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**Pump off/gas lock motor controller for electrical submersible pumps.**

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A pump off/gas lock motor controller for electrical submersible pumps (ESP) uses a flow rate or flow/no-flow sensor to shut down the ESP when it no longer is pumping fluid so that damage to the ESP is avoided.

**EP 0 314 249 A2**

## PUMP OFF/GAS LOCK MOTOR CONTROLLER FOR ELECTRICAL SUBMERSIBLE PUMPS

The use of reduced voltage (soft) starters for electrical submersible pumps (ESP's) with the past few years has led to an opportunity to increase production by pumping off ESP's, i.e., pumping well fluid levels down to the pump intake in order to obtain maximum production from a well by lowering its bottomhole pressure. Operating an ESP in this mode means that the ESP is continually cycled on and off as the unit is pumped off, shut down for a short period of time to allow the well to partially fill, and then restarted. This could not have been done prior to the use of soft starters since ESP failure was common on restart.

Reliable pump off detection and control is critical to ESP pump off operation in order to prevent an ESP from continuing to operate after it has become gas-locked. Failure to shut down a gas locked ESP will result in premature failure due to overheating. Gas locking occurs when an ESP ingests sufficient gas so as to no longer be able to pump fluid to the surface, the result of either large gas bubbles being present in the well fluid or of the pump intake being uncovered at pump off. In accordance with the present invention an ESP pump off controller has been developed to meet the needs of reliably detecting and shutting down an ESP when gas locked or pumped off since existing ESP motor controllers have been proven to inadequately control under these critical conditions.

Existing ESP motor controllers have been adapted from surface motor control packages where motor operation is more stable and motor control is less critical. For example, it is not critical for a motor controller to prevent a surface centrifugal pump from running dry, but a downhole ESP will fail rapidly if it is run after losing fluid flow to the surface. These motor controllers monitor the running current (or power consumption) of the motor and compare it to a manually adjustable, fixed setpoint. When the current drops below this underload setpoint for a prescribed length of time, the motor is shut down.

Experience has shown that existing motor controllers are unreliable in detecting pump off or gas locking in ESP's. The reason for this unreliability is that the manually entered setpoints are often guessed, or at best, based on varying rules of thumb which may have no correlation to what is going on downhole. As a result, setpoints are frequently set too high causing premature shutdown and loss of production or set too low failing to shut the ESP down when gas locked or pumped off, causing failure of the ESP and loss of production.

The primary purpose of the present invention is

to provide a motor controller and method for the use thereof for shutting down an electrical submersible pump motor (ESP) when the ESP is no longer pumping fluid so that damage to the ESP is avoided. The motor controller uses a surface flow rate or flow/no flow sensor to shut down the ESP when it is no longer pumping fluid. The controller detects gas locking of the pump at pump off or due to large gas bubbles in the well fluid as well as detecting if a valve is closed and the ESP is pumping into a blind. The method according to the invention for detecting pump off or gas lock of an electrical submersible pump in an oil well comprises: deploying a flow sensor in the surface production tubing or flowline from the well; utilizing said flow sensor to activate a relay when sensing a loss of flow rate in the production tubing; causing said relay to shut down the electrical submersible pump when a loss of flow rate in the production tubing is sensed by the flow sensor; employing a pump up delay timer to override a no-flow signal from the sensor after starting the electrical submersible pump while fluid is being pumped to the surface but has not yet arrived; and utilizing a shut down timer to establish the length of time of loss of flow rate necessary to signal a pump off or gas lock of the electrical submersible pump and discriminate temporary surface flow rate drops not due to pump off or gas locking of the electrical submersible pump.

Other purposes, distinctions over the art, advantages and features of the invention will be apparent to one skilled in the art upon review of the following description with reference to the drawing, in which:

Figure 1 shows a block diagram of a preferred controller sequence of steps developed in accordance with the present invention.

State of the art controllers for electrical submersible pumps (ESP's) are unreliable in detecting when an ESP pumps off or gas locks. Pump off normally results in the ESP becoming gas locked (no longer being able to pump fluid to the surface) and the ESP will rapidly fail due to overheating if not shut down. There is an opportunity to increase production by operating ESP's in pump off cycles, and the present invention provides an economically attractive improved method to control a pumping off ESP.

Testing in accordance with the present invention has shown that the discharge flow rate from the well head can be used directly to indicate when pump off or gas locking is occurring. In a non-gassy well, the fluid flow rate is fairly constant with

flow rate going to zero when the ESP gas locks at pump off. In very gassy wells, detection of pump off is much more difficult since flow rate can normally be highly variable and even temporarily stop due to gas slugging in the production tubing. In this case, gas locking is distinguished from normal gas effects by the duration of time that the flow rate remains zero. Flow rate stops only temporarily due to gas breakout in the tubing, but stops permanently if the ESP is gas locked.

The flow rate oriented pump off/gas lock controller of the present invention uses either a flow measuring device or a flow/no flow sensor (as are known to the art) to determine when flow rate goes to zero. The pump off controller requires two timers to program delays in the switching logic. One timer is used for a pump up delay so that the flow sensor will not shut the ESP down after start up while fluid is being pumped to the surface but has not yet arrived. Another timer is required to determine the length of time that flow rate must remain at zero before the ESP will be shut down. This feature allows the unit to discriminate between flow rate drops due to gas slugging effects and drops due to actual gas locking of the ESP by requiring flow to stop for a long enough period of time that will indicate the pump is gas locked.

Testing was conducted using a commercially available flow/no-flow sensor (other types of sensors could be employed) that was mounted in the production tubing at the surface of the well and which activated a relay whenever it sensed a loss of flow rate. The sensor uses two probes, one of which is heated, that extend into the fluid and measures the temperature differential between the probes. The temperature differential increases as the cooling effect of the fluid decreases, i.e., decreasing flow rate or decreasing thermal conductivity of the fluid flowing past the probes.

The pump up delay timer is set to correspond to the average pump up time for the well which depends on pump depth, pump flow rate, and tubing size (this is about 30 to 45 minutes for a 500 bpd pump set at 1500 m from the surface). The shut down timer is set for most wells so that no-flow would have to be sensed for about 10 to 60 seconds, preferably about 15 seconds, before the ESP would be shut down.

In order for the pump off/gas lock controller to adequately control the ESP in pump off and gas lock situations, it is set up to take over the underload motor control functions from the existing ESP motor controller. This is accomplished by wiring the pump off/gas lock controller in series with the existing motor controller and deactivating the existing motor controller underload function by setting its underload level to its minimum value. This puts the pump off/gas lock controller in underload con-

trol of the ESP and leaves the motor controller in control of overload and timer functions. Putting the pump off/gas lock controller in complete underload control of the ESP is preferable to having both the pump off/gas lock controller and the existing controller in joint underload control since the existing motor controller can have its underload levels set too high causing premature shut down of the ESP and negate the positive effects of the pump off/gas lock controller.

Having thus generally described the apparatus and method of the present invention, as well as its numerous advantages over the art, the following is a more detailed description of a preferred embodiment thereof given in accordance with specific reference to numbered steps of Figure 1 of the drawings:

Step 1) mounting a flow/no-flow sensor or flow rate measuring device in the production tubing or flowline at the surface which activates a relay whenever it senses a loss of flow rate;

Step 2) detecting no-flow with the sensor;

Step 3) employing a pump up delay timer to override the no-flow signal from the sensor after starting the ESP while fluid is being pumped to the surface but has not yet arrived;

Step 4) utilizing a shut down timer to establish the length of time that flow rate would have to remain at zero before the ESP is shut down, in order to allow the unit to discriminate temporary surface flow rate drops due to free gas going through the pump or gas slugging in the tubing from long term drops due to gas locking of the ESP; and

Step 5) shutting off the ESP when the shut down timer senses pump off of the ESP.

The foregoing description of the invention is merely intended to be explanatory thereof, and various changes in the details of the described method and apparatus may be made within the scope of the appended claims without departing from the spirit of the invention.

## Claims

1. A method for detecting pump off of an electrical submersible pump in an oil well comprising:
  - deploying a flow sensor in production tubing from the well at the surface;
  - utilizing said flow sensor to activate a relay when sensing a loss of flow rate in the production tubing;
  - causing said relay to shut down the electrical submersible pump when a loss of flow rate in the production tubing is sensed by the flow sensor;
  - employing a pump up delay timer to override a no-

flow signal from the sensor after starting the electrical submersible pump while fluid is being pumped to the surface but has not yet arrived; and utilizing a shut down timer to establish the length of time of loss of flow rate necessary to signal a pump off of the electrical submersible pump and discriminate temporary surface flow rate drops not due to pump off of the electrical submersible pump.

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2. The method of Claim 1 including shutting off the electrical submersible pump when said shut down timer senses pump off of the electrical submersible pump.

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3. The method of Claim 1 wherein said flow sensor has two probes which are extended into fluid in the production tubing, one of the tubes being heated, and measuring the temperature differential between the probes to determine the flow/no-flow in the production tubing.

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4. The method of Claim 1 wherein the delay timer is set to correspond to the time required to pump fluid to the surface when the ESP is started and the shut down timer is set from about 10 to 60 seconds.

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5. An apparatus for detecting pump off of an electrical submersible pump in an oil well comprising:

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means for deploying a flow sensor in production tubing from the well at the surface;

means for utilizing said flow sensor to activate a relay when sensing a loss of flow rate in the production tubing;

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means for causing said relay to shut down the electrical submersible pump when a loss of flow rate in the production tubing is sensed by the flow sensor;

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means for employing a pump up delay timer to override a no-flow signal from the sensor after starting the electrical submersible pump while fluid is being pumped to the surface but has not yet arrived; and

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means for utilizing a shut down timer to establish the length of time of loss of flow rate necessary to signal a pump off of the electrical submersible pump and discriminate temporary surface flow rate drops not due to pump off of the electrical submersible pump.

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6. The apparatus of Claim 5 including means for shutting off the electrical submersible pump when said shut down timer senses pump off of the electrical submersible pump.

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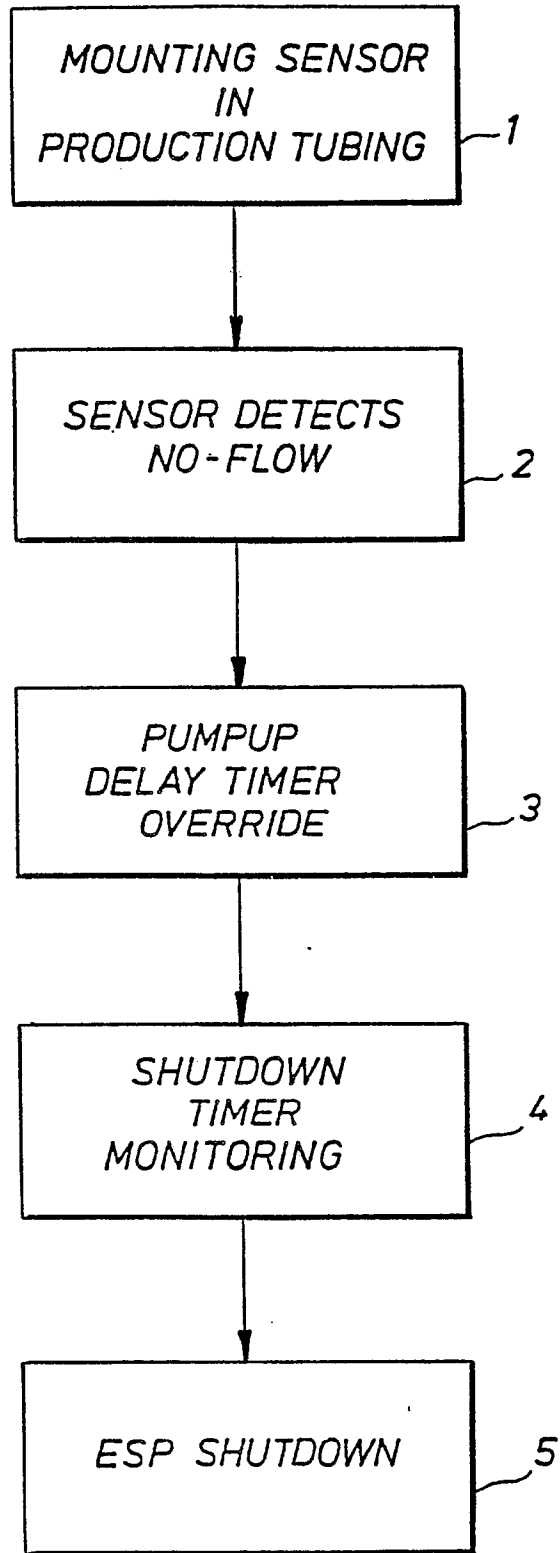


FIG.1