Introduction:

Dual String Gas Lift Completions:

Dual string gas lift installations comprise of two producing zones, each with its own tubing string in a single production casing, where the gas-lift-gas is injected at surface into the common annulus. Despite the known operational issues associated with dual string gas lift completions, the benefits of the dual completion are used from an economics point of view because of their reduced drilling costs when developing fields with multi-stacked reservoirs. The dual string completion enables two independent horizons to be exploited from a single wellbore, so long as the given reservoirs are not too great a distance apart i.e., <1000-ft. In some offshore platforms, there may also be insufficient surface space to accommodate the required well count to adequately develop the multiple reservoirs with single completions, hence the dual string completion is favoured to address the limited well count footprint on the platform itself.

Compared to single completions, dual completions have a higher initial completion cost, and have more operating problems than single well gas lift installations, and are also more difficult and expensive to work-over. Dual string completions often produce less efficiently, usually because one string consumes the available gas-lift-gas from the other string due to valve dome pressure and valve port size interaction under prevailing and changing operating conditions.

Dual String Gas Lift Valve Type and Spacing Design:

From a dual gas lift design perspective, there are many rules of thumb approaches that are listed in the literature, attempting to address the well unloading and operational instability issues typically associated with dual string gas lift completions.

Complexity at the nodal analysis design level arises from only being able to address single-string completion design and unloading, where the valve pressure and rate relationships are not fully captured due to the dynamics of the second string being absent during the gas lift design phase. Usually it is the long string’s gas lift design that is performed first, setting a maximum depth of injection for unloading and operation at the dual string packer depth. The valve spacing on the short string is usually arbitrarily spaced one or more joints above the valves designed for the long string. From only being able to design the valves based on single string interaction adds further complexity due to the dynamic valve responses not taking into consideration the impact of the other string during unloading and operation. Once the well has been unloaded and in operation, there may be a requirement to shut-in the well again and change out the gas lift valves using different dome pressures and port sizes by means of wireline workover techniques until a more stable production status can be achieved, which is a costly iterative process.

IPM Modelling:

It is well known the value PROSPER offers the end-user community with the multitude of well design and diagnoses capabilities that are available, including the single-completion transient gas lift simulator, enabling dynamic well unloading and valve operation to be understood and resolved as required to rectify multi-pointing gas injection, etc. Gas lift equilibrium curves can also be constructed that describe the actual production rate when the well is gas-lifting from any particular depth.
**REVEAL Complex Well Design:**

The dual string gas lift completion can be created directly in **REVEAL** using the well **Equipment Builder**, or created separately using **RESOLVE's WellBuilder** DataObject, then simply imported directly into **REVEAL**.
The following figures illustrate the dual string well construction each approach offers, and depict the existing dual string gas lift completion design being investigated:

**WellBuilder Existing Dual String Gas Lift Completion View:**

Detailed well equipment can be added and placed at the respective location in the completion as required from the *Equipment Browser.*
REVEAL Existing Dual String Gas Lift Completion View:

Well Unloading and Well Flow Analysis:

As gas is injected into the annulus, the kill fluid is expelled through the unloading valves of each string. The following transient wellbore results show the gas injection impact on fluid density in the annulus, tubing and second tubing, as well as indicating where the gas-lift-gas is being injected.
Time = 1-Day Prior to Starting Gas Injection:

Annulus, tubing and second tubing show kill fluid density prior to gas injection.

Gas Injection Started Showing Fluid Density Changes:

Gas density now in annulus up to first unloading valve.

Long-string fluid density reduction and positive flow due to gas injection.

Kill fluid to packer depth.

Second tubing reverse flowing and not unloading.
Note in the above figure that due to the valve attributes of the second string, it does not unload and instead reverse flows fluids into the reservoir.

Well Flowing Status after Unloading:

The following figure shows the annulus fluid is now gas up to the deepest point of injection being reached for the long-string. The long-string shows as producing, with the second string not flowing:

Gas Lift Valve Injection Depth Analysis:

We will see from reviewing the valve results that the unloading sequence was unsuccessful, as the second string (short) partially unloaded, then it was only the long-string that produced, essentially consuming all the available gas-lift-gas. The transient valve response can be fully investigated, including throttling behaviours to diagnose what happened, as well as provide a means to change valve attributes.

The gas lift design investigation may also consider changing valve types if desired until the well has been correctly unloaded and stable dual-string production has been achieved. Investigation will also show which valves have been open on the short string, bringing understanding of when and why they closed, and if the long string is multi-pointing.

Investigation of Valve Performance:

The convention in REVEAL for reporting gas lift valves is sequential, such that GLV1 corresponds to the first unloading valve on the long-string, GLV2 is then the first unloading valve on the short-string (second tubing),
where GLV3 will be the second unloading valve on the long-string, etc.

The following figure shows the gas lift unloading valve’s gas injection rates, note that the second string gas lift valves throttled and closed due to current valve attributes responding to changing tubing gradients:

The above figure also illustrates that the long-string is multi-pointing due to incorrect valve sizing and dome pressure settings, and all the short string valves close due to incorrect valve characteristics to operational tubing pressure that controls PPO valves.

**Short String Valve Investigation:**

To simplify the analysis, the focus will be on the first valve of the short string (GLV2), where the following valve attributes can be plotted to understand why the PPO valve closed:

- Gas injection rate
- Dome Pressure
- Valve inlet pressure (or annulus pressure can be selected)
- Outlet pressure (or second tubing pressure at depth from WellPipe results can be selected)
Valve attributes (or type) can now be changed until stable well production has been achieved.

**REVEAL Gas Lift Valve Database:**

The well Equipment Builder in **REVEAL** enables detailed well completion equipment to be described, as well as containing a gas lift valve database, where valve attributes (and types) can be changed as required until stable well production has been achieved.
Dual String Gas Lift Valve Re-design:

The design of PPO valves depend on the tubing pressure gradient in the well, which is less well known since it is influenced by dynamic factors such as BS&W, inflow performance, fluctuating tubing pressures, etc. It is clear from the above response of the second tubing that the production pressure was not fully understood. For this case, IPO valves will also be designed and installed in the short string based on the now known pressure gradients.

The following figure now shows all unloading valves have throttled and closed, with both strings operating at the desired deepest point of injection from having reviewed the gas lift valve design:

The following figure shows details of GLV5, which is the last unloading valve on the long-string. Valve throttling can be clearly seen due to changing casing pressure’s interaction with the valve dome pressure that serves to throttle and close the valve:
Now that we have achieved well unloading and desired stable production, the simulation run-time can be extended to evaluate well production stability and connect to the surface network in GAP through RESOLVE enabling global optimization, flow assurance, etc., studies to be evaluated.

Summary:
Complex wells can easily be constructed directly in REVEAL, or using RESOLVE’s WellBuilder DataObject then imported directly into REVEAL, enabling multi-string well performance to be investigated.

REVEAL’s transient wellbore modelling capabilities adds further value and capability enabling the complex behaviour of dual gas lift completion performance to be evaluated. Well unloading strategies, including understanding gas lift valve re-design requirements to obtain stable well production can be studied from being able to evaluate the transient gas lift valve throttling behaviours with respect to changing well gradients, etc. Valve modelling capabilities provide the basis to evaluate PPO and IPO valve combinations, providing invaluable knowledge as to what valve type and or valve combinations deliver stable well production performance.

Longer-term well stability from implementing the gas lift valve designs can be further studied from extended forecasting to verify well stability prior to implementing wireline valve change-out operations. For extended forecasting, REVEAL automatically changes from transient wellbore simulation to adaptive time-stepping based on the Max $dT$ value specified at the schedule level. RESOLVE integration enables implementation of extended modelling approaches, linking the wells to GAP, addressing field management, global optimization, flow assurance, etc., requirements.

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