Optimisation of Gas Lift
Well Clean-up Operations

by Juan Carlos Mantecon
WELL CLEAN-UP

Well Clean-up is the period when drilling debris and fluids are still coming out of the well with produced hydrocarbon

- Minimum Rate and time to clean the well
- Size of testing equipment
- Multi-layer production results.
- Influence on WHT
- Comparison of well completion designs
WELL CLEAN-UP

• Well Clean-up to MODU or FPSO?

• Well cleanup becomes a concern for the planned unloading scenario
  – Well stream is not allowed to be brought to the process if the mud concentration is higher than
    • 1 vol-% for LSOBM (Low-Solid-Oil-Based-Mud), and
    • 0.2 vol-% for OB WARP (Oil-Based WARP Mud)
  – It can be temporarily routed to the export line, but only for a short period (36 hrs) as the early water break-through can result in off-spec for the export crude

• Minimum Rate required to Clean-up the well and the corresponding time are of extreme importance
WELL CLEAN-UP

• Can we unload the well to a production fluid filled line?

• Would artificial lift (GL) be necessary?

• Dewatering only the riser would solve the problem?

• An ESD or a trip when the fluid density at the well or at the riser was at maximum value would create unloading problems?
WELL CLEAN-UP – Gas Lift
Production Well Clean-up Schedule – No Drilling Fluids

Trend Plot
- QLST [STPD] (RISER.PIPE-5.2) "LIQUID VOLUME FLOW AT STANDARD CONDITIONS"
- VALVOP [\] (WELL TEST CHORE) "RELATIVE VALVE OPENING"
WELL CLEAN-UP – Gas Lift
Production Well Clean-up Schedule – No Gas Lift

Trend Plot

QLST [STB/D] (RISER.PIPE-5.3) "LIQUID VOLUME FLOW AT STANDARD CONDITIONS"

VALVOP [ ] (WELL TEST CHoke) "RELATIVE VALVE OPENING"
When using gas lift (300 scf/min of N2 during the first 4 hours), it took approximately 4.3 hours to clean-up the well.
WELL CLEAN-UP – Gas Lift
Production Well Clean-up – Gas Lift
WELL CLEAN-UP – Well Completion Design Comparison
Gas/Condensate Big Bore Well – 30 MMscfd
WELL CLEAN-UP – Well Completion Design Comparison
Gas/Condensate Big Bore Well – 150 MMscfd
WELL CLEAN-UP – Well Completion Design Comparison
Gas/Condensate Monobore Well – 60 MMscfd
WELL CLEAN-UP
Dual Well Completion
WELL CLEAN-UP – Annular Gas Lift
Production Fluid Filled Flowline Well Completion
Well Testing – Transient Modelling
Well Testing has become more challenging

- Offshore rig rates are at an all time high
- Wells are becoming bigger and longer
- Deeper waters and more complex reservoirs.
- In this environment, well clean-up and flow assurance issues such as slugging and hydrates can significantly extend the planned duration of well-tests.
Well Testing – Transient Modelling
Well Testing has become more challenging

- The ability to predict and being prepared to deal with such problems can:
  - optimise well test equipment design
  - reduce operational risk

- Potential for saving millions of dollars in:
  - Rig-time
  - Wellbore completion equipment damage
  - Reservoir formation damage

- Minimising safety hazards
- Minimising environmental impact.
Well Testing – Transient Modelling
Application of New Tools

• Traditional well flow software only model steady-state flow

• New specialised software to model the transient behaviour of wells - unloading of completion fluids from rate=0 until steady state flow conditions are reached.

• Key outputs at any time and at any point in the well include:
  • slug sizes and frequency
  • fluid composition and hold-up
  • pressure-temperature trends

• This information enables optimum equipment design so all parameters are within the allowable operating envelope at any time of the well test operation.
Well Testing – Transient Modelling
Application of New Tools

- Different initial conditions (facilities backpressure, underbalanced pressure and drilling fluids types) can be modelled.

- Beanup rates and well-test sequencing can be changed to optimise the operation from well clean-up to steady state conditions, including any emergency shut-down (ESD) and “what if” analysis.

- Ultimately this tool can be the basis of a simulator used by well-test personnel to “virtually” run through a complete well-test operation.
The clean-up simulations were started from the initial underbalanced conditions with different choke sizes.

The well models were allowed to run until the brine, diesel and lost circulation mud (LCM) had been displaced from the well and steady state conditions were obtained.

LCM was included in the model to assess the effect of backproducing mud lost into the formation during drilling. This provided the worst case conditions for the clean-up of the well and the restart of the well after an ESD.
Well Testing – Transient Modelling
Otway Case Study

Initial Conditions

- A diesel cushion length of 1635 m MD was required to obtain a 150 psi underbalanced condition, measured at the bottom reservoir inflow point

- A constant backpressure of 100 psia was applied downstream of the choke in the model – relevant when $F < CF$

- One inflow point was considered – Single-Forchheimer
Well Testing – Transient Modelling
Otway Case Study

Boundary Conditions

• The injectivity was assumed to be zero for each zone (this is the worst clean up case scenario), since allowing the injectivity to equal the productivity (default) would permit fluid back into the reservoir during the shut-in simulations.
  • No analysis of cross flow between productive units was performed (injectivity=0 eliminates this possibility).

• The average seawater temperature at seabed was assumed to be 13°C with a sea current velocity 0.5m/s

• The average ambient air temperature was assumed to be 28°C, and the average wind velocity 7m/s
Well Testing – Transient Modelling

Minimum Clean-up Rate

Choke Size Sensitivity Runs

- Clean-up simulations were started from initial conditions using choke sizes of 0.5”, 0.75”, 1”, 1.5”, 2” and 3”.

- 200 bbl of LCM was included in the model as a mass source from the reservoir to simulate the production and clean up of this extra amount of fluid.

- The inflow of the LCM was constrained by the bottom-hole pressure, so that the LCM flowrate modelled was the maximum that could occur under realistic conditions.
Well Testing – Transient Modelling
Minimum Clean-up Rate – Simulation Results

- The clean-up time was defined as the time taken for the original liquid content in the well to be completely unloaded, excluding fluids below the Unit 5 inflow point where no gas was available to lift the liquid (rat hole).

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Well Testing – Transient Modelling
Minimum Clean-up Rate – Simulation Results

TM-1 Clean-up - Flowrates 3” Choke

TM-1 Clean-up - Flowrates 1.5” Choke

TM-1 Clean-up - Flowrates 1” Choke

TM-1 Clean-up - Flowrates ¾ “ Choke
Well Testing – Transient Modelling
Minimum Clean-up Rate – Simulation Results

TM-1 Clean-up – Total Oil content in well for each choke size

TM-1 Clean-up – Temperature at wellhead for all choke sizes
Well Testing – Transient Modelling
Minimum Clean-up Rate – Simulation Results

TM-1 Clean-up - Initial Well Conditions ass choke sizes

TM-1 Clean-up - 3" Choke after 120 sec

TM-1 Clean-up - 3" Choke after 220 sec

TM-1 Clean-up - 3" Choke at SS
Well Testing – Transient Modelling
Minimum Clean-up Rate – Simulation Results
The purpose of this activity was to determine the minimum rate and time required to clean-up the TM-1 well, if an ESD were to occur during the clean-up operation.

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Well Testing – Transient Modelling
Minimum Clean-up Rate – Simulation Results - ESD
Conclusions

• The following conclusions are specific to the dynamic simulation on the TM-1 well:

  – Choke sizes 1.5” or larger allows rapid clean-up of the brine and LCM from TM-1. The clean-up time for a 1.5” choke was 1:08 hours.

  – Flowrates using the 0.5” and 0.75” choke sizes would not provide sufficient gas velocity within the well tubing to completely remove the brine, even though the majority of wellbore fluids were unloaded at moderate or low rates.

• The modelling shows that proper clean-up necessary for accurate well testing could not be achieved with these smaller choke sizes.
Conclusions

- The following conclusions are specific to the dynamic simulation on the TM-1 well (cont.):

  - Although a 1” choke can clean-up the well, the clean-up time was 15:40 hours. This indicates that the standard welltest package with a gas handling limit of ~50 MMscfd may be sufficient to handle the clean-up of TM-1. However it would take almost 14 hours longer to clean the well than if it had been cleaned-up using a 1 ½” choke at 114 MMscfd steady-state gas flowrate, which would require a high rate well-test package.
Conclusions

• The following conclusions are specific to the dynamic simulation on the TM-1 well (cont.):

• If an ESD occurred during the course of the cleanup, simulations indicate that:
  – with choke sizes greater than 1 ½”, all liquids would be cleaned up from the well.
  – the 0.5” and 0.75” choke sizes would not provide sufficient gas rate to lift all the fluids from the wellbore.
  – it will take a long time to lift all the fluids out of the wellbore with a 1” choke. Although the bulk of the liquid would be lifted out of the well initially, only 15.5 barrels would be lifted out of the well after 48 hours of cleanup, with 19 barrels remaining in the well (excluding the volume in the rathole)
Conclusions

• General

– The knowledge of the minimum flowrates required to clean up the wells enables appropriate design and sizing of well test equipment.

– In this case, dynamic modelling indicated that a standard welltest package may be adequate for cleaning up this big bore gas well with 9 5/8” production tubing, though the equipment would be operated at or near its limits.

– The simulation indicated that a high rate well-test package costing significantly more may not be required, although it would have allowed a significantly faster well cleanup.
Conclusions

- **General**
  
  - Dynamic modelling allows the investigation of a well’s behaviour during unloading, including the effect of an ESD.
  
  - Dynamic well modelling is a useful tool to optimize well-test design.

  - Analysis of the simulation results provides a basis for optimal equipment selection and a better preparation of well completion and testing jobs reducing risk, safety hazards and environmental impact.
Virtual Downhole Gauge

Better Reservoir Analysis from Well Test Data Optimisation

– Better Radius of investigation and reserves calculation - deconvolution technique.

  – High resolution data from separator and the time resolution by history matching the rate to the downhole pressures using Dynamic Model.

– Model the well test and validate model during well clean-up
– Predict BHP during test from THP
be dynamic

Thank You!

Any Questions?