THE OPTIMIZATION OF ARTIFICIAL LIFT METHODS WITH THE USE OF A FLOW AND PRESSURE OPERATED CONTROL SYSTEM

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ABSTRACT

The industry continues to look for automated devices that can assist in optimizing artificial lift performance, with the object of improving efficiency and reducing the workload placed on the level of operator personnel dictated by economic requirements. An intermittant control system has been designed that monitors the critical pressure points of the well and surface facilities, together with flowing condition, and uses them to dictate the Shut In and Flow or Injection cycles in order to optimize its performance. The advantage of this type of intermittent control system (ICS) is that well conditions, rather than time cycles, dictate the intermitting cycle. This control method has been utilized in conjuction with a multiplicity of artificial lift methods and in most cases production increases of 10 to 500% have been achieved, while the amount of operator time required to ensure optimum performance has been greatly reduced.

This paper will discuss the critical points of measurement and their relationship to optimum well and lift method performance. The author will also discuss the application of this flow and pressure control system to several artificial lift systems such as plunger lift, intermittent gas production, gas lift and reciprocating rod lift systems.

INTRODUCTION

Many performance related problems can be experienced when artificial lift methods are applied to remove liquids from oil and gas wells. Most of the problems are recognized by production and pressure measurements at the surface, therefore monitoring production and pressure points relevent to the artificial lift methods performance is the key to any control system. This control system actuates motor control valves at surface to create Shut In and Flow or Injection cycles, depending on the type of artificial lift that has been applied to the well. The electronic controller when used in conjuction with static and differential pressure transducers monitors the relevant pressure points and runs through a sequential control algorithm which controls valve actuation. The ICS has full remote communication capabilities through a standard modbus protocol. This allows the operator to have remote access to the surveillence data retained within the ICS as well as the ability to change settings remotely.

FLOWING GAS WELL NEARING OR FALLING BELOW CRITICAL VELOCITY APPLICATION

The loading up of gas wells with produced fluids becomes a problem when the velocity of the gas traveling up the tubing string becomes too low to carry the liquids to surface as stated in Turners equation – 1. The accumulation of these liquids in the production tubing creates a hydrostatic head pressure on the formation and in turn causes an increase in the flowing bottom hole pressure and a consequent loss in production. This loss in production can be significant depending on the amount of hydrostatic pressure that has been created and can be determined if an accurate measurement of flowing bottomhole pressure or casing pressure increase is available. This increase can be used in a calculation with the productivity index of the reservoir (PI) or placed in relationship with an inflow performance ratio curve (IPR) for analysis of the production loss.

Since critical velocity is relevent in this type of application, it is what is used to calculate a shut in point for the controller. First, a critical velocity rate is calculated at a certain flowing tubing pressure and then reverse calculated into a flow measurement across an orifice plate measured in inches of water (hw). This hw measurement is programmed into the controller for the initiation of the shut in period. Since facility pressures are notorious for fluctuation, this reverse calculation into hw is a better measurement point to monitor, rather than the actual critical velocity rate established at a set flowing tubing pressure. This is because established critical velocity rates do not compensate for the increased facility pressures that create increased flowing tubing pressures and in turn change the critical velocity rate needed for continuous liquid removal. However, with the controller setting being programmed in hw, the increase in facility pressures is compensated for due to the use of a constant hw across an orifice plate increases the calculated gas volume as facility pressures increase and in turn tracks a critical velocity curve. (An example of critical velocity rates calculated from a constant value for hw are illustrated in the attached Table 1.)

Once a shut in point has been established, it is programmed into the controller as an OFF PRESSURE LIMIT and is used in the controller algorithm to initiate a motor control valve into a closed position. During this Shut In period multiple pressure points can be monitored to ensure that the well has built enough well head pressure to remove accumulated liquids in the production tube, overcome facility pressures and resume flow above critical velocity. The differential pressure between the Tubing and the sales line pressures is most commonly used to initiate the flow cycle which is achieved by programming an ON PRESSURE LIMIT into the controller. The controller monitors the tubing and sales line pressures and calculates the difference between them, once the calculated difference meets the ON PRESSURE LIMIT the controller initiates the flow period by opening the motor control valve. This method of initiating the flow cycle also compensates for fluctuating facility pressures, so that, as facility pressure increases the tubing pressure must increase as well, before a flow cycle is initiated. This will ensure successful removal of accumulated liquids and a well pressure high enough to overcome facility pressure and resume flow above critical velocity. This is just one example of the monitoring and cycle initiations that the controller is capable of utilizing. The controller can easily be programmed through the key pad and display terminal to use one point of measurement or the differential between two points of measurement to initiate both the shut in and flow cycles.

PLUNGER LIFT CONTROL APPLICATION

Plunger Lift has become a widely recognized method of artificial lift when used in conjunction with advanced plunger lift control systems and the more efficient plungers available on the market today. The pressure and flow operated control system has proven to operate plunger lift systems more efficiently and with less failure caused by adverse operating conditions. Plunger lift is a method that uses the well's own gas energy as the prime mover of the accumulated liquids that have gathered in the production tubing while flowing at rates below critical velocity. The plunger itself creates an interface between the accumulated liquids and the gas stored in the reservoir, and the annulus if available, to drive the liquids to surface. Most plunger lift control systems are operated with a sequence of timing related parameters and some adjust the timing parameters automatically based on a plunger failure. While timing of these parameters (ie. Off time- On Time) is a method that has been practiced since the invention of the plunger lift system, it has also had very little relevance to the well or the surface conditions. These can fluctuate on a day to day basis, making plunger lift performance very erratic and extremely difficult to optimize. With the use of the pressure and flow operated control system the well conditions and surface pressures are accounted for on a real time basis. Plungers require a sufficient amount of reservoir pressure to overcome the liquid hydrostatic pressure in the production tubing and the surface facility pressures, that commonly fluctuate, to lift the plunger and its liquids to surface. With electronic pressure transducers the tubing, casing and sales line pressures are used as critical monitoring points to initiate the On Cycle once the ON PRESSURE LIMIT has been met, this almost always ensures the plungers efficiency in carrying the liquids to surface. The control system can use one, or the differential between two, of the critical pressure points as an indicator that sufficient pressure has been reached.

Following are two scenarios which illustrate the use of this controller in plunger lift applications:

> In the case of fluctuating sales line pressure, the differential between either tubing or casing pressure and sales line pressure is used to initiate the On Cycle. To achieve this the operator programs the amount of differential pressure that will be required to lift the plunger into the ON PRESSURE LIMIT. Once the ON PRESSURE LIMIT has been met or exceeded the control system will open the motor control valve allowing the well to exhaust the tubing head pressure down to the sales line pressure, which in turn will create the differential across the plunger to lift it and its liquids to surface. The well will continue to flow until an OFF PRESSURE LIMIT has been met. The flow option is most commonly selected to initiate the off cycle, but critical pressure points such as casing pressure can also be used.
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> In the case of wells with erratic fluid entry, the differential pressure between the casing and tubing is most commonly used, this is a direct indicator of the amount of hydrostatic fluid head that has accumulated in the tubing. Most plunger lift wells are only capable of carrying a fluid column to surface that is equal to 50% of the difference between the casing pressure and the sales line pressure as stated by Ferguson and Beauregard *– 2.*
> For example: CP 500 – SLP 100 = 400# / 2 = 200# In this case the ON PRESSURE LIMIT would need to be set at 200#. The controller will monitor the tubing and casing pressures until the differential pressure between them has reached 200# or less before it initiates the on cycle.

The ability to initiate the On and Off Cycles using a multiplicity of selective critical monitoring points, in a real time control algorithm, has made the pressure and flow operated controller very adaptable to wells requiring more advanced control algorithms. The control system has documented proof of performance in this application.

A selection of operating parameters commonly used to control plunger lift installations is illustrated in the attached Table 2.

GAS LIFT VALVE CONTROL APPLICATION

Gas Lift is a form of artificial lift that uses the introduction of injection gas, through pressure operated valves placed at depths throughout the tubing string, to assist in lifting fluids to surface. Gas lift designs vary in operating pressures and valve placement, depending on data obtained through bottom hole pressure testing, surface facility pressures and compressor capabilities. Gas lift is used on a variety of wells with different producing characteristics and reservoir pressures. One of the drawbacks of gas **lift** is that the introduction of injection gas continuously into the well in turn creates back-pressure on the reservoir. When gas lift is applied to gas wells that are in need of assistance in liquid removal, the back-pressure created by gas lift becomes restrictive when trying to optimize well performance. The Pressure and Flow operated controller can be installed to measure the flowing condition of the well and either, permit injection gas only when the gas rate falls below an acceptable level, or shut off the injection gas once the flowing condition exceeds an acceptable level. In this application both the ON PRESSURE LIMIT and the OFF PRESSURE LIMIT are set to monitor the gas rate flowing into the compressor suction.

When the controller recognizes when a flow rate exceeds the ON PRESSURE LIMIT, indicating that the injection gas has assisted the well in removing the accumulated liquids and reached a flowing condition acceptable to the operator. It then closes the injection gas line and opens the sales gas line both of which are mounted on the discharge of the compressor. This allows the well to produce without the back-pressure created by the injection gas and in turn allows for additional drawdown on the reservoir for increased production. The well will continue to flow with out injection gas being introduced until the wells flowing condition falls below an acceptable level that has been set into the controllers OFF PRESSURE LIMIT. This indicates that the well has again accumulated liquids into the production tubing causing liquid loading and a loss in gas flow rate. The controller will then close the sales line and open the injection gas line, so that the gas lift valves can assist in unloading the accumulated liquids. This type of control has resulted in significant increases in production when used on gas lift assisted gas wells.

RECIPROCATING ROD LIFT APPLICATION

Rod Lift is form of artificial lift that was designed to lift fluids from wells that do not have enough associated gas or bottom hole pressure to flow. Rod Lift has been applied to wells with high gas to liquid ratios and the result has been a continuous problem with gas locking the down pump. The flow and pressure operated control system has been installed on the casing head of high GLR pumping wells to assist in minimizing the problem of gas locking. The highest amount of success with this type of application has been on wells with very little area in the tubing / casing annulus ((2 3/8" X 4 ½")(2 7/8" X 5 ½")) *to* allow for down hole separation of the gas and liquid that enter the wellbore. The problem normally occurs after the rod pump has removed enough liquid from the well when it becomes capable of surging strong heads of gas flow up the annulus. When this has occurred the annulus gas flow will carry with it liquids that will become suspended in foam or suspended above a tubing anchor. **As** long as the well continues to flow even the slightest amount of casing head gas up the annulus, the fluids will remain suspended until enough liquid has accumulated in the annulus to create enough hydrostatic head pressure on the formation to kill virtually any gas flow up the annulus. At that time the liquids will start to fall back to bottom and knock the gas lock from the pump and then the pump will again be able to pump the fluids to surface, just as it was designed *to* do. After the **pump** has removed enough of the liquids to reduce the hydrostatic head pressure from the formation, the formation will again start to surge gas and carry liquids up the annulus starving the pumps intake and again gas locking the pump. Monitoring the casing head gas flow can easily recognize this problem. The operator will see strong heads of gas flow that drop to a very minimal flow rate. The flow and pressure operated control system when installed will recognize the low flow rate, as an indicator set into the OFF PRESSURE LIMIT, that the casing needs to be closed to force the liquids that are blocking the gas flow to fall back to bottom to be pumped to surface. The casing is reopened when the surface casing pressure builds to a set pressure programmed into the ON PRESSURE LIMIT, indicating the fluid hydrostatic head pressure has been replaced by gas pressure and the casing gas flow is ready to resume. The initial heading that can happen when the casing is reopened can be controlled by pilot regulators installed, which work in conjunction with the control system. This type of application control has resulted in minimizing extreme bottom hole pressure fluctuations created by suspended liquids and gas locked pumps. The control allows the operator to recognize a lower average bottom hole pressure and in return recognize increased production.

CONCLUSION

The flow and pressure operated control system allows the well to dictate valve actuation, that will assist in the lifting of fluid and the efficiency of its lift method. The control system runs through an advanced control algorithm, activated by points of measurement that a lease operator is familiar with and are pertinent to the performance of the well and its lift method. The system was designed to be user friendly, by only having two settings that dictate the valve actuation. This eliminates the need for a lease operator to guess at the amount of time needed, either during a shut in or a flow cycle to achieve optimum performance. The system responds based on real- time data, therefore it is considered pro-active and not re-active.

REFERENCES

1. Turner R.G., Hubbard M.G., Dulker A.E.—JPT—Nov. 1969, Analysis and Prediction of minimum flow rate for the continuos removal of liquids from gas wells.
2. Ferguson P.L., Beauregard E.—SWPSC—April 1983, Will Plunger Lift Work In My Well?

Table 1
Critical Velocity Rates Calculated from a Constant Value of hw

This table uses the following constants:

Tubing Size	2 3/8" EUE (1.995"ID)	Meter Tube	2"
Gas Gravity	.6 (**Air** = 1)	Orifice Dia.	1.25"
Pseudocritical Temperature	356.1"F	Coeff.	8.329
Pseudocritical Pressure	673.9psig.	hw(in. water)	13"
Atmospheric Pressure	14.4psia.		
Resevoir Temperature	180°F		
Wellhead Temperature	72°F		
N2	0%		
H2S	1.5%		
c 0 2	0%		

FTP	Critical Velocity mcf/d	Pm	Q,Mcf/d
50#	267.1	50	288
100#	357.8	100	386
150#	431.1	150	464
200#	494.7	200	532
250#	552.2	250	594
300#	605.2	300	650
350#	654.9	350	703
400#	702.0	400	753
500#	790.2	500	847
600#	872.5	600	934
700#	950.4	700	1016
800#	1025.1	800	1095
900#	1097.1	900	1171
1000#	1166.9	1000	1245

Table 2
Commonly Used Operating Parameters for Plunger Lift Well Control using a
Flow and Pressure Operated Control System

INITIATE ON CYCLE for PLUNGER LIFT WHEN:

1. Tubing Pressure > or = ON PRESSURE LIMIT (Looks for Tubing Pressure to exceed a set point)

2. Casing Pressure > or = ON PRESSURE LIMIT (Looks for Casing Pressure to exceed a set point)

3. Tubing – Line > or = ON PRESSURE LIMIT (Looks for Tubing Pressure to build to a set point above Line Pressure)

4. Casing – Line > or = ON PRESSURE LIMIT (Looks for Casing Pressure to build to a set point above Line Pressure)

5. Casing – Tubing > or = ON PRESSURE LIMIT (Looks for Casing and Tubing Pressure differential to lessen)

INITIATE OFF CYCLE for PLUNGER LIFT WHEN:

1. When the plunger has arrived. (Used on Oil wells)

2. Casing Pressure < or = OFF PRESSURE LIMIT (Looks for Casing to fall below a set pressure)

3. hw < or = OFF PRESSURE LIMIT (Looks for Flow rate to fall below a set differential in inches of water))

4. Casing-Tubing > or = OFF PRESSURE LIMIT (Looks for differential between Casing and Tubing to increase)

5. Casing-Line > or = OFF PRESSURE LIMIT (Looks for differential between Casing and Line Pressure to increase)