CASE STUDIES

THE TRANSIENT GAS LIFT SIMULATOR IN PROSPER (IPM10.0)

INTRODUCTION

In IPM 10.0 one of the new features is the ability to perform Transient Gas Lift Designs, and this article is designed to provide the context behind the development whilst also showing the functionality that is possible.

The conventional approach in performing gas lift design (both in terms of unloading and operating the well) is to use steady state assumptions, which of course stem from the simplifications assumed in the API design methods. The API design standards were created with hand calculations in mind, and as such make a number of simplifying assumptions to reduce the iterations required in finding a suitable design. In reality however, all gas-lift wells begin production through unloading of the kill fluid which is a transient process.

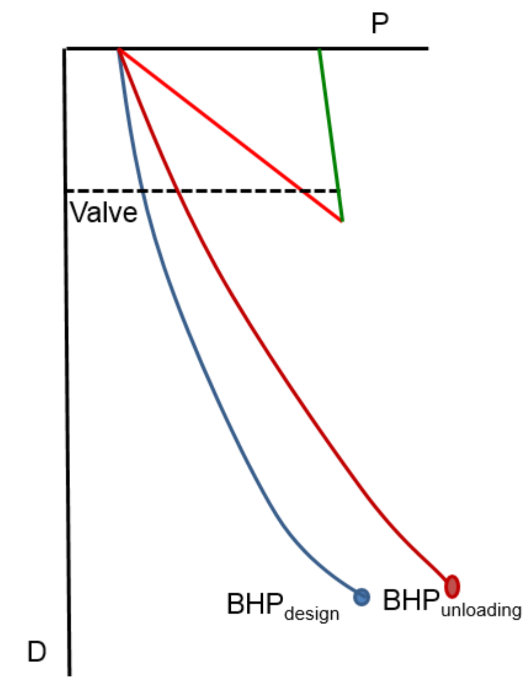
Therefore in some circumstances using empirical design methodologies, and assuming steady-state conditions can result in designs that exhibit operational challenges such as multi-pointing, unstable production and poor lift efficiency.

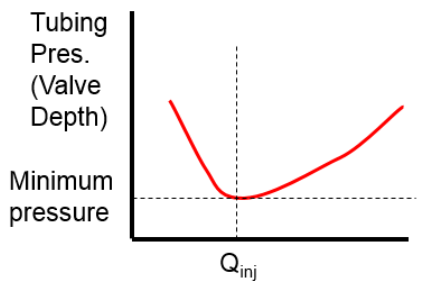
CHRONOLOGY OF GAS LIFT DEVELOPMENT

The standard API design methodology (published in the 70s and subsequently updated over time) is based on assuming a single liquid design rate used to establish the desired pressure gradient (sometime referred to as the objective gradient) from which the valve spacing, sizes and unloading mechanics are determined. Over time some of the simplifying assumption have been modified, and equally some have not.

To address the limitation of a single rate, over a decade ago PROSPER allowed the user to selecta rate, or alternatively use a gas lift performance curve. Moreover, a series of additional functionalities were introduced to enhance the gas-lift design procedures, some of which are explained below. These are all still limited by steady state assumption, but are improvements on the original API methodology.

Use IPR for Unloading





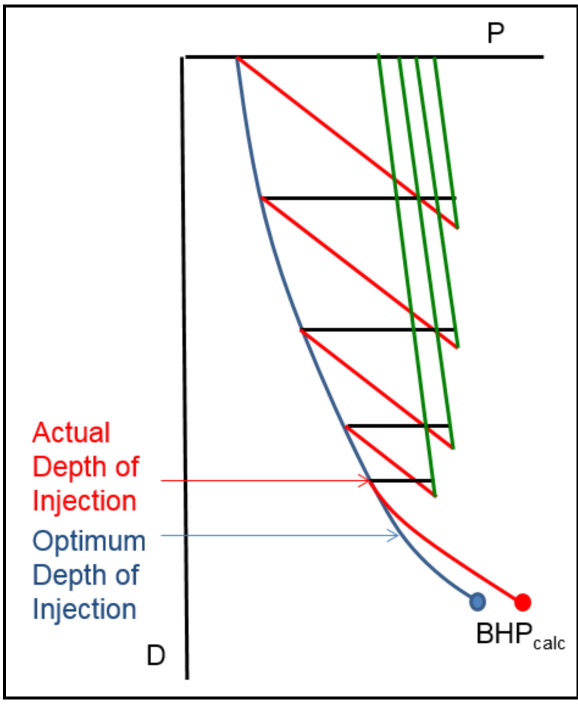
When sizing the valve, the API method uses a minimum transfer dP to estimate the dP across the valve, and back calculate the required valve port size. This may lead to over-sizing the valve port size, which may result in valve throttling and unstable well unloading.

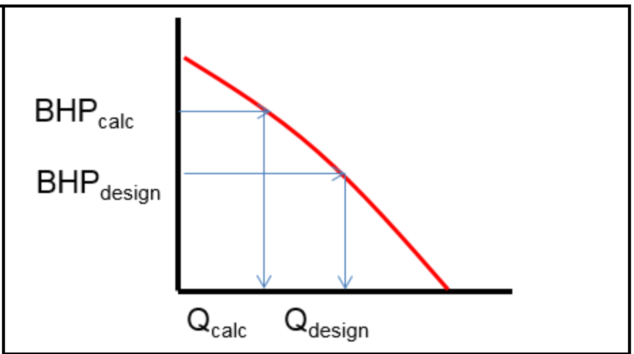
To address this, the ***Use IPR for Unloading*** option uses the IPR to find the liquid rate, from which the gas lift rate is found. This is then used to determine the required port size and ensures that the valve is not over-sized. (As always, further details are available in the PROPSER user guide)

CASE STUDIES

THE TRANSIENT GAS LIFT SIMULATOR IN PROSPER (IPM10.0)

Check Rate conformance with IPR





When determining the valve spacing in the standard design method, it is possible for the final orifice depth to differ from the optimum depth. This will change the bottomhole pressure and hence the shape of the objective gradient – requiring a new design to be performed.

The Check Rate with IPR option is used to ensure that the calculated rate is the same as the design rate. If the two rates do not correspond then the design is restarted with a smaller design rate. This is continued until the two rates converge. This ensures that the design rate can actually be delivered by the reservoir.

These functionalities have existed in PROSPER for well over a decade now, and go some way to ensuring that the gas-lift design captures as much of the physics in the unloading process using steady state approaches. However, all steady state methods are an approximation since the unloading process exhibits accumulation and is as such transient: thus the modelling approach must capture this- and is now possible in IPM 10 using the ***Transient Gas Lift Simulator***.

TRANSIENT GAS LIFT SIMULATOR

The transient gas lift simulator is used to model the transient unloading process and capture whether the steady state design proposed is indeed possible in reality. The simulator allows an engineer to confirm whether a well is unloaded, and whether the final injection is at a single point in the annulus or if multi-pointing is occurring. Additionally it can diagnose whether stable production can be achieved.

METHODOLOGY

The simulating engineer can thus use this tool within PROSPER to perform sensitivities with a view to finding conditions which stabilise the well, assess any proposed design and assess the production changes that are likely to result. The transient gas lift simulator model uses energy, mass and momentum conservation equations coupled with pressure and temperature change during the unloading process, to capture:

- IPO and PPO TUALP's valve dynamic performance models (capturing throttling flow)
- Nozzle - Venturi and orifice valves
- Co-current and counter-current multiphase flow pressure drop
- Multiphase flow through Subsurface Safety Valve
- Reservoir inflow and back flow into reservoir
- Transient heat transfer is modelled in the formation and wellbore
- Joule-Thompson effects for two-phase mixtures using the approach by Alves, et al.

CASE STUDIES

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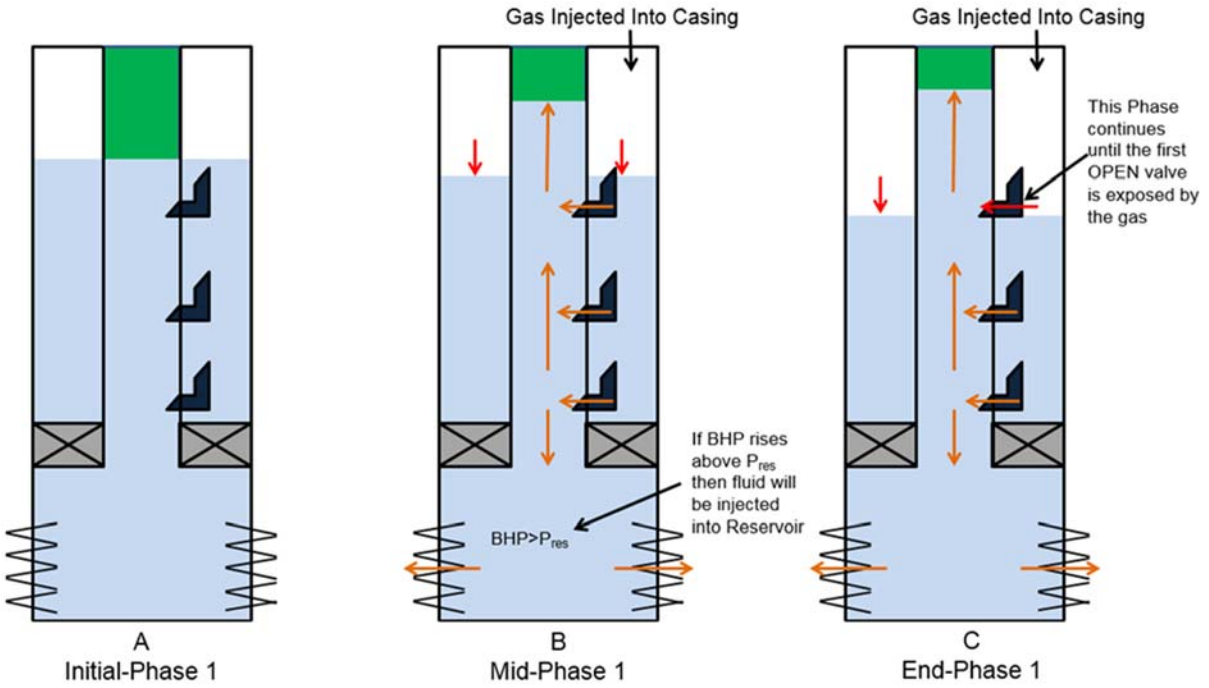
PHASE 1

The transient unloading process occurs in two phases both of which are shown diagrammatically and explained below:



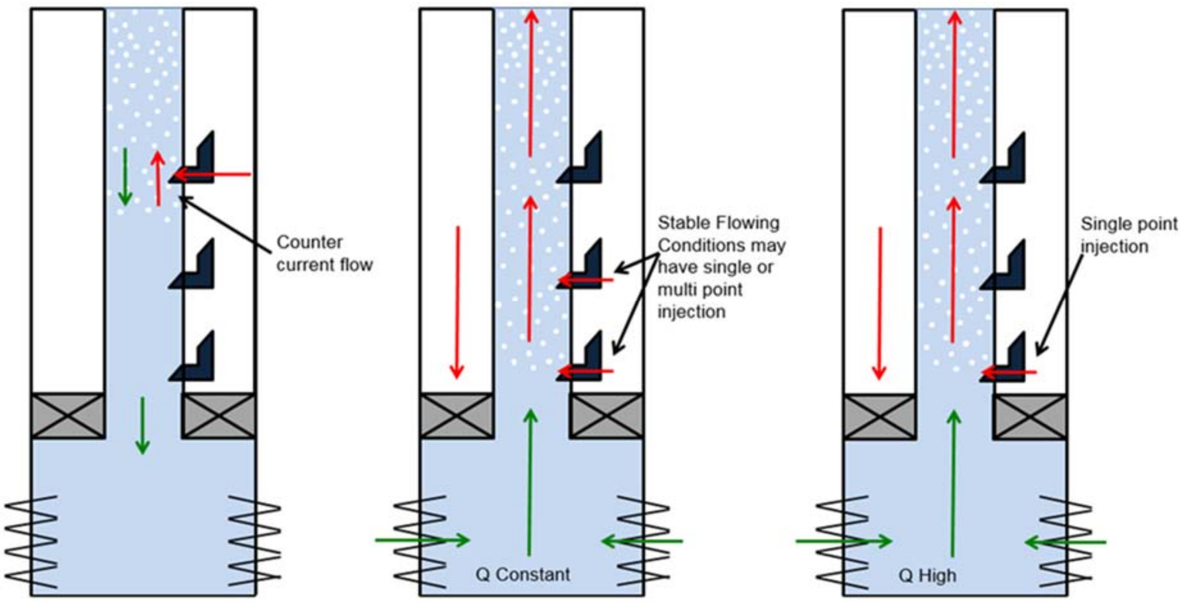
- Initially, at time zero, the well is not producing and contains a stagnant kill fluid up to a specific liquid level.
- As gas is injected into the casing (beginning of the transient unloading process), the casing head pressure increases causing gas to displace the annulus liquid level down the well.
- Due to the hydrostatic pressure of the kill fluid, all valves are initially open, allowing the annulus kill fluid to flow through the valves into the tubing at different depths along the well.
- As the liquid level in the casing reduces, the tubing liquid level increases. This will increase the hydrostatic pressure in the tubing causing the bottomhole pressure to increase. This can be the onset of back flow into the reservoir.
- If kill fluid could damage the formation, an operator may install a check valve (standing valve) at the bottom of the tubing to produce the loss of kill fluid into the formation.
- The casing pressure continues to increase (to reduce the annulus liquid level and increase the tubing liquid level). During this period it is also possible for the kill fluid to be produced to the surface or lost to the formation.
- This phase continues until the first open valve is reached by the injected gas in the annulus.

CASE STUDIES

THE TRANSIENT GAS LIFT SIMULATOR IN PROSPER (IPM10.0)

PHASE 2

When injected gas enters the tubing from the annulus via the first gas lift valve, phase 2 begins.



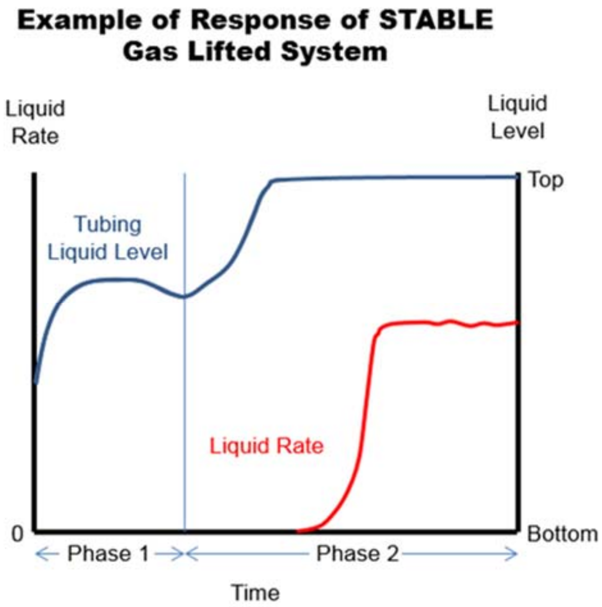
- Initially, kill fluid can still back flow into the formation because the bottomhole pressure has not decreased below the static reservoir pressure. During this period, counter-current two-phase flow (rising gas and failing liquid) may exist.
- As gas begins to be injected into the tubing, the liquid column above the gas lift valve lightens, at this stage some formation fluid may be produced into the well, and due to gravity/buoyancy effects will rise to the surface taking some kill fluid with it. Thus at surface some formation and kill fluid will be produced.
- During this process, the lower valves continue to transfer liquid from the annulus and drop the liquid level in the annulus so that deeper injection can be achieved. As more gas lift valves are exposed, it is possible for multipoint injection to occur.
- Once formation fluid is produced, a transient temperature distribution in the wellbore will exist, as hot reservoir fluid is produced, heat transfer from the tubing to annulus and surrounding formation will occur.
- This can affect the dynamic valve performance as the change in tubing temperature can change the valve dome temperature which would consequently affect the valve dome pressure. This can affect the control and performance of the valve.
- Eventually, flowing conditions in the well stabilise with time and the unloading process is complete. The system can be said to be stable.

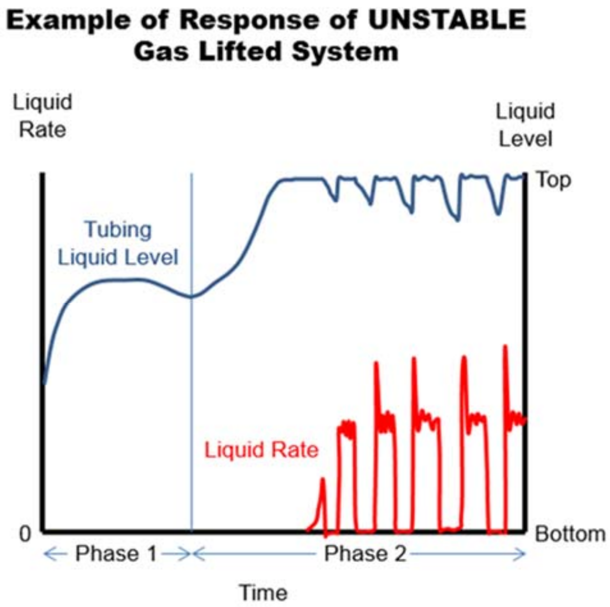
CASE STUDIES

THE TRANSIENT GAS LIFT SIMULATOR IN PROSPER (IPM10.0)

RESULTS

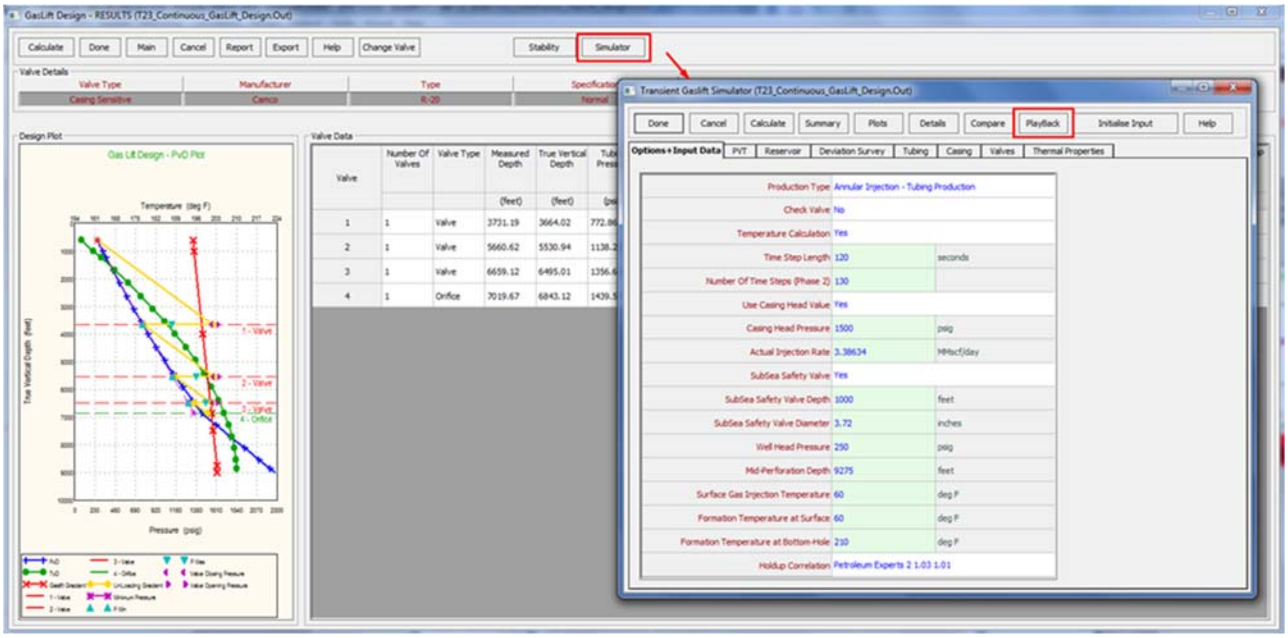
The simulator combines the unloading process (transient pressure) with heat transfer (transient temperature) through a double iteration method to obtain the true unloading characteristic. If the system continually changes with time (e.g. injection depth constantly switch) then the system never reaches steady flowing conditions and can be said to be unstable (see below).





IPM10: TRANSIENT GAS LIFT SIMULATOR

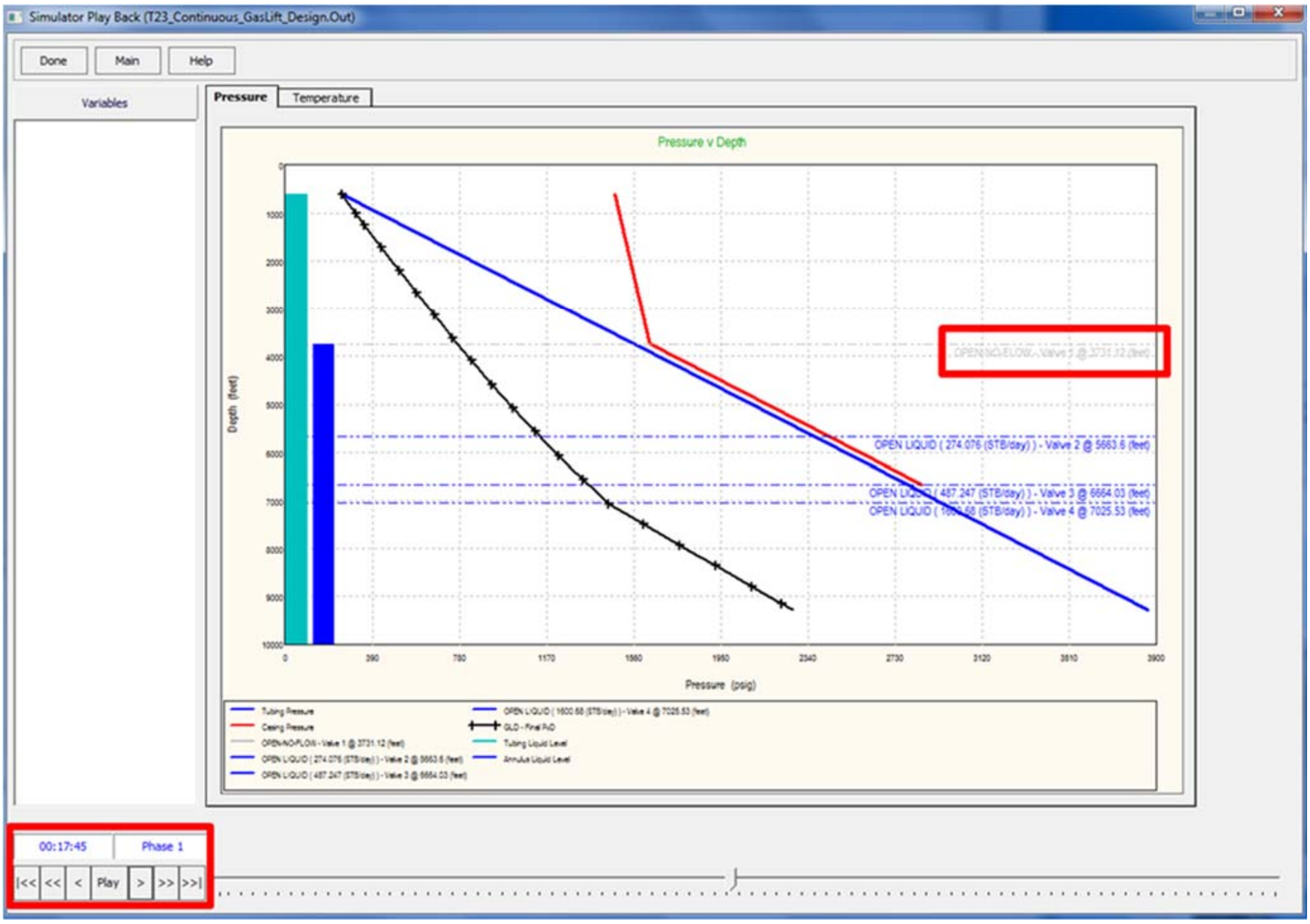
The below screen shots are from the PROSPER user guide Tutorial that is available to any user with valid licence. Having performed the standard ***"new gas lift design"*** the results from the design (valve spacing and mechanics) can be populated in the ***transient gas lift simulator*** to verify the design.



CASE STUDIES

THE TRANSIENT GAS LIFT SIMULATOR IN PROSPER (IPM10.0)

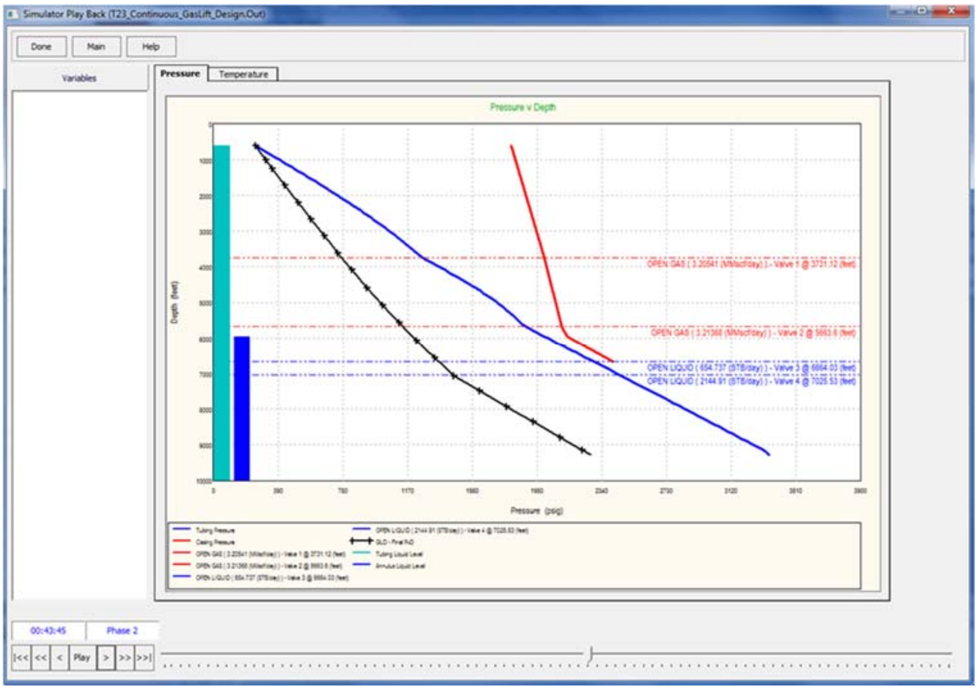
- Using the “PlayBack tool”, we can reviewing the **phase 1** and **phase 2** unloading process in the well.
- The black line represents the pressure gradient achieved by the standard gas lift design. The blue line represents the tubing pressure at the current timestep. The red line represents the casing pressuring at the current timestep.



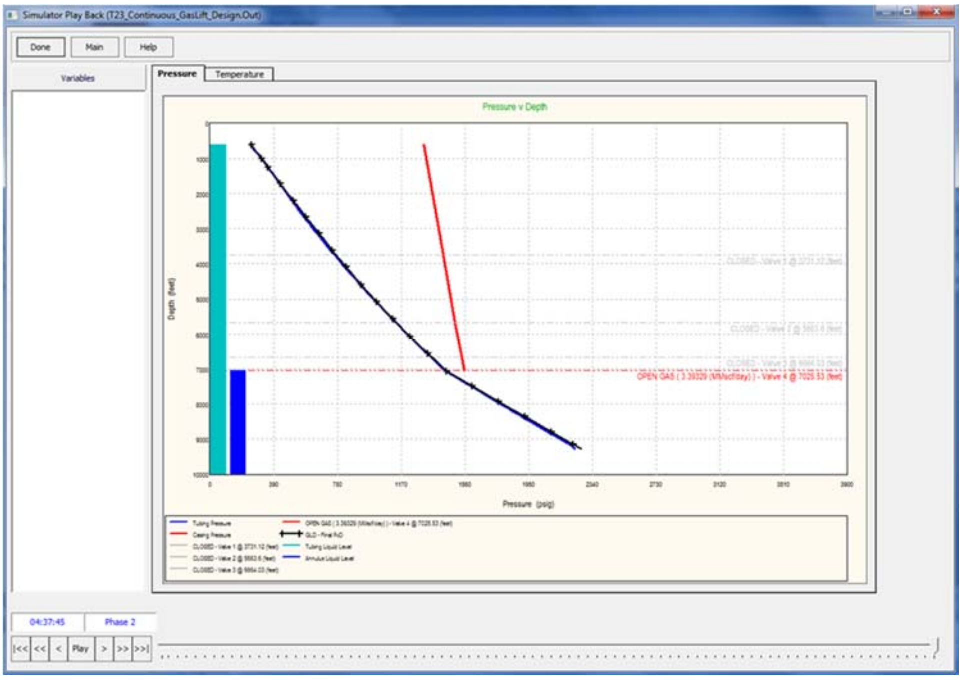
- In this example, the simulator shows that it will take approximately 18 minutes to complete phase 1. At this point, the shallowest valve will begin to option and inject lift gas into the tubing.
- The valve status displays 'OPEN NO-FLOW' because the valve is currently throttling (i.e. at the current tubing pressure it is not possible to inject). This response is captured by the dynamic valve performance models.
- Progressing forward in time, once the second valve begins to inject gas the tubing pressure lowers and the first valve also opens and injects gas. The unloading process now multi-points and continues to lower the tubing pressure, as shown below by sliding the time scale.

CASE STUDIES

THE TRANSIENT GAS LIFT SIMULATOR IN PROSPER (IPM10.0)



As the tubing pressure is lowered so does the casing pressure, this in turn causes valves to begin to close until injection only occurs in the deepest point, as shown below.



CONCLUSIONS

In this context, the new gas lift design performed in PROSPER using enhancements such as *Check Rate conformance with IPR* and *Use IPR for unloading* verifies that the above well can be unloaded and achieve stable production with confidence.