time, since the magnet 61 rests against the stop 63, in the proximity of said switch, and its magnetic effect pulls the movable electrode of the switch away from its fixed electrode, or the mercury pool if a mercury switch is used.

The electric current actuating the motor 15 passes through the resistances 31—37, heating said resistances, which transmit the heat to the adjacent bi-metallic coils 41 and 43. The heating of the coils 41 and 43 causes these coils to develop, in well known manner, a torque effect which is applied to the shaft 49, thus rotating said shaft and the arm 51, for example, in clockwise direction. The pulley string 53 transmits this rotation to the pulley 55, which moves the magnet 61 away from the stop 63 towards the running stop 65, thereby permitting the switch 67 to close. After the magnet comes against the stop 65, any further rotation of the arm 51 under the effect of further increases of temperature results merely in a slipping action of the belt 53 on pulley 55, this arrangement thereby serving as a protective clutch.

Since the heating of the coils 41 and 43 proceeds quite rapidly once the motor 15 starts operating, the switch 67 closes very soon thereafter, so that by the time the branch control circuit 2 opens, for example, after the segment 29 has rotated past the switch 23 and has permitted said switch to open, the circuit of the magnetic switch 21 remains energized through the branch of the controller 20, holding switch 21 closed to continue supplying power to the motor 15.

When, after a certain period of pumping, for example after two hours, all the fluid accumulated in the well has been exhausted, the pump begins to "pump off," that is, the motor 15 continues to reciprocate the pump in the well at the same rate without any appreciable amounts of fluid being lifted to the surface. Since the work done is the product of a force by the distance acted through, or in the present case, a function of the product of the weight of the well fluid by the distance through which this fluid is being lifted, it will be seen that considerably less energy will be required to operate the pumping equipment

when it is "pumping off" than when it is working at full load. Thus, for example, if the pump 15 required 3½ kilowatts for operation at full load, it may require only about 2 kilowatts when pumping off. The amount of current taken by the motor 15 being thus greatly reduced, the heating effect of the resistors 31—37 is likewise decreased below a predetermined minimum an the bi-metallic coils, upon cooling, reverse the torque applied to the shaft 49, and thus pull the magnet back to the stop 63, opening the switch 67 and thus stopping the motor 15 by the de-energization of the circuit of the magnetic switch 21 and the opening of said switch.

The use of the recording device of Fig. 2 in the controlling system described hereinabove is advantageous for the following reasons.

In setting the time-responsive control circuit 2, it is important to know the length of time required by the pumping installation to deplete the well, and the optimum time required by the well to accumulate the required amount of oil for the next pumping period. For this purpose, the control circuits 2 and 20 may be removed or rendered inoperative in any desired manner, for example, by closing a switch 81, and the pumping operations may then be controlled manually by means of the switch 18 while recording the performance of the pump by means of the devices shown of Fig. 2 or 3.

A typical record chart for a period of 24 hours is shown in Fig. 4. This chart shows that the pump was started at noon (point A) and operated at full power for approximately one hour. At B, the well became depleted and the pump operated at reduced power for the next five hours, raising merely a trickle of oil. The operation of the pumps was therefore manually stopped at C. After leaving the well shut down for three hours, pumping was resumed and continued for two hours. As shown at D in the diagram, practically no oil was produced during the second hour of this period. The well was then shut down for four hours, and again pumped for two hours, as shown at E. The production results being substantially the same as at D, the pumping system was thereafter adjusted for automatic control, pumping being started every four hours by the controller 2, and being automatically stopped approximately one hour after the start of each pumping period by the controller 20, the performance of the pumping equipment being checked if desired by recording diagrams similar to these shown in Fig. 4. In some cases, the optimum length of the pumping and shut-down period being very accurately determined by the above procedure, it may sometimes be found possible to control thereafter the pumping installation by manual control.

Although the present system has been described for simplicity with regard to a single phase motor, it is understood that it is fully applicable to three-phase operation. It is further understood that although the above description referred to operation under normal conditions of intermittent pumping and shut-down periods, the principle of the invention may be applied for controlling or stopping pumping operations when some abnormal conditions develop in the pumping system. For purposes of illustration such case will be described with regard to the operation of a three-phase pump motor.

As shown in Fig. 5, a motor 150, driving a well pump installation similar to that of Fig. 1, is supplied with three-phase current over lines 170, 180 and 190 controlled by a magnetic switch 210 similar to switch 21. The lines 170, 180 and 190 are provided with transformers 173, 183 and 193, whereby three phase current is supplied to a control system 200, comprising resistors 231, 233, and 235 fed by said transformers, a bi-metallic coil 243, or a plurality of such coils, a rotatable shaft 251 and magnet 261, similar to these described with regard to Fig. 1.

It is known that a three phase motor will continue to run as a single phase motor in case of failure in one of the lines supplying the current. Such condition is, however, bad as tending to overheat the motor. With the arrangement shown in Fig. 5, a change in the amount of heat supplied by the resistors 231—235 to the bi-metallic strip 243 occurring upon the motor 150 changing from three-phase to one-phase operation, causes the magnet 261 to swing toward the switch 267 and to open said switch, thus operating the magnetic switch 210 and stopping the motor 150.

The motion of the magnet towards or away from switches 67 to 267 has been described hereinabove with regard to Figs. 1 and 5 in a purely illustrative manner and without limiting in any way the scope of the present invention, it being understood that the direction of said motion is determined in every case by the particular type of switch used, such as a normally open or normally closed switch, the object being in every case to effect a proper actuation of the circuit controlling the supply of power to the pump motor.

It is further understood that each of the circuits shown in Figs. 1 and 5 is susceptible of use with all the features shown in either figure, but omitted for brevity in the other, such as time controllers, recorders, transformers, switches, pulleys, etc.

I claim as my invention:

1. In a well installation comprising a pump for lifting a fluid to the surface, an electric motor to drive said pump, and a power circuit for energizing said motor, a branch circuit connected to said power circuit, a switch in said branch circuit, time responsive control means for closing said switch at predetermined time intervals, a second branch circuit connected to said power circuit in parallel with said first branch circuit, a switch in said circuit, and control means responsive to a decrease of the current flowing in the power circuit for opening said second switch.

2. In a well installation comprising a pump for lifting a fluid to the surface, an electric motor to drive said pump, and a power circuit for energizing said motor, a branch circuit connected to said power circuit, a switch in said branch circuit, time responsive control means for temporarily closing said switch at predetermined time intervals, a second branch circuit connected to said power circuit in parallel with said first branch circuit, a switch in said circuit, control means responsive to a decrease of the current flowing in the power circuit for opening said second switch, and switch means in the power circuit adapted to be maintained in a closed position when at least one of said two branch circuit switches is closed, and to be maintained in an open position when both said branch circuit switches are open.

3. In a well installation comprising a pump for lifting a fluid to the surface, an electric motor to drive said pump, and a power circuit for energizing said motor, a control circuit connected to said power circuit, said control circuit comprising a magnetically operable switch, a magnet

adapted to move with regard to said switch, thereby closing and opening said switch, a rotatable shaft adapted to move said magnet, bi-metallic coil means having one fixed end and one end attached to said shaft, resistor means connected in the motor power circuit, said resistor means being positioned adjacent to said bi-metallic coil means, whereby the torque exerted by said coil means on said rotatable shaft is varied in accordance with the heat developed by the current passing through said resistors and transmitted to said bi-metallic coil means.

4. In a method for intermittently pumping a well producing small quantities of fluid, the steps of pumping a well throughout a time period longer than that necessary for the pumping equipment to deplete the fluid in the well, recording the rate of energy consumption by the pumping equipment throughout said period, determining from said record the exact length of that effective portion of said period during which the fluid was heing pumped from the well with a high rate of energy consumption, shutting the well down for an arbitrary period of time, repeating and recording the pumping and shut-down operations, determining from the record the optimum length of the shut down period necessary for the well to accumulate the desired quantity of fluid, and adjusting the well for automatic pumping operation wherein said well is started for consecutive pumping operation periods at intervals of time equal to the sum of an effective pumping period and an optimum shut down period.

5. In a method for intermittently pumping a well producing small quantities of fluid, the steps of pumping a well throughout a time period longer than that necessary for the pumping equipment to deplete the fluid in the well, recording

the rate of energy consumption by the pumping equipment throughout said period, determining from said record the exact length of that effective portion of said period during which the fluid was being pumped from the well with a high rate of energy consumption, shutting the well down for an arbitrary period of time, repeating and recording the pumping and shut-down operations, determining from the record the optimum length of the shut down period necessary for the well to accumulate the desired quantity of fluid, and adjusting the well for automatic pumping operation wherein said well is started for consecutive pumping operation periods at intervals of time equal to the sum of an effective pumping period and an optimum shut down period and is stopped after the start of each pumping period in response to a decrease in the rate of energy consumption by the pumping equipment indicative of the depletion of the fluid in the well.

GRAFTON A. SMITH.

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