DEVELOPMENT OF RECOMMENDED PRACTICES FOR SELECTION OF ARTIFICIAL LIFT SYSTEMS FOR GAS WELL DELIQUIFICATION

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ABSTRACT

Attendees of the annual Gas Well Deliquification Workshop have expressed interest in having a set of industry-accepted recommended practices for selecting artificial lift systems for gas well deliquification. The Artificial Lift Research and Development Council (ALRDC) has initiated a process to define these practices and make them readily available to the industry.

This presentation will describe the process being used and the progress that has been made. It will invite participation by others in industry.

BACKGROUND

Many people think of gas wells as free flowing with no need for artificial lift. However, many gas wells produce some liquids – condensate, water, or both – at some stage in their life cycle. If this liquid is not removed from the well, it will accumulate in the wellbore, inhibit production of natural gas, and limit the ultimate recovery of gas from the reservoir.

The accumulation of liquid in the wellbore causes an increased pressure against the gas production formation. (See Figure 1.) This increased pressure, or back pressure, inhibits gas flow from the reservoir into the wellbore. It also inhibits gas flow up the wellbore to the surface. The liquid in the wellbore can also enter the reservoir and cause a water blockage that will further inhibit gas flow into the wellbore. Therefore, to maximize gas inflow and outflow, and to maximize ultimate recovery from the reservoir, it is necessary to remove any accumulated liquid from the wellbore and keep it removed on a continuous basis.

In the earlier stages of a gas well's life cycle, liquid may be removed by the natural flow of the gas itself. If the flow rate is high enough, the gas flow velocity may exceed the "critical" velocity. When the velocity is above "critical," the liquid that is present is carried to the surface by the gas in the form of mist or small droplets. However, when the reservoir pressure declines with age, the inflow performance declines with formation blockage, or the amount of liquid increases, the natural gas flow velocity may fall below "critical" such that liquids can no longer be removed from the well on a continuous basis. At this stage, some form of artificial lift is needed to remove liquids from the well and the near-wellbore portion of the reservoir.

ARTIFICIAL LIFT METHODS USED TO DELIQUIFY GAS WELLS

At least fifteen artificial lift methods are used to deliquify gas wells.

Sucker Rod Pumping

If gas wells produce significant amounts of liquid, conventional sucker rod pumping may be used. Here a challenge is to prevent the gas from interfering with the pumping action. Typical strategies include setting the pump intake below the perforated intervals and/or using an effective form of gas separation below the pump intake. In such cases, liquids are typically pumped up the tubing and gas is allowed to flow up the tubing-casing annulus.

Progressing Cavity Pumping

Progressing cavity pumping (PCP) has the advantage that it is not easily gas locked, since the pumping process is based on a continuous movement of the pump rotor in the stator. (See Figure 2.) PCP's have the following limitations in gas deliquification applications: (1) many pumps, particularly high volume models, have limited head capacity; so depth of application is often limited; (2) they can't withstand high temperatures since the pump stators contain elastomers which continue to cure and become brittle at high temperature; (3) stator elastomers are generally sensitive to aromatic content and can not be run in the presence of high API gravity fluids such as condensates. For these reasons, they can't be set too deep or allowed to pump off to a "run-dry" state; and, they can only be run in wells where the produced fluids are compatible with the elastomers.

Electrical Submersible Pumping

Electrical submersible pumping (ESP) is used when large volumes of liquid (normally water) must be produced. Their advantage is the ability to lift large volumes of liquid from deep wells. ESP's may become gas locked, so use of downhole gas separators or some form of pump-off control may be necessary. And, the ESP motor must be cooled as high temperature can damage the motor windings. Therefore, there must be sufficient flow of liquid past the motor to keep it cool. In many cases, this prevents operators from being able to set the pump below the perforations, unless some form of pump shroud is used.

Hydraulic Pumping

There are two types of hydraulic pumping systems: (1) open systems where the injected fluid to operate the pump is commingled with the produced fluid at the pump, and (2) closed systems where the injected fluid is kept separate from the produced fluid and returned to the surface through a separate flow path. Due to its complexity, hydraulic pumping is seldom used for gas well deliquification, but some new designs are being tried in the industry.

Tubing Plungers

There are several types of tubing plungers; the primary types are single stage and two stage. For single-stage plungers, production from the well must be stopped to allow the plunger to fall and sufficient pressure to build to lift the plunger back to the surface. For two-stage plungers, the shut-in time can be kept to a minimum since the plunger ball and body fall separately. The primary advantage of tubing plungers is that no external source of energy is needed; the plunger is lifted to the surface, along with any accumulated liquid above the plunger, by the natural pressure of the well. The primary limitation is that they may not be able to work when the reservoir pressure falls to a very low level; so they may not be able to fully deplete the gas reserves in the reservoir.

Casing Plungers

Casing plungers are used in wells with no tubing. They work on a similar principle, except there is no annulus for pressure to accumulate to lift the plunger. Pressure must build up below the plunger.

Soap Sticks

Soap sticks are used to mix with the liquid in the well to create a foam which is much lighter than the native liquid. The foam can be produced from the well by the natural flow of the gas. The primary advantage is low cost, and they can be used when a well first experiences liquid loading, without the need to install an expensive artificial lift system. The limitations are the cyclic nature of dropping soak sticks, and in some cases, the difficulty in reaching the full depth of the well.

Batch Chemical

When dropping soak sticks is insufficient for some reason, chemical can be injected into the well in batches. The principle is the same; the chemical mixes with the liquid in the wellbore to form a foam that is produced by the gas. The limitation is that it is cyclic in nature. And different chemicals are needed for water and condensate.

Continuous Chemical

An alternative to cyclic injection is continuous injection of chemical through a capillary string. The advantages are that the chemical is injected continuously and can be injected at the desired depth. The limitation is that the flowing gas must lift the foamy liquid.

Velocity Strings

As indicated above, liquid will be removed from the well by natural gas flow if the velocity is above "critical." Since velocity is a function of the gas flow rate and the cross-sectional area of the flow path, the velocity can be increased by reducing the cross-sectional area. Often, wells are initially completed with large tubing size to allow high gas production rates. As the rate decreases with pressure decline and other factors, it may be possible to sustain critical velocity by installing a smaller tubing size, or by producing up the annulus between the original tubing and a smaller insert string. The disadvantage is that this may work for a given set of conditions but no longer work when conditions change.

Surface Compression

Many operators install surface compression systems. These may allow the well to be operated with a lower wellhead pressure since the gas pressure is boosted so it will flow from the wellhead to the production facility. The lower wellhead pressure may translate to a lower bottom-hole pressure, and thus may permit increased inflow. Also, the lower pressure may result in a lower critical velocity, thus permitting the well to produce liquids longer in its life.

Continuous Gas-Lift

Continuous gas-lift may be used to inject gas into the well, near or below the perforated interval. The added gas can lift the liquid to the surface and can provide additional gas flow so "critical" velocity is maintained. In principle, gas-lift can be used to fully deplete a well if just the correct amount of gas can be injected at the correct depth.

Intermittent Gas-Lift

An alternative to continuous gas-lift is intermittent gas-lift where "slugs" of gas are injected to produce "slugs" of liquid. In oil wells, intermittent gas-lift is normally used in lower rate wells or wells with a low bottom-hole pressure. In gas wells, intermittent gas-lift may make more sense in wells that produce more liquid, since the primary objective is to remove liquid, and not to maintain "critical" flow at all times.

Vortex Flow

The concept with vortex flow is to introduce vortices in the flowing gas stream that better carry the liquid droplets to the surface. The liquid is swirled to the outside of the tubing leaving gas and droplets to flow in the tubing. This is a relatively new, largely untried technique. Design techniques are being developed.

Liquid Injection

This technique is to inject water into an underlying zone and allow gas to migrate up the casing. Pumps may be involved but no liquid is produced to the surface.

INTRODUCTION TO THE PROCESS OF DEVELOPING THESE GUIDELINES

The guidelines for selecting the most appropriate artificial lift system are being developed on a web site supported by the Artificial Lift R&D Council. It is www.alrdc.com. The web page is Recommendations. There is a page for artificial lift selection for gas well deliquification. Anyone in the industry may access this site to see the progress being made and use the materials as they are drafted and placed on the site.

When the guidelines are complete, they may be disseminated to the industry in a variety of ways including:

- One the web
- In a book or notebook
- In workshops or seminars
- In general or company-specific training courses

The method(s) of dissemination are yet to be determined.

SECTION I --- GUIDELINES FOR CREATING AN OPTIMUM ARTIFICIAL LIFT SELECTION PROCESS

This section contains guidelines to be followed by people in Operating Companies, Service Companies, and others who are responsible for creating an optimum artificial lift selection process for their organization. All of these can have a substantial impact on the "best" form of artificial lift. Sub-sections include information on:

- Know your business. Guidelines are different for Operating Companies and Service Companies. They may be different for companies that primarily produce oil instead of gas. They may be different for domestic vs. international operations. They may be different for onshore vs. offshore operations.

- Know your company. Guidelines may be different for large vs. small companies. They may vary for integrated vs. independent companies. They may be influenced by the history or culture of operations in the company.

- Know your economics. Some companies focus on maximizing revenues, some on minimizing capital costs, some on minimizing operating costs. Some companies are more concerned with safety and environmental protection than with either income or costs.

- Know your staff. Some companies have staff that understand and can work effectively with some forms of artificial lift but not others. If an artificial lift system is not well understood, operated, and maintained, it may fail.

- Know your suppliers. Some forms of artificial lift may not be available in some locations. If suppliers aren't available to provide, help install, and help maintain artificial lift equipment, it may fail.

- Know your reservoirs. Some reservoirs are subject to pressure depletion; some are not. Some are water drive and may produce large volumes of water; some may not. Some are deep and hot; some are not.

- Know your wells. Some wells are in cold climates; some are in hot areas. Some wells are deep; some are shallow. Some use large tubulars; some use small ones. Some are straight; some are deviated. Some produce sand; some don't. Some have junk in the hole; some are clear. Some produce significant amount of water; some don't. Some produce both condensate and water; some produce only one liquid or the other.

- Know the performance of your wells. Some wells have inflow restrictions; some don't. Some wells produce in a stable manner; some are very unstable. Some produce with stable water or condensate ratios; some are variable.

- Know your surface system. Some surface systems are compact; some are very wide-spread. Some systems have good power infrastructure; some have no power available. Some are easily visited by staff; some are in very remote areas.

SECTION II --- GENERAL GUIDELINES FOR ARTIFICIAL LIFT SYSTEMS

This section presents the fundamentals of gas well deliquification including how to recognize when liquid loading is beginning to occur, and how to calculate the critical velocity needed to lift liquids from the well.

It contains general guidelines for each of the fifteen forms of artificial lift listed above. For each type of artificial lift, the guidelines listed below are provided. Each set of guidelines, for each type of artificial lift, is developed by a team of industry experts. These are listed in a later section of this paper.

- Practical limits of each type of artificial lift
  - Depth limits
  - Size limits
  - Pressure limits
  - Temperature limits
  - Rate limits
  - Limits with sand, corrosion, erosion, H_2S, CO_2, etc.
  - Power requirements
  - Operating requirements
  - Maintenance requirements

- Cost guidelines
  - Capital expenses (CAPEX)
  - Operating expenses (OPEX)
  - Repair & maintenance expenses (R&M)

- Life expectancy guidelines
  - Infant mortality (early time failure)

- Normal operating life

SECTION III --- GUIDELINES FOR SELECTING THE MOST APPROPRIATE ARTIFICIAL LIFT SYSTEM

This section contains guidelines to be followed to select the most appropriate artificial lift system for a given field.

- Pertinent issues to consider. This sub-section reviews the pertinent issues, some of which are enumerated in the "process" section above, that must be considered when selecting the most appropriate artificial lift system for a given field.

- Use of artificial lift selection tools. This sub-section reviews the various artificial lift selection tools and tables that have been developed in the industry and presents guidelines on how to use them.

- Checking artificial lift economics. The guidelines don't contain actual costs and benefits, but will contain suggestions for evaluating capital, operating, and repair/maintenance costs of various artificial lift options.

- Choosing the artificial lift system supplier. As indicated earlier, not all suppliers of artificial lift systems are well versed in each type of artificial lift system, not all are position to serve local needs, and not all are staffed to provide needed services in the local area.

- Choosing the specific artificial lift system. Finally, the specific artificial lift system must be chosen for each particular well in each field. When all of the other criteria discussed above have been considered, this may be quite obvious. But it still must be done with care.

SECTION IV --- GUIDELINES FOR OPTIMUM APPLICATION OF EACH ARTIFICIAL LIFT SYSTEM

This section contains guidelines to be followed once the artificial lift system has been selected. This section covers:

- Recommended guidelines for installation, operation, maintenance. Selection of an artificial lift system is only the first step. Once it has been selected, it must be properly installed, operated, and maintained over the long term. These guidelines are essential for successful use of the artificial lift system for effective gas well deliquification.

- Automation, surveillance, optimization. In modern times with normal staffing limitations, artificial lift systems can not be successfully deployed without an effective automaton, surveillance, and optimization system to support their operation and optimization. These guidelines are essential for profitable use of artificial lift over the long term.

- Training. Often people in the Operating Company or those who serve the company are not experienced and fully trained to take maximum advantage of the artificial systems in their fields. These guidelines provide a clear path for providing this necessary training.

PEOPLE IN INDUSTRY WHO ARE WORKING ON THE GUIDELINES

A large number of people in the industry have volunteered to help prepared these guidelines. Those that are currently involved are listed below. The facilitator of each sub-section is shown in bold print.

- Sucker rod pumping: **Jim Lea,** Norm Hein, Tom vanAkkeren, And Cordova
- Progressing cavity pumping: Facilitator to be selected, Ken Saveth, Staff from R&M Energy Systems
- Electrical submersible pumping: **Rick Webb**, Steven Breit, Staff from Centrilift, Staff from Reda
- Hydraulic pumping: **Bryan Dotson,** James McAdams, Staff from Weatherford
- Tubing plungers: **Bill Hearn**
- Casing plungers: **Bill Hearn**
- Soap sticks: **Dan Casey**
- Batch chemical: **James Archer,** Sam Toscano, Jose Macias, Staff from Weatherford
- Continuous chemical: **James Archer,** Sam Toscano, Jose Macias, Staff from Weatherford

- Velocity strings: **Larry Harms**
- Surface compression: **Larry Harms**
- Continuous gas-lift: **Boots Rouen**, Cleon Dunham
- Intermittent gas-lift: **Boots Rouen**, Cleon Dunham
- Vortex flow: **Norm Hein**
- Liquid injection: **Jim Lea**, Francisco Alhanati

INFORMATION SUPPLIED BY TEAM MEMBERS

In addition to drafting the sections on this guideline, several team members have provided other information that will prove useful in the guidelines. Each of these documents may be downloaded from the web site.

- Foam lifting manual — NAM (Shell The Netherlands)
- Reservoir information — Chesapeake Energy
- Liquid loading in the Cotton Valley — Echometer
- Data summary — Weatherford
- Introduction to artificial lift methods — Weatherford
- Adaptive product technology for CBM — Weatherford
- Artificial lift selection guidelines — PL Tech

CURRENT STATUS OF THE PROJECT

As of the end of January 2008, the status is as shown below. By the time of the 2008 Southwestern Petroleum Short Course, this status should change since there is a meeting of the project team scheduled for Thursday, February 28, 2008, the day after the 2008 Gas Well Deliquification Workshop.

- Introduction: Fully drafted
- Section I: Fully drafted
- Section II: Eight of twenty sub-sections partially drafted.
- Section III: Four of six sub-sections partially drafted.
- Section IV: Three of four sub-sections partially drafted.

INVITATION FOR OTHERS TO JOIN THE EFFORT

Others are welcome to join the team for defining guidelines for selection of artificial lift systems for gas well deliquification. If you have experience and interest in a particular form of artificial lift, contact the person who is in charge of the sub-section that deals with that method and volunteer your services. If you are interested in working on Sections I, III, or IV, contact the author of this paper.

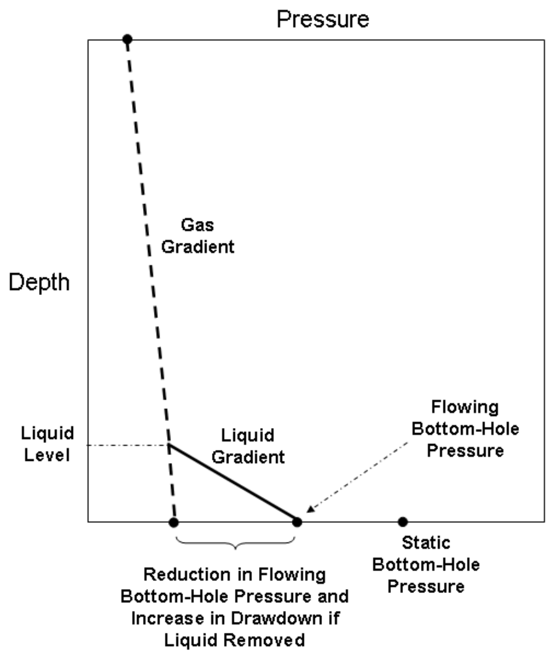

Figure 1 -Increased flowing bottom-hole pressure caused by liquid presence in wellbore

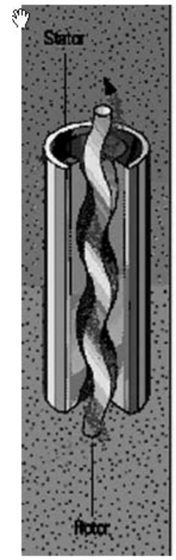

Figure 2 - PCP Pump Rotor and Stator