Unconventional Gas Lift

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ALRDC Gas Lift Workshop
June 7th-11th 2021

Artificial Lift
R&D Council

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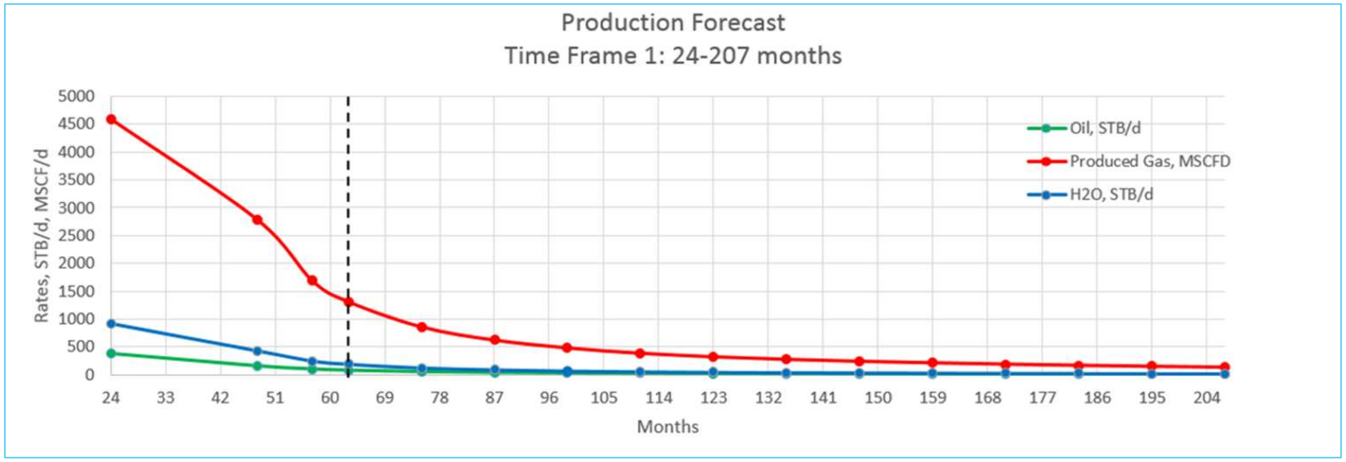
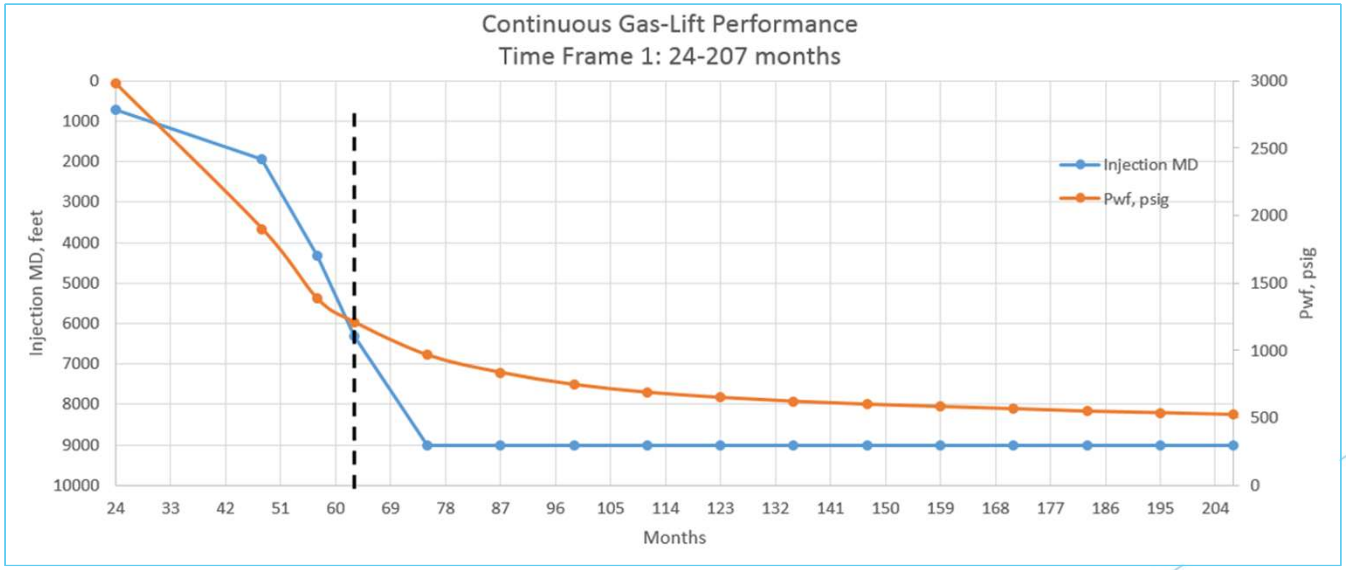
Overview

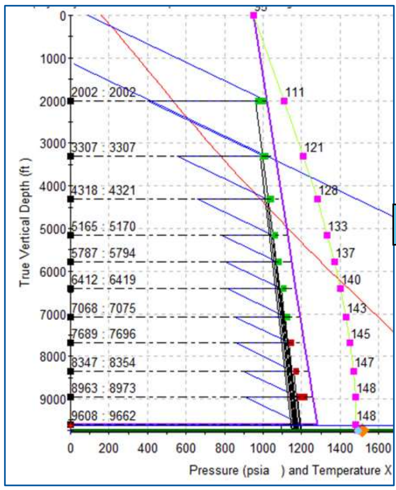
- Operational Issues
- Surface facility designs
- Production Strategy
- Q&A

Life of well production profiles

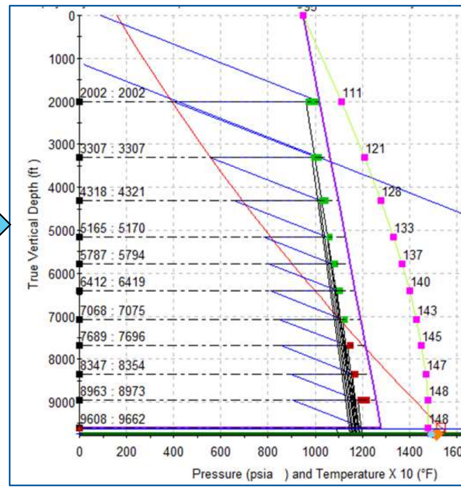




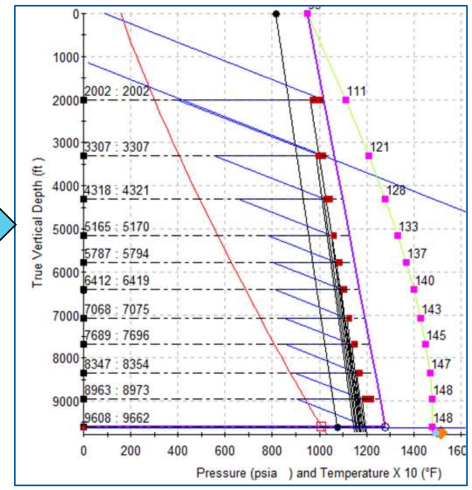
Life of well production profiles



6 mos.



12 mos.

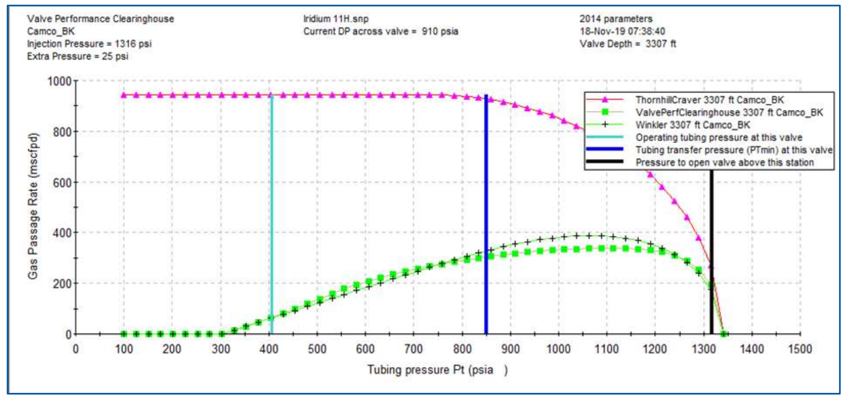


24 mos.

Operational Issues

Valve Reliability Issues

- Flow Cutting
- Throttling / Chattering
- Bellows Failures
- Plugging
- Elastomer Failures



Operational Issues

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Other Issues

- Compressor trips / outages
- Gas Availability
- Hydrates / choke freezing issues
- Paraffin
- Slugging / Surging
- Sand Production
- Frac Hits

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Lift revisions over time

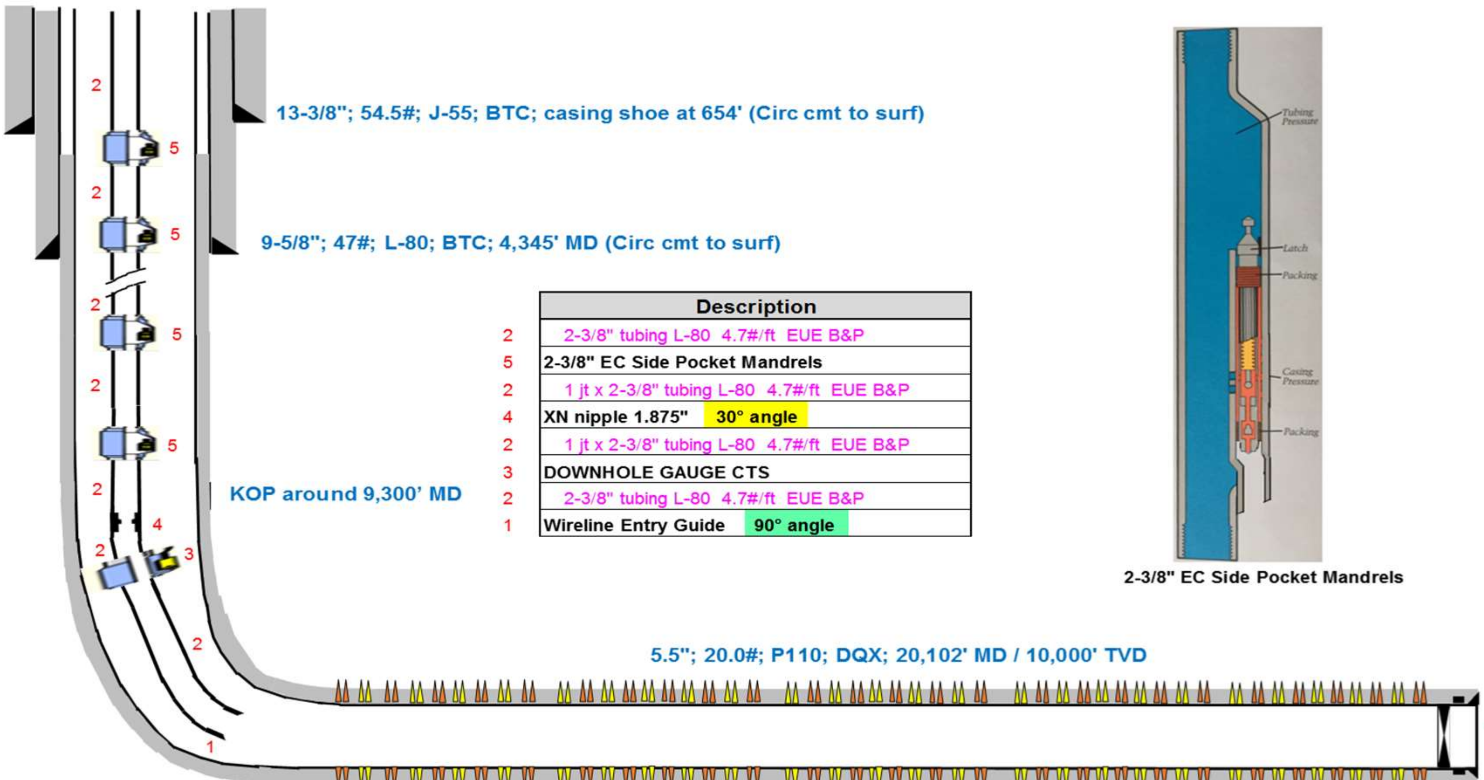
- Stage 1, Flowback: Flow up Casing
- Stage 2, Initial AL: Annular Gas Lift
- Stage 3, Mature AL: Tubing Flow Gas Lift
- Stage 4, Late-life AL: IGL, GAPL, Plunger Lift, SRP, etc.

Annular Gas Lift Configurations

Typical Annular Gas Lift Installation Types

1. 2-3/8” EC Ported Side Pocket Mandrels and No Packer.
2. 2-3/8” EC Ported Side Pocket Mandrels with Sliding Sleeve and Packer.
3. 2-3/8” IM Mandrels, 1.00” Gas Lift Valves, No Packer.
4. 2-3/8” Side Pocket Mandrels With Sliding Sleeve and Packer.

EC Ported Side Pocket Mandrels No Packer



	Description
2	2-3/8" tubing L-80 4.7#/ft EUE B&P
5	2-3/8" EC Side Pocket Mandrels
2	1 jt x 2-3/8" tubing L-80 4.7#/ft EUE B&P
4	XN nipple 1.875" 30° angle
2	1 jt x 2-3/8" tubing L-80 4.7#/ft EUE B&P
3	DOWNHOLE GAUGE CTS
2	2-3/8" tubing L-80 4.7#/ft EUE B&P
1	Wireline Entry Guide 90° angle

2-3/8" EC Side Pocket Mandrels

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EC Ported Side Pocket Mandrels, SS, and Packer

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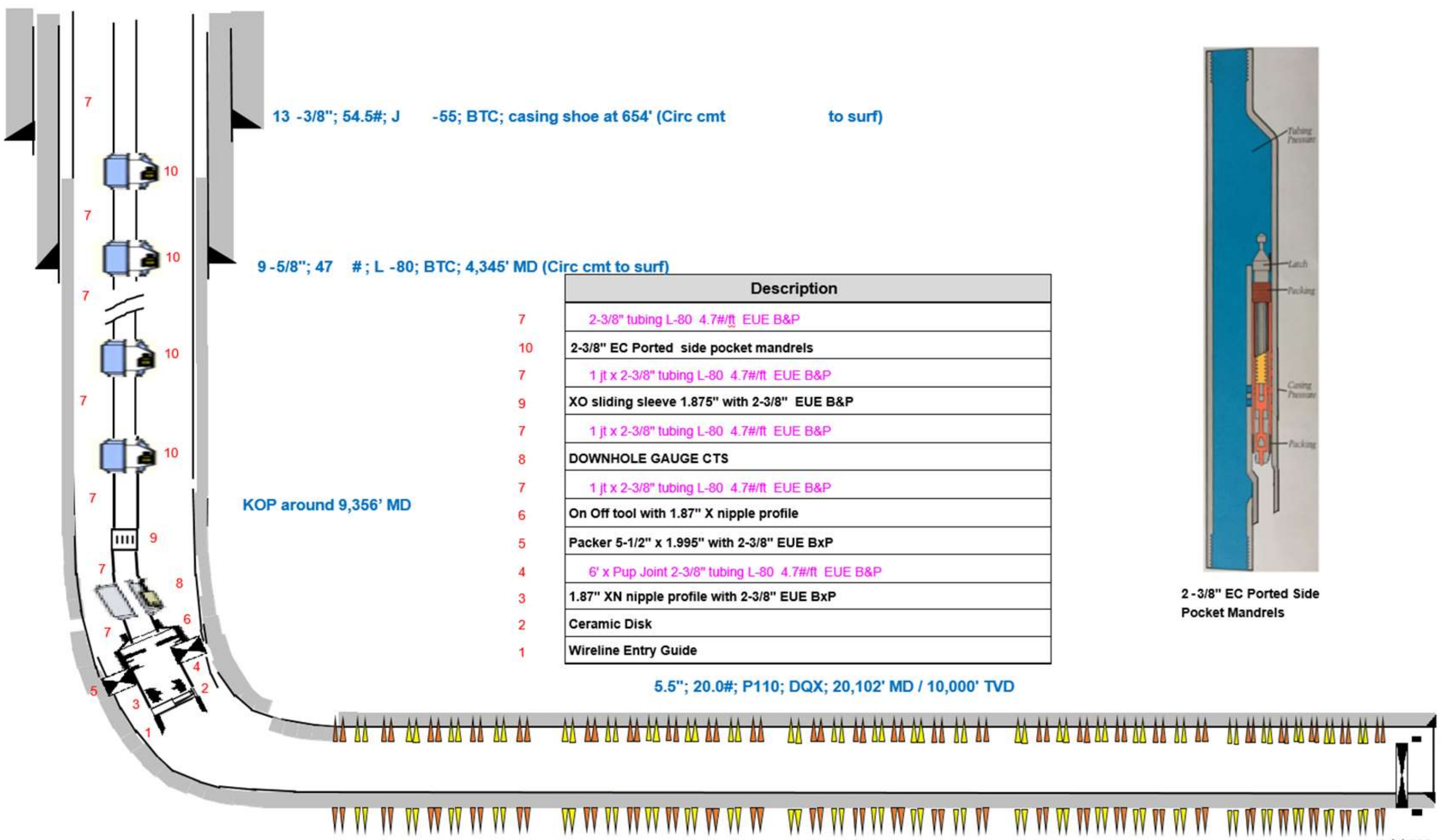
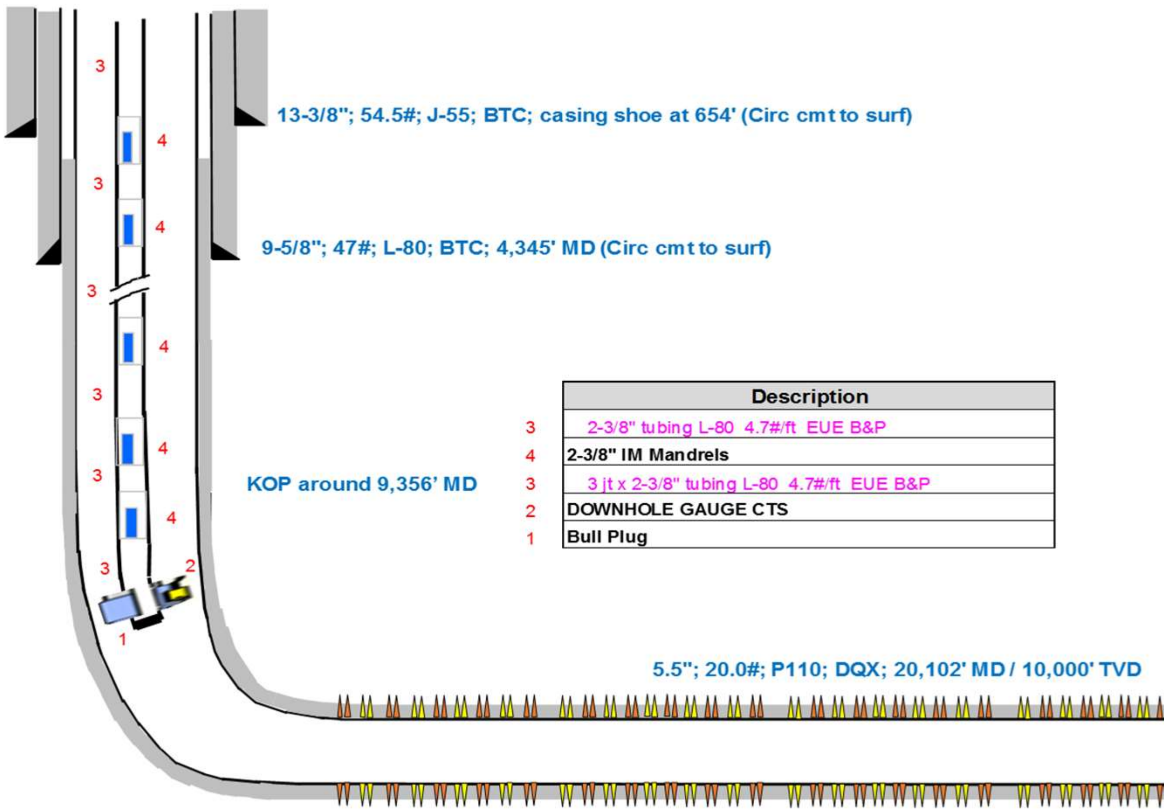


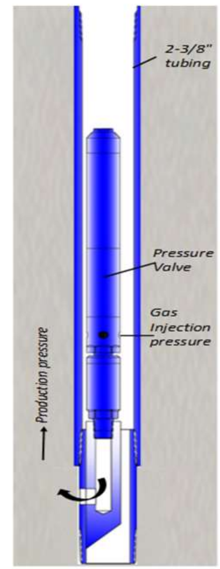
	Description
7	2-3/8" tubing L-80 4.7#/ft EUE B&P
10	2-3/8" EC Ported side pocket mandrels
7	1 jt x 2-3/8" tubing L-80 4.7#/ft EUE B&P
9	XO sliding sleeve 1.875" with 2-3/8" EUE B&P
7	1 jt x 2-3/8" tubing L-80 4.7#/ft EUE B&P
8	DOWNHOLE GAUGE CTS
7	1 jt x 2-3/8" tubing L-80 4.7#/ft EUE B&P
6	On Off tool with 1.87" X nipple profile
5	Packer 5-1/2" x 1.995" with 2-3/8" EUE BxP
4	6' x Pup Joint 2-3/8" tubing L-80 4.7#/ft EUE B&P
3	1.87" XN nipple profile with 2-3/8" EUE BxP
2	Ceramic Disk
1	Wireline Entry Guide

2-3/8" EC Ported Side Pocket Mandrels

IM Mandrels No Packer



	Description
3	2-3/8" tubing L-80 4.7#/ft EUE B&P
4	2-3/8" IM Mandrels
3	3 jt x 2-3/8" tubing L-80 4.7#/ft EUE B&P
2	DOWNHOLE GAUGE CTS
1	Bull Plug



2-3/8" IM Mandrels

Standard Side Pocket Mandrels, Packer, and Sliding Sleeve

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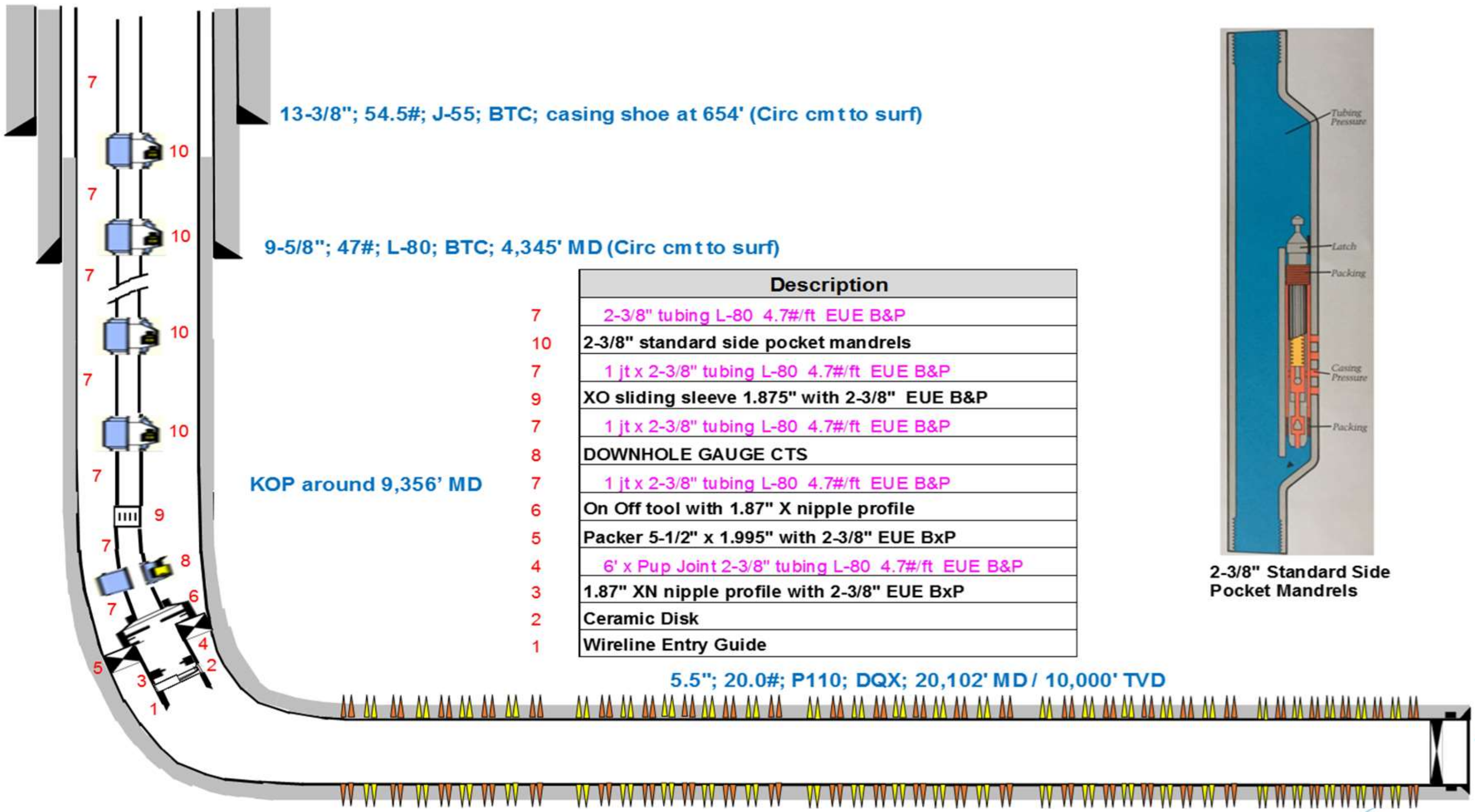

	Description
7	2-3/8" tubing L-80 4.7#/ft EUE B&P
10	2-3/8" standard side pocket mandrels
7	1 jt x 2-3/8" tubing L-80 4.7#/ft EUE B&P
9	XO sliding sleeve 1.875" with 2-3/8" EUE B&P
7	1 jt x 2-3/8" tubing L-80 4.7#/ft EUE B&P
8	DOWNHOLE GAUGE CTS
7	1 jt x 2-3/8" tubing L-80 4.7#/ft EUE B&P
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2	Ceramic Disk
1	Wireline Entry Guide

2-3/8" Standard Side Pocket Mandrels

Annular Gas Lift Configurations

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In Summary…

- Pros and Cons to each configuration
- No one-size-fits-all solution

Intermittent Gas Lift Installations

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Intermittent GL Basics

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- Gas injected in series of pulses.
- Useful in low productivity wells near end of life.
- Tubing typically no larger than 2-7/8”.
- Typical rates: 25 to 300 blpd
- Max. rates of 600 blpd using chambers.
- Least efficient of artificial lift methods.
  - Total system efficiency typically 10-20%.

Intermittent GL Basics

- Characteristics
  - Intermittent injection into the tubing
  - Low FBHP
  - Choke controlled using a pilot-operated valve or time-cycle controller
  - 3 Types of Completions: Closed, Semi-Closed or Open
  - Fallback losses Typically 5 - 7% per 1000 ft of tubing
  - Require rapid injection of gas – pilot operated valve

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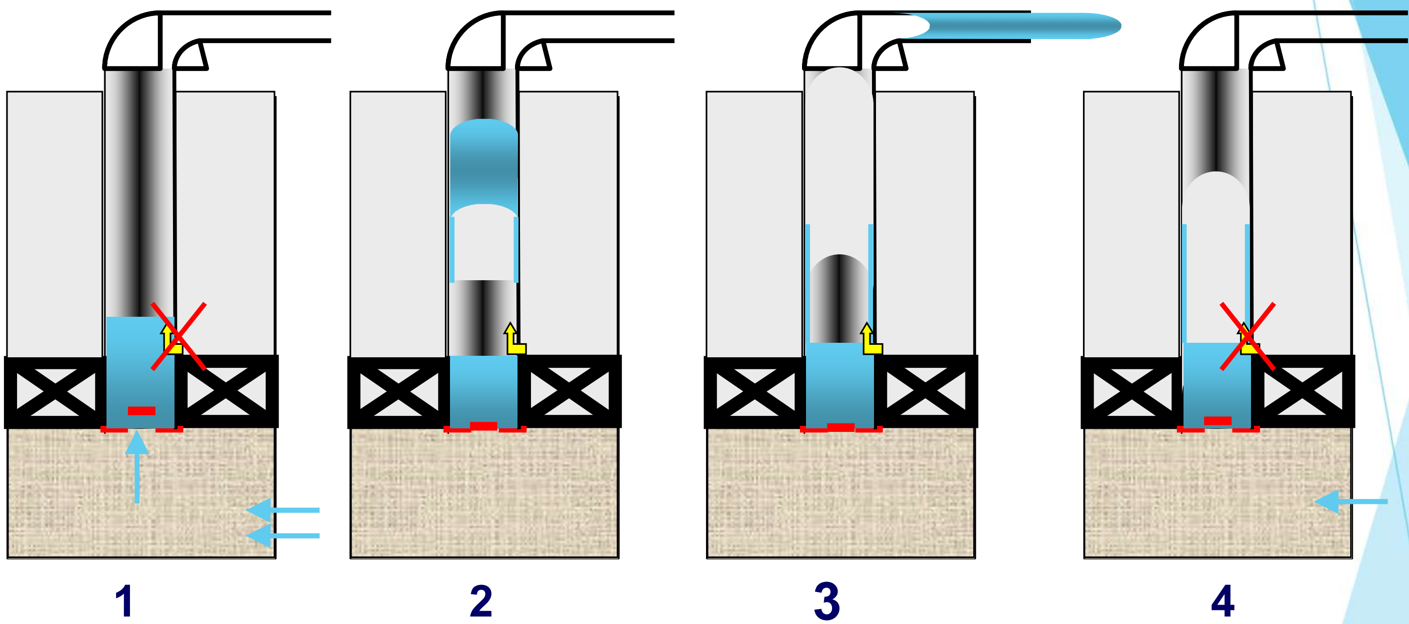
Intermittent GL Basics

- Applications
  - Low or intermediate producing rates
  - Wells previously on cont. gas lift
  - Low BHP and low P.I.
  - Low BHP and high P.I.
  - High BHP and low P.I.
  - Deep points of injection

Intermittent GL Basics

- Categories
  - Conventional IGL
  - Chamber Lift
  - Plunger-assisted Gas Lift

IGL Cycle



Valve closed Inflow to produce slug, until valve opening pressure is reached.	Gas injected into tubing and slug lifted with some fallback. No inflow.	Fluid is produced at surface. Rapid drop in tubing pressure pulls in gas from casing. No inflow.	Fallback and rapid gas injection continue until valve closing pressure reached. Inflow starts.

IGL-Fallback

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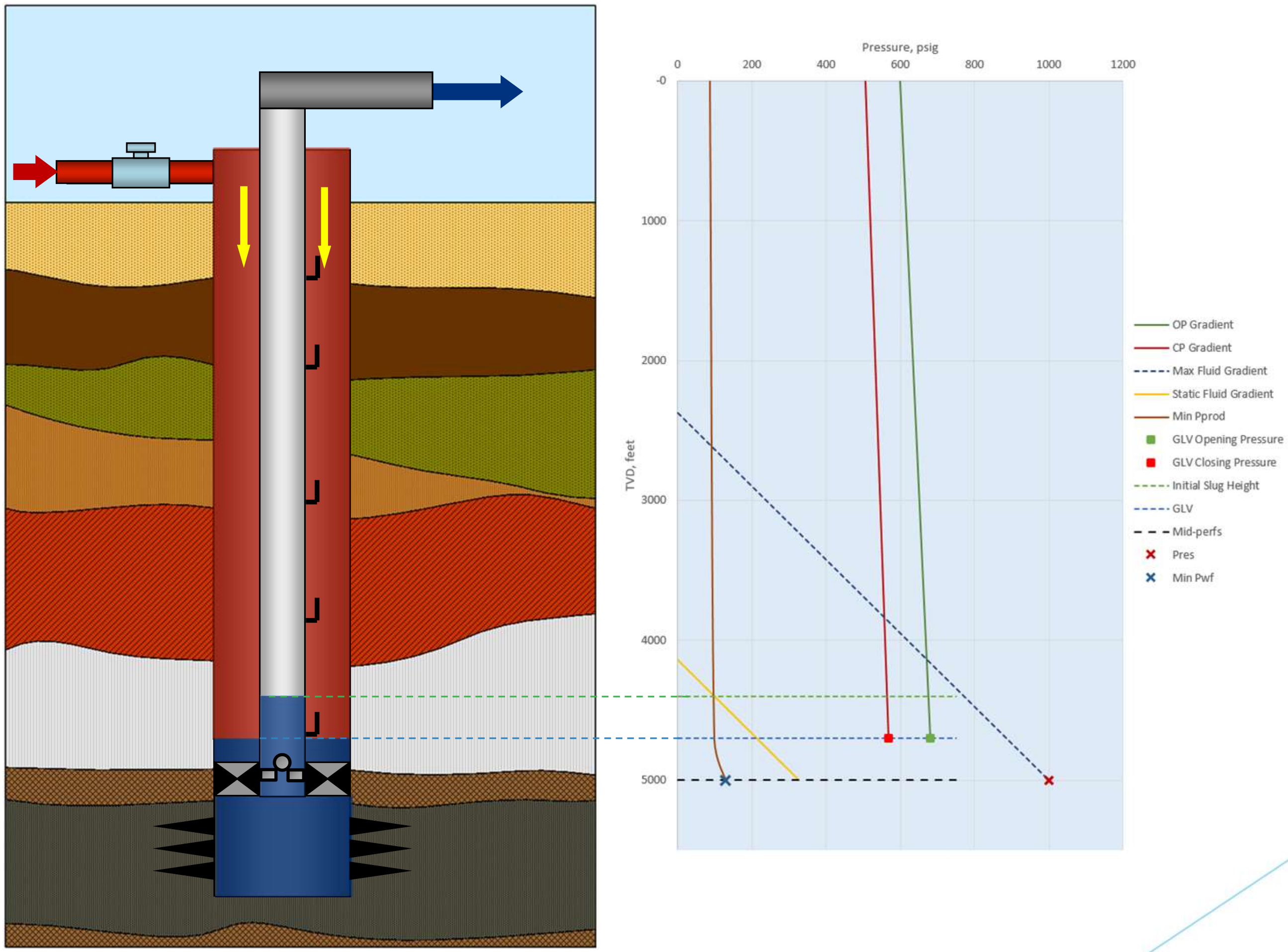
- **Fallback occurs through two mechanisms:**
  - 1. The lift gas rises quicker than the fluid it is pushing, which can cause the formation of fluid droplets that may drop back down the tubing.
  - 2. Fluid can cling to the tubing walls, and start to slide back down the well.
- **As little as 30% of the original fluid slug may actually be produced at the surface.**
  - Therefore, the success of IGL depends upon the control of fallback. However, recovery rates must also be balanced against operational costs, so a good IGL design is essential.

Intermittent GL Basics



Pilot Valve - Basics

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Pilot Valve Benefits

- Drawdown to ~500# +/- 100# @ 9,700' at 60° in a horizontal, 100' from TVD
- No issues with gas kick handling from horizontal
- Less susceptible to sand/solids catastrophic failures
- Cheap installation/repair ~$15k to $65k

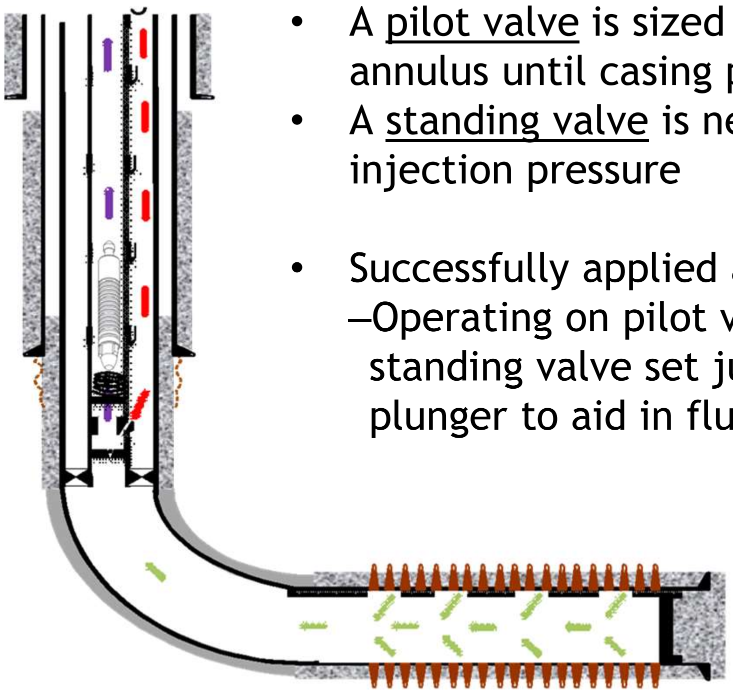
Pilot Valve Drawbacks / Constraints

- Susceptible to paraffin - If plunger not utilized
- Surveillance is more difficult vs continuous gas lift operations
- Valve **will** fail and need to be replaced ~6 mo – 1 yr (Need a good SL crew & clean tbg)
- Design range is <150 bfpd - Above this, conventionally gas lift

Pilot Valve - Basics

Intermittent Lift

- Gas periodically injected at a single deep point in the tubing
- Tubing liquid load produced by gas slug expansion



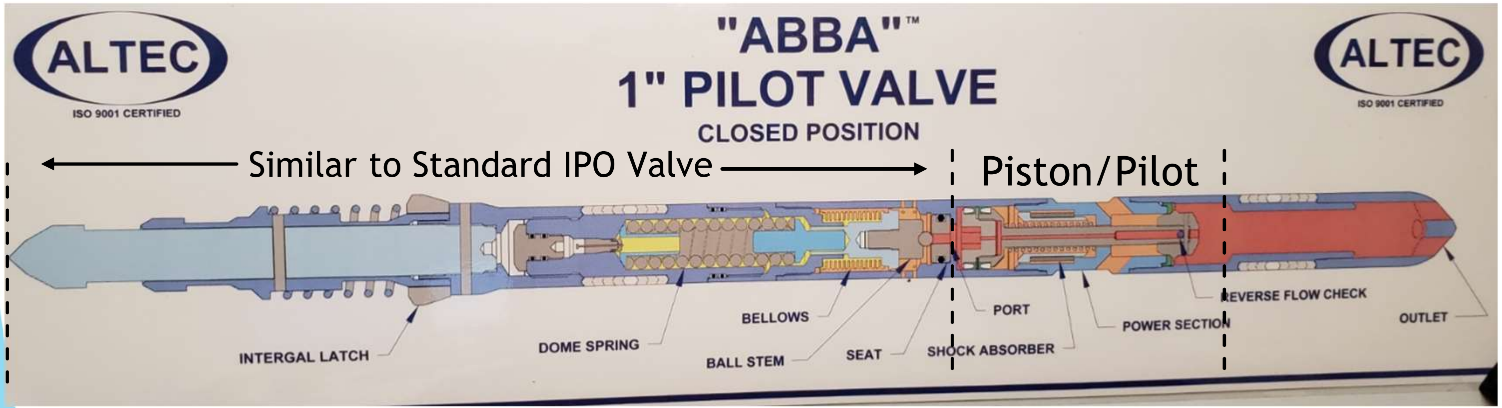
- A pilot valve is sized to allow the rapid injection of gas compressed in the annulus until casing pressure drops and the valve closes
- A standing valve is necessary to prevent the reservoir exposure to injection pressure

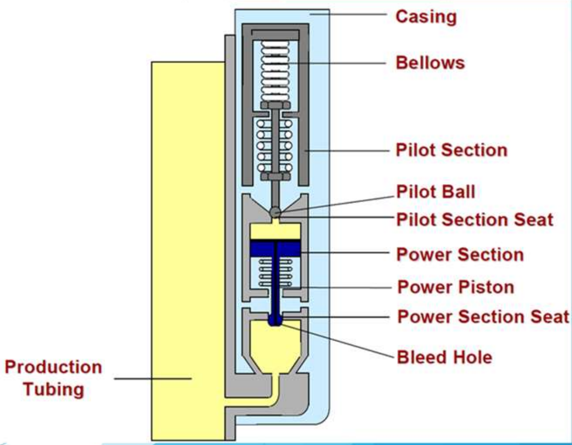
- Successfully applied as Intermittent Lift and Gas Assisted Plunger Lift:
  – Operating on pilot valve in side-pocket mandrel, packer loaded with standing valve set just above kickoff point, both with and without plunger to aid in fluid fallback and paraffin

Pilot Valve - Basics

Pilot Valve Function

- The valve opening / closing mechanics follow the same equations as a standard Injection Pressure Operated valve.
- The principal difference is the piston which actuates allowing the casing to blown down rapidly.





Pilot Valve - Basics

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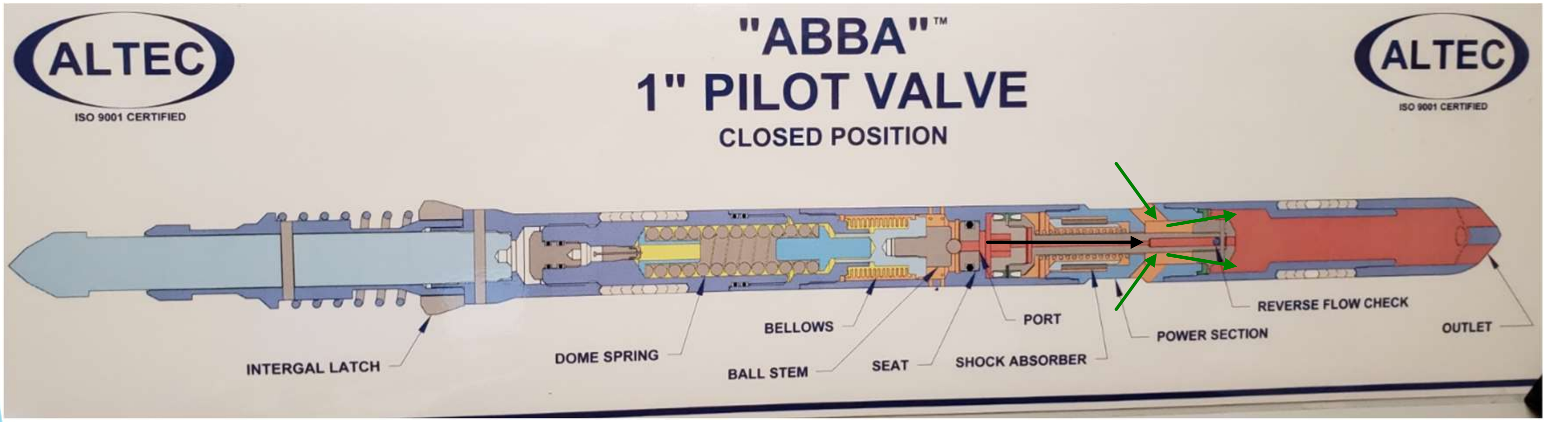
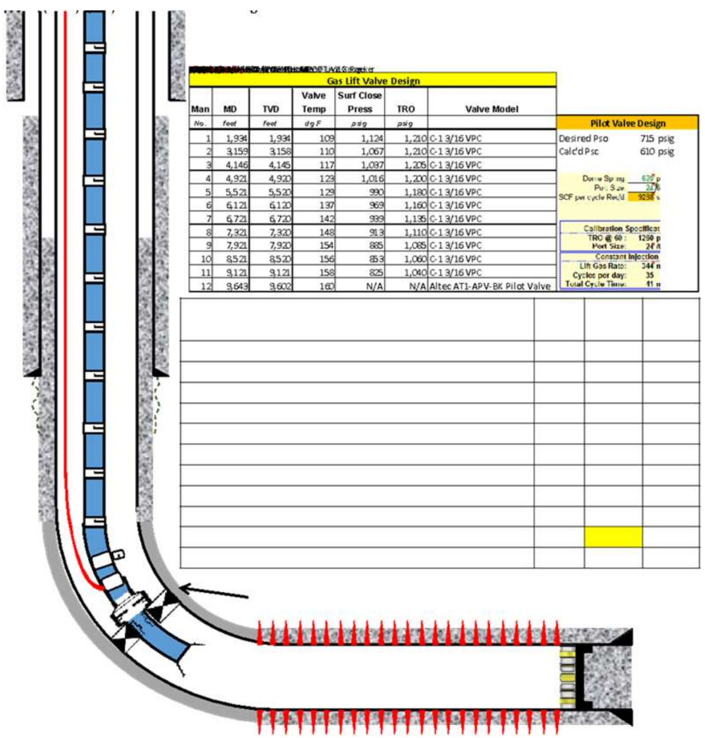
Pilot Valve Function

- Valve opens ball off of seat
- Gas flow through small port shifts Piston open
- Casing gas surges through ports exposed by shifted piston



Pilot Valve – Wellbore Diagram Example



Gas Lift Valve Design

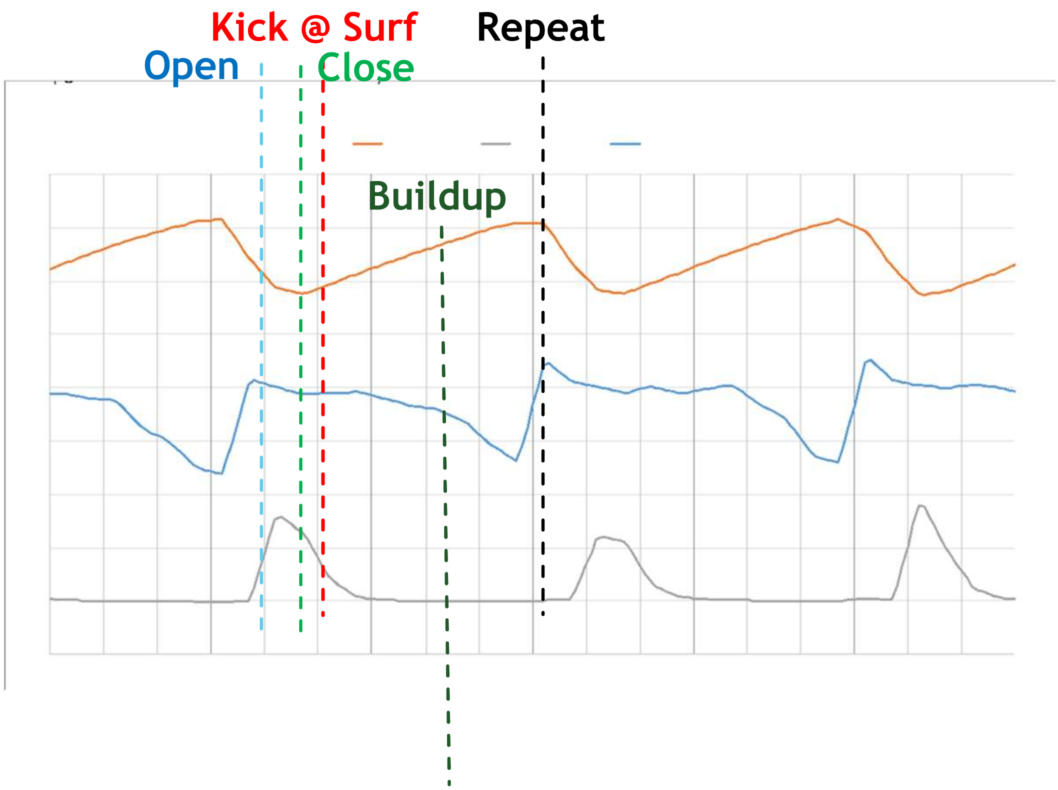
Man No.	MD feet	TVD feet	Valve Temp dg F	Surf Close Press psig	TRO psig	Valve Model
1	1,934	1,934	109	1,124	1,210	C-1 3/16 VPC
2	3,159	3,158	110	1,067	1,210	C-1 3/16 VPC
3	4,146	4,145	117	1,037	1,205	C-1 3/16 VPC
4	4,921	4,920	123	1,016	1,200	C-1 3/16 VPC
5	5,521	5,520	129	990	1,180	C-1 3/16 VPC
6	6,121	6,120	137	969	1,160	C-1 3/16 VPC
7	6,721	6,720	142	939	1,135	C-1 3/16 VPC
8	7,321	7,320	148	913	1,110	C-1 3/16 VPC
9	7,921	7,920	154	885	1,085	C-1 3/16 VPC
10	8,521	8,520	156	853	1,060	C-1 3/16 VPC
11	9,121	9,121	158	825	1,040	C-1 3/16 VPC
12	9,643	9,602	160	N/A	N/A	Altec AT1-APV-BK Pilot Valve

An intermittent lifted pilot gas lift well is identical to a standard gas lifted well, save for replacing the orifice in the bottom side pocket mandrel with the pilot valve and installing a standing valve

Typical operations:

- Set the pkr/pilot valve down in the curve between 45 – 60 degrees, close to TVD
- Run 2-3/8” packer if possible (OD vs Drift)
- Utilize a pump out plug (vs. a blanking plug)
- Install profile nipples for future BHA
- Run a SPM so we can SL retrieve Pilot/Orifice
- Provide short jt depths for correlation
- Utilize Pilot Valves & associated BHA
- Run unloading valves
- Plungers as needed for paraffin, slug recovery

Pilot Valve Operation - Cycle Process



Pilot Valve Operation – Unloading to Valve

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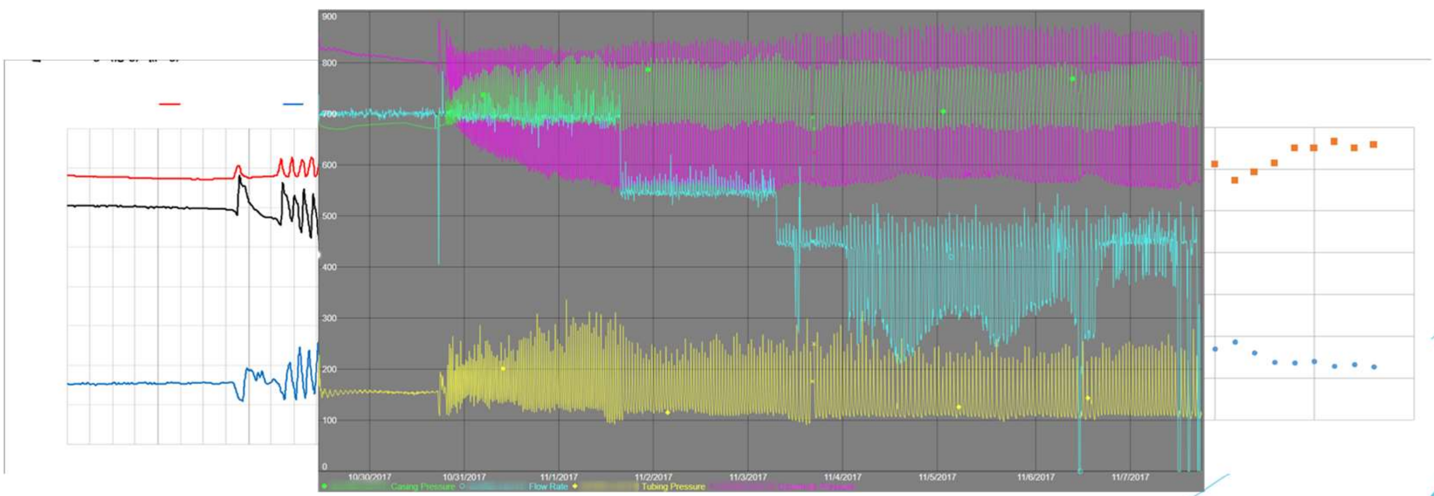
Pilot Unloading Process

- Valve unloading process is normal down to pilot, with the pilot functioning as an **orifice until Pilot closing casing pressure achieved**
- You should then see the pilot close, and then actuate, with a small spread
- The pilot should continue to actuate, with the **spread growing** as the tubing load above the pilot is reduced, until the design spread is achieved
- We recommend you operate the well with a **high initial gas lift rate**, and **then step down the rate**, as shown below, once pilot action has been maintained and desired spread is achieved. This should help to ensure you draw down the well to Psc, but don't excessively cycle your pilot



Pilot Valve Design - Equations

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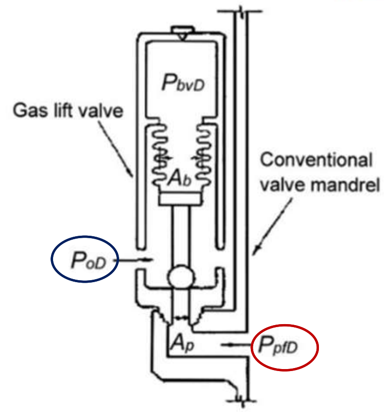
Initial opening pressure in a well

(Fig. 8c) Closing force = opening forces.

$$P_{bvD(n)}(A_b) = P_{oD(n)}(A_b - A_p) + P_{pfD(n)}(A_p) \text{ ....(7)}$$

$$P_{bvD(n)} = P_{oD(n)}(1 - A_p / A_b) + P_{pfD(n)}(A_p / A_b) \text{ ....(8)}$$



So open = fn (P_{bv}, Port, P_{pfD}) (* & temp affect)

Valve closing pressure in a well

P_{bvd} (A_b) = P_{oD} (A_b)

P_{bvd} = P_{oD} *(remember these are at depth)*

So close = fn (P_{bv}) (* & temp affect)

Spread

Spread = $P_{so} - P_{sc}$ = *fn (Port,* P_{bv}, P_{pfD}*)*

Cycle Gas Vol = fn (Spread, Annulus Cap)

$$\frac{P_{kick}}{P_{atm}} = z * \frac{V_{kick} * Tkick}{V_{atm} * T_{atm}}$$

Valve	Bellows (A_b)	Port	Port Diam	Port (A_p)	A_p/A_b	$1-(A_p/A_b)$	TEF $A_p/A_b \div (1-A_p/A_b)$
	in²	64ths in	in	in²	-	-	-
C-1	0.31	8	1/8	0.013	0.043	0.957	0.045
C-1	0.31	10	5/32	0.021	0.067	0.933	0.071
C-1	0.31	12	3/16	0.029	0.095	0.905	0.105
C-1	0.31	16	1/4	0.051	0.166	0.834	0.199
C-1	0.31	20	5/16	0.080	0.257	0.743	0.346
C-1	0.31	24	3/8	0.114	0.368	0.632	0.582

0.006 lapped seat adjustment

http://petrowiki.org/Gas_lift_valve_mechanics

**Note: These equations ignore the dome spring Altec utilizes*

Pilot Valve Design - Considerations

1) Control for Surface Closing Pressure (P_{sc} & P_{bvD})

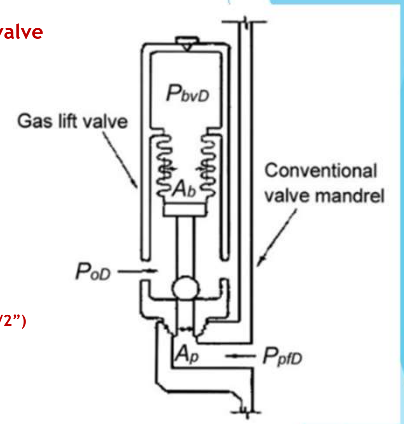
So as to not get stuck as an orifice, the valve must be allowed to close, hence, **$P_{bvD} > P_{min\ fbhp\ @\ valve}$**

2) Control for Surface Opening Pressure (P_{SO} < $P_{sc\ 1\ valve\ up}$ less 50 to 100 #)

So as to not get stuck operating on the unloading valve above the pilot valve

3) Control for Casing Pressure Spread (P_{so} - P_{sc})

Spread must displace the tbg volume. A **normal dP =~ 90-120# (for 2-7/8" x 5-1/2") & ~50-90# (for 2-3/8" x 5-1/2")**



4) Control for Port Size

For a fixed P_{bvD}, and an estimated column of liquid prior to each kick, the control we have for spread is the TEF (**port size**).
If we decrease port size, tbg has less effect, csg will open sooner – less spread – less mcf per kick & vice versa, increasing port size will increase the spread and resulting gas blown down in the csg to the tbg

Pilot Valve Design – Pso & Psc Examples

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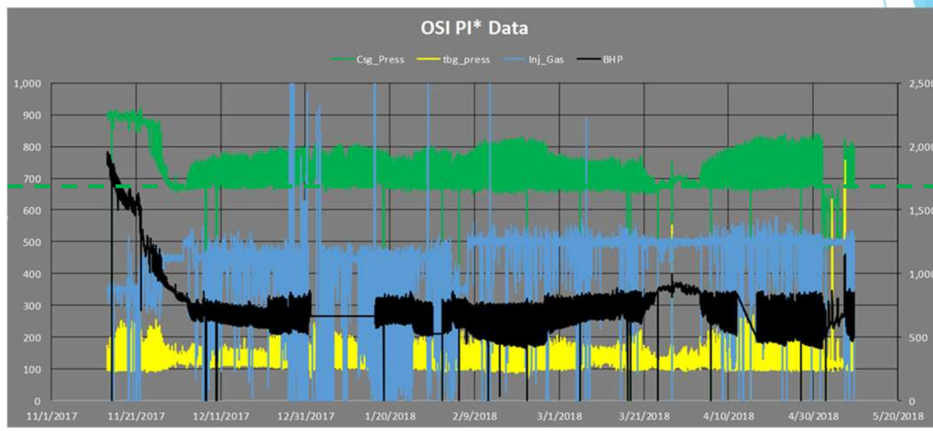
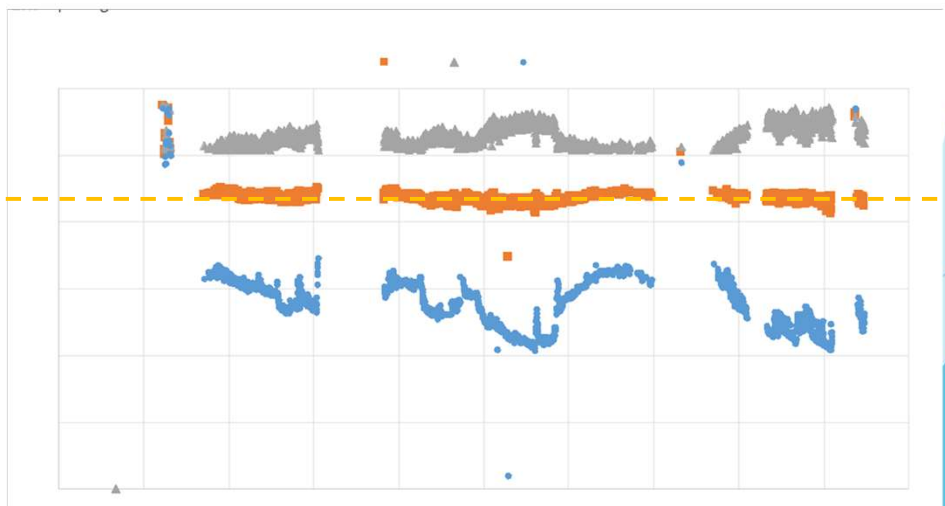
Fixed Closing Pressure (P_{sc})

$P_{csg\ close\ @\ depth}$ = 918#
Design = 832# ; delta 85#





Fixed Opening Pressure ($P_{bv\ @\ Depth}$)

As load comes up, P_{so} comes down,
Obeying the gas lift valve equations
$P_{csg\ open\ @\ depth}$ = 1,060#
Design = 1,009# ; delta 51#

Pilot Valve Design – Column Load

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Max Theoretical Tubing Liquid Column above Pilot Load (Injection Pressure Limitation) (70% factor for crit. velocity)

$$Max\ Liquid\ Head\ (ft) = \mathbf{70\%} * \frac{\left(\boldsymbol{Injection\ Pressure\ @\ Depth} - (Tubing\ Press\ +\ Orifice\ Depth\ *\ Gas\ Grad)\right)}{Reservoir\ Grad}$$

Estimated Tubing Liquid Column above Pilot (Reservoir Limitation)

$$Estimated\ Liquid\ Head\ (ft) = \frac{\boldsymbol{FBHP\ @\ Orifice}\ - (Tubing\ Press + Orifice\ Depth\ * Gas\ Grad)}{Reservoir\ Grad}$$

You should QC that the estimated liquid column does not exceed the max column from your design pressure

Pilot Valve Design

Inputs | ~Variable Inputs | Design Inputs

Critical Outputs

1.00" PILOT VALVE DESIGN SHEET

Date: 28-Sep-17

Pilot valve TVD:	9650	feet	Oil Gradient:	0.353	psi/foot
Pilot valve MD:	9714	feet	Water Gradient:	0.455	psi/foot
Mid Perforation TVD:	9730	feet	Mixed Gradient:	0.419	psi/foot
Est. mid perfs SBHP.:	700	psig			
Desired P_{SO}:	715	psig	Calculated P_{SC}:	595	psig
Ambient Temp.:	80	deg F			
Therm. Grad	0.0084	oF/FT.			
W/H Liftgas temp:	80	deg F			
Net oil test rate:	21	bbls/d	Calculated Gross per day:	60	bbls/d
WHBP (static)	150	psig	Barrel per cycle:	3.67	bbls
Gas Gravity:	0.82				
Oil Gravity:	42.0	API	Tubing Load:	666	psi @ valve depth
Water spec. Gravity:	1.05		Pc at valve depth:	1,009	Pso @D
BS&W	65%	%	Rec. max load:	706	70% of max load
Percent Fallback	5%	per 1000'	Tbg load using SBHP:	666	psig @ orifice
Casing O.D.:	5.5	inches	Annulus capacity:	0.01522	bbls/foot
Casing I.D.:	4.892	inches	Tubing Capacity:	0.00579	bbls/foot
Tubing O.D.:	2.875	inches			
Tubing I.D.:	2.441	inches	Temp. at P.V.	161	deg F
			Temp. at Mid Perfs:	162	deg F
Dome Spring:	490	psig			
Port Size:	24	/64			
SCF per cycle Req'd:	8829	scf	Calc'd for specified port size:	11197	scf

Calibration Specification		
TRO @ 60 :	**1220**	**psig**
Port Size:	**24**	**/64 inch**
Constant injection		
Lift Gas Rate:	**183**	**mscf/d**
Cycles per day:	**16**	
Total Cycle Time:	**88**	**minutes**

F-1	0.63416
F-2	0.36584
Effective Seat Dia.:	0.38000
Tubing effect factor:	0.577

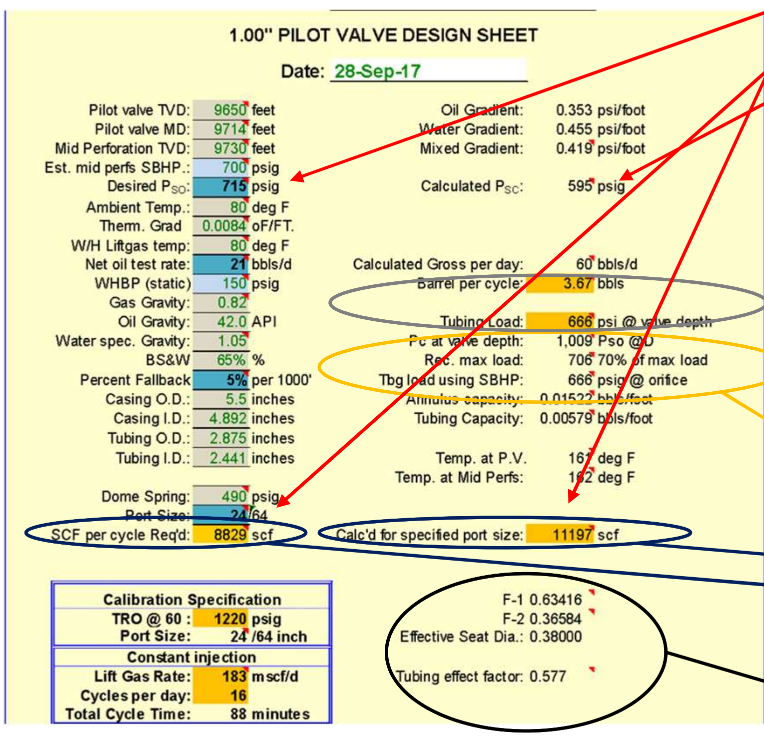
Key Parameters impacting PTRO

- Desired Pso
- Tbg Load at Pilot
- Port Size
- Backpressure
- Fallback
- Temps/Fluid Grads

Pilot Valve Design

Inputs | ~Variable Inputs | Design Inputs

Critical Outputs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Pilot valve MD:	9714	feet	Water Gradient:	0.455	psi/foot
Mid Perforation TVD:	9730	feet	Mixed Gradient:	0.419	psi/foot
Est. mid perfs SBHP.:	700	psig			
Desired P_{SO}:	715	psig	Calculated P_{SC}:	595	psig
Ambient Temp.:	80	deg F			
Therm. Grad	0.0084	oF/FT.			
W/H Liftgas temp:	80	deg F			
Net oil test rate:	21	bbls/d	Calculated Gross per day:	60	bbls/d
WHBP (static):	150	psig	Barrel per cycle:	3.67	bbls
Gas Gravity:	0.82				
Oil Gravity:	42.0	API	Tubing Load:	666	psi @ valve depth
Water spec. Gravity:	1.05		Pc at valve depth:	1,009	Pso @D
BS&W	65%	%	Rec. max load:	706	70% of max load
Percent Fallback	5%	per 1000'	Tbg load using SBHP:	666	psig @ orifice
Casing O.D.:	5.5	inches	Annulus capacity:	0.01522	bbls/foot
Casing I.D.:	4.892	inches	Tubing Capacity:	0.00579	bbls/foot
Tubing O.D.:	2.875	inches			
Tubing I.D.:	2.441	inches	Temp. at P.V.	161	deg F
			Temp. at Mid Perfs:	162	deg F
Dome Spring:	490	psig			
Port Size:	24	/64			
SCF per cycle Req'd:	8829	scf	Calc'd for specified port size:	11197	scf

Calibration Specification		
TRO @ 60 :	1220	psig
Port Size:	24	/64 inch
Constant injection		
Lift Gas Rate:	183	mscf/d
Cycles per day:	16	
Total Cycle Time:	88	minutes

F-1 0.63416
F-2 0.36584
Effective Seat Dia.: 0.38000
Tubing effect factor: 0.577

Guide

…Fill in well & reservoir data (set pilot as deep as possible)

1) Enter P_{so} w/ standoff of 50-100# from Unloading Valve
2) Vary port size until Delta csg vol sufficient to unload tbg
3) Verify P_{sc} is reasonable

Stuff to Check / Know

Bbl per kick is based off of "SBHP" & the resulting tubing load (lesser of res / lift capability) & the fallback

Head Calcs

Worst case column calcs to make sure your Csg P at depth when piloting exceeds the maximum expected fluid column above the pilot for first cycle
So good is if Rec. max load > Tbg load using SBHP.
Tbg load should not exceed Pc @ valve depth

Gas Volume Calcs

Delta Csg Vol = $V_{annulus}$ @ P_{so} - $V_{annulus}$ @ P_{sc}
Rqd SCF Vol = V_{tbg} @ $P_{Load + Backpressure}$ -> V_{tbg} @ P_{atm}
Delta Csg Vol > Rqd SCF Vol for the system to displace tbg

Tbg & Csg Pressure Scalars resulting from Valve Equations & TEF

Pilot Valve Design – What to Investigate?

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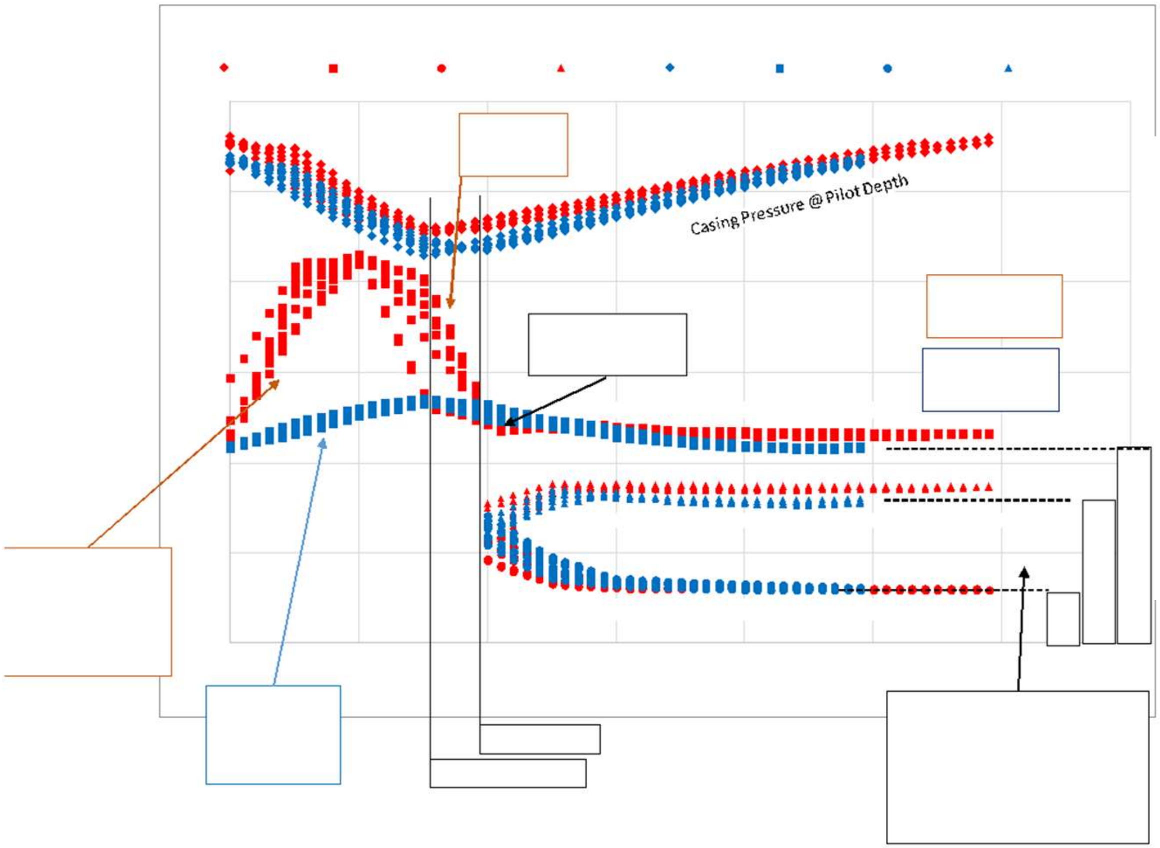
Key Parameters Impacting PTRO

- **Desired Pso - How do our operating pressures compare to the design?**
- **Tbg Load at Pilot - What loads are the valves operating against?**
- **Port Size - Do we need to run large ports?**
- **Backpressure - Is the calculated required gas volume okay?**
- **Fallback - What kind of fallback are we seeing? 2-7/8” vs 2-3/8”?**
- **Temps/Fluid Grads - Are our assumptions okay?**

Pilot Valve Parameters - Fallback

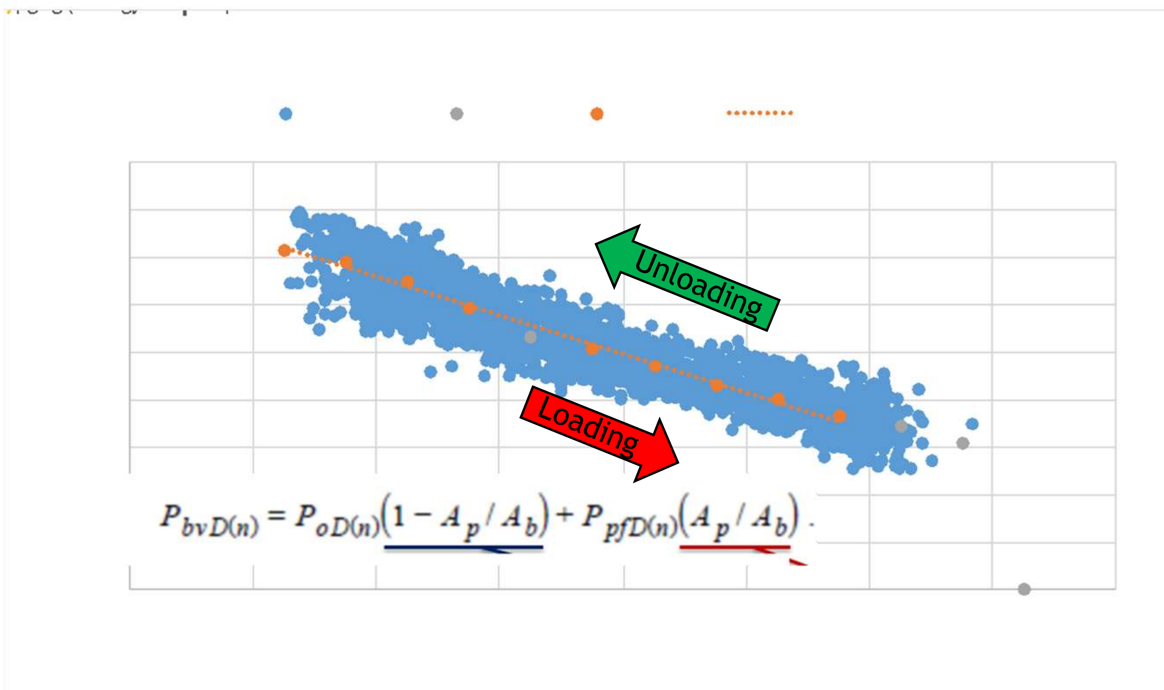


Two similar wells:
2318H w/ gauge above SV
& **2319H w/ gauge below SV**

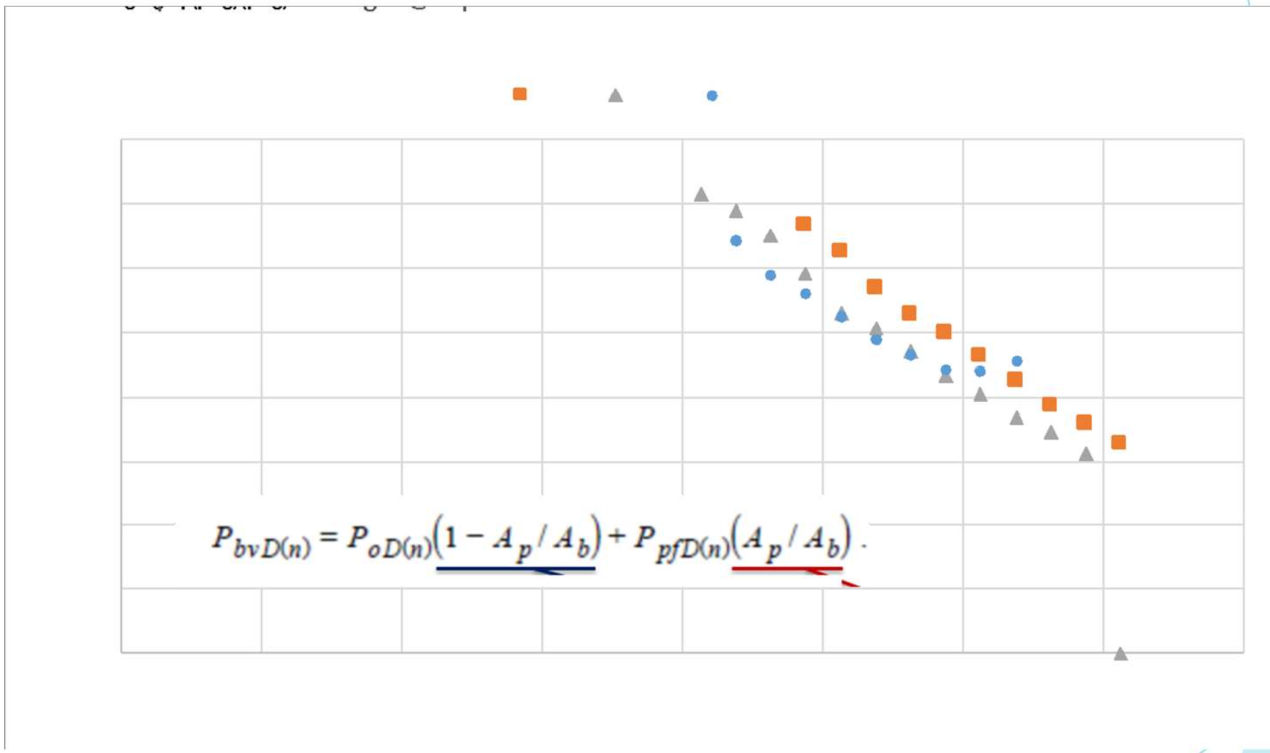
Allows us to see behavior of fluids on either side of SV during kick

Also allowed us to figure a way to **estimate fallback** for wells with gauges

Pilot Valve Parameters - Spread w.r.t. P_{tdo}

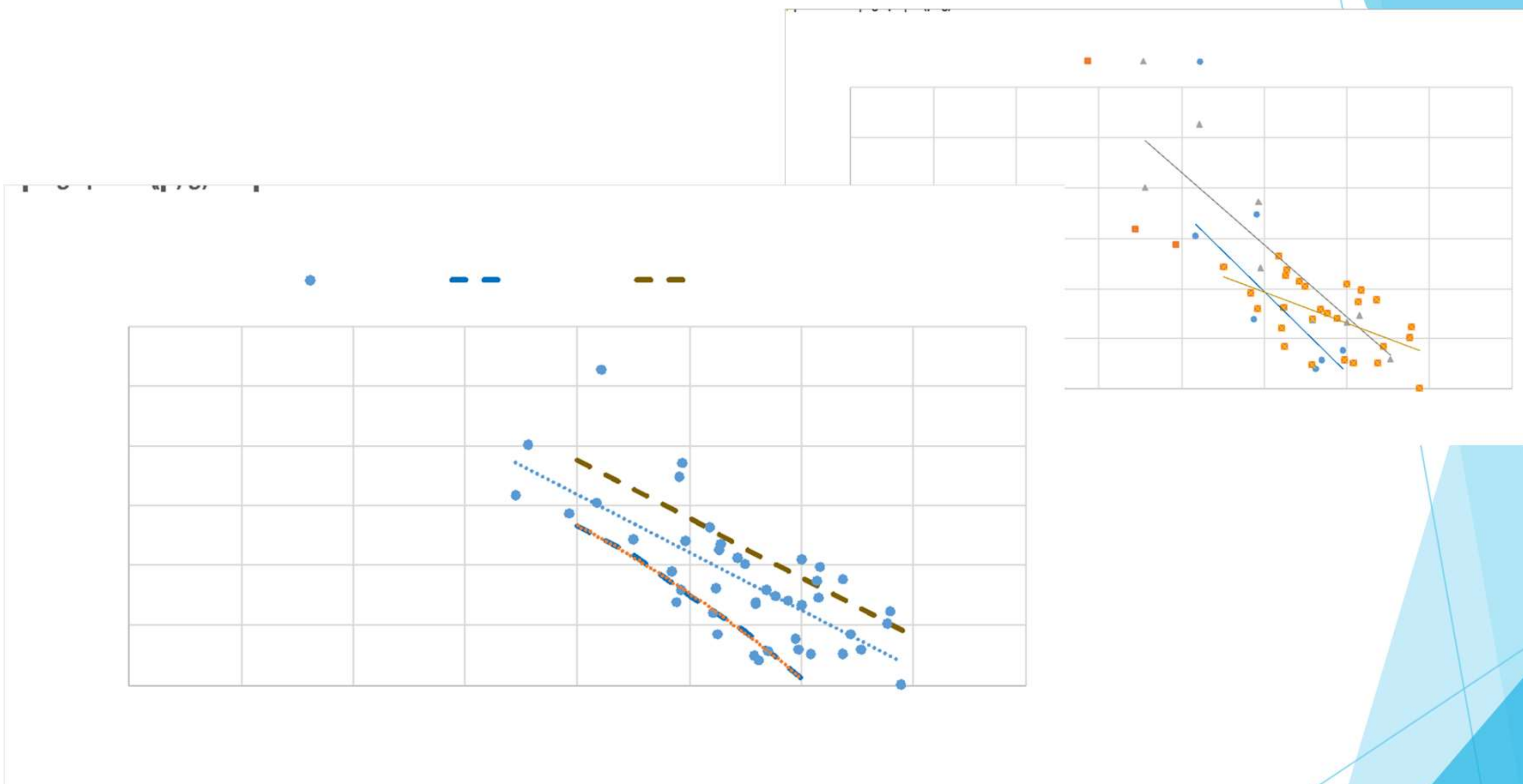


Pilot Valve Parameters - Spread w.r.t. P_{tdo}



$$P_{bvD(n)} = P_{oD(n)}\left(1 - A_p / A_b\right) + P_{pfD(n)}\left(A_p / A_b\right).$$

Pilot Valve Parameters - Fallback v Spread

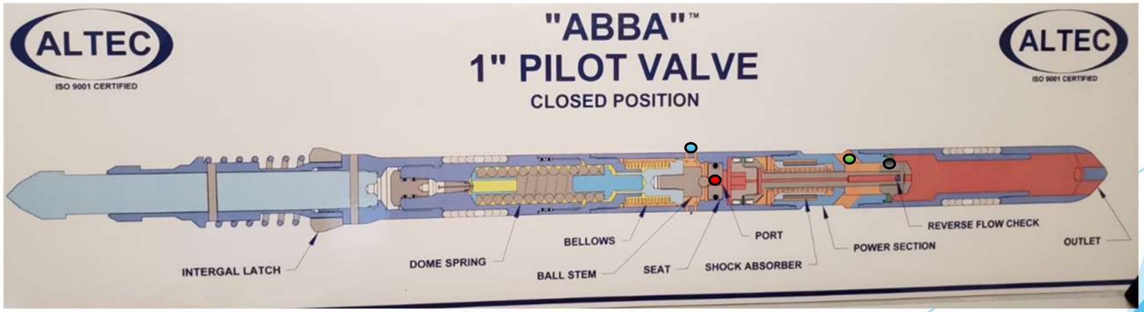


These are far less than 5% per 1,000’ = 50% ; Above 110# seeing FB below 1% per 1,000’

Pilot Valve Troubleshooting – Failure Modes

Common Failure Modes

- Design/Temperature – Occurs ~Immediately
  - Valve never pilots (Pd & Psc too low) – Acts as orifice - ~fixed 550# casing P
  - Uncontrolled Piloting (Pd/Port too high/large) – Lifts above until Ptod increases
- Trash Buildup – Occurs Randomly & Commonly
  - In Casing port - Stuck closed – Operate on above valve until you surge the well
  - In Seat - Stuck Closed (common) – Gas unable to activate piston
  - In Pilot Section ports – Reduced throughput – Greater fallback – Lower Spread
  - In Piston Seal - Sticks Open – Acts as orifice (most common) [*can also stick closed, rare]
- Fatigue – Bellows Cycles (~6 mo to 1 yr) – Predestined
- Standing Valve
  - Scale/Solids – Less/No tubing effect – Blown dry – Circulate high



Pilot Valve Troubleshooting

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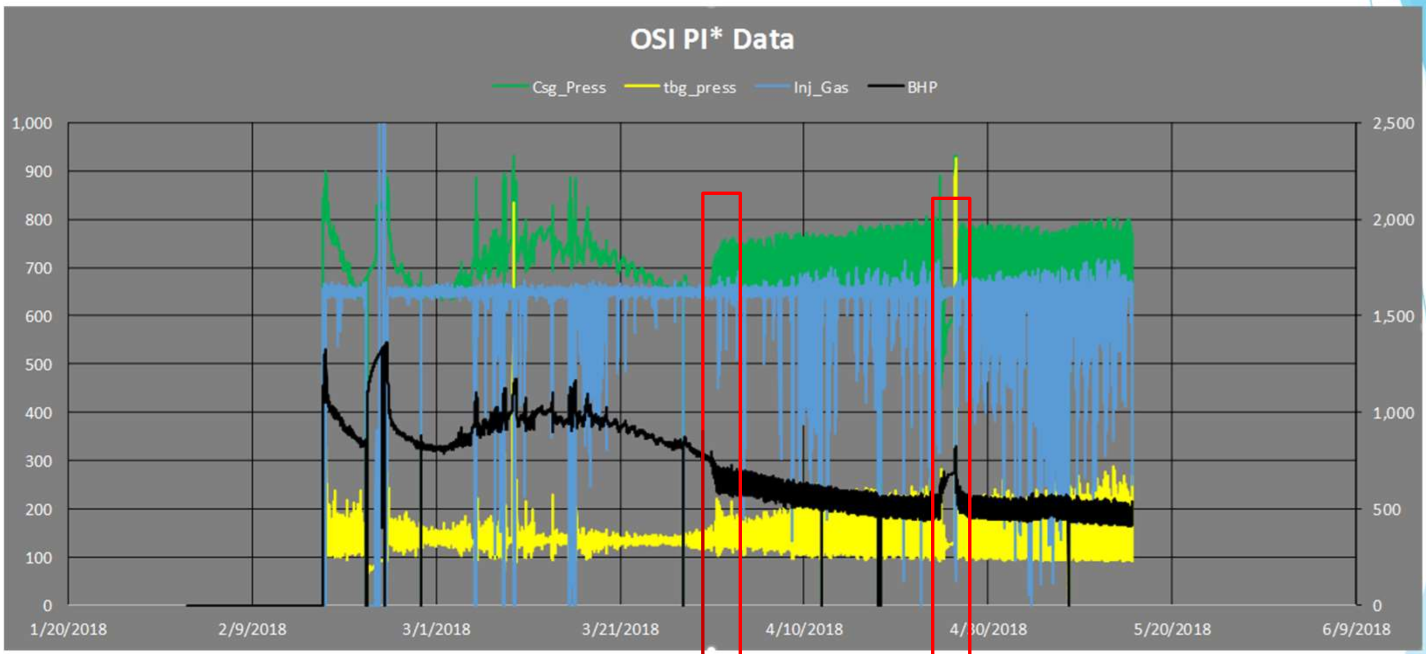
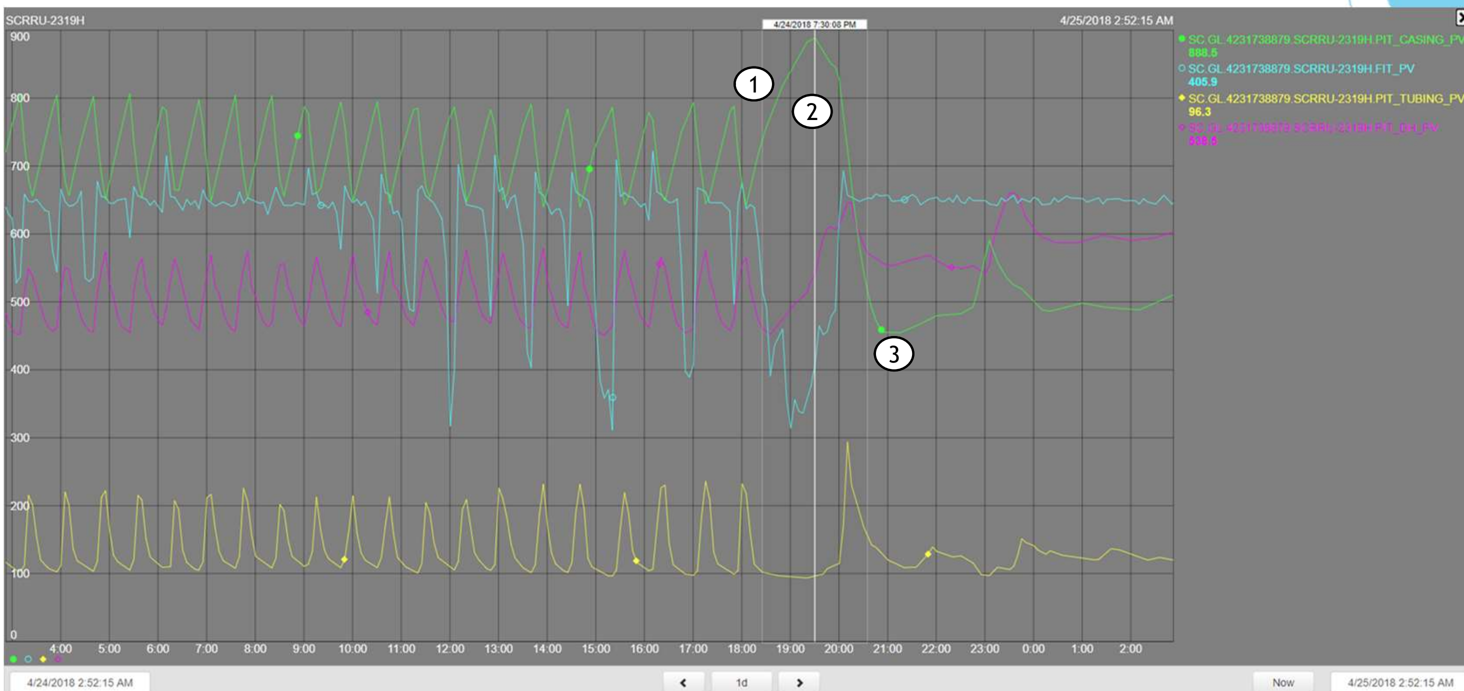


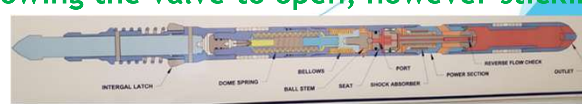
Why did it stop piloting? And how did you fix it?

Why did it start piloting at this instance?

Pilot Valve Troubleshooting



1. Valve stuck closed - Why? — Crud in the port? - Tubing load not helping valve open
2. Why open at 890#? — Junk shifted in valve, allowing the tubing to help the valve open
3. Which way is valve stuck? — Junk shifted in valve, allowing the valve to open, however sticking the piston open



Pilot Valve Troubleshooting

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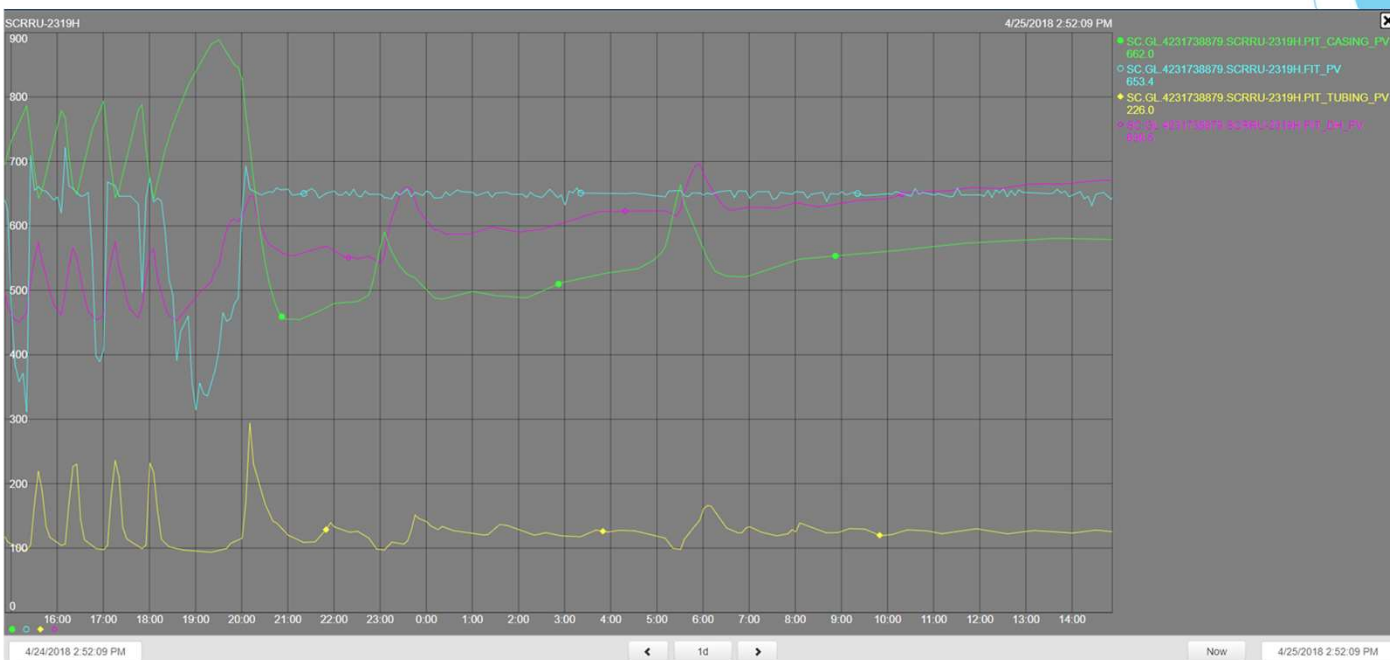
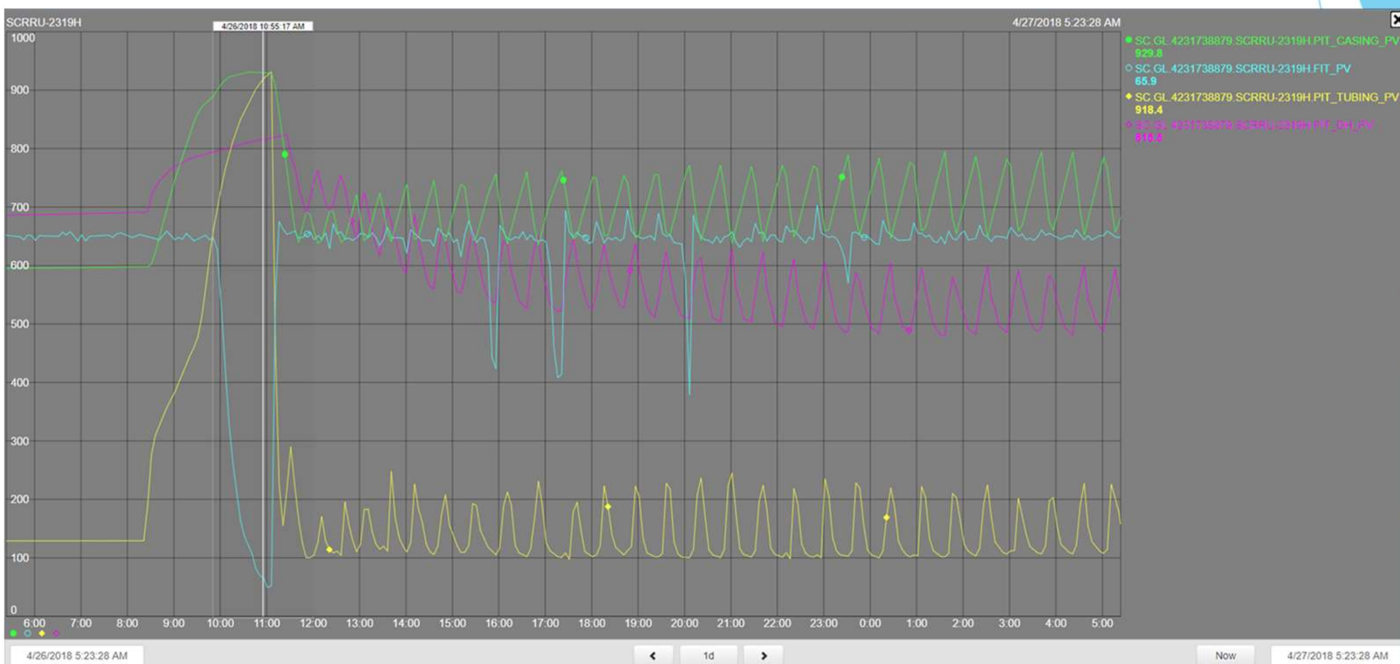


Valve stuck open - What do you do?

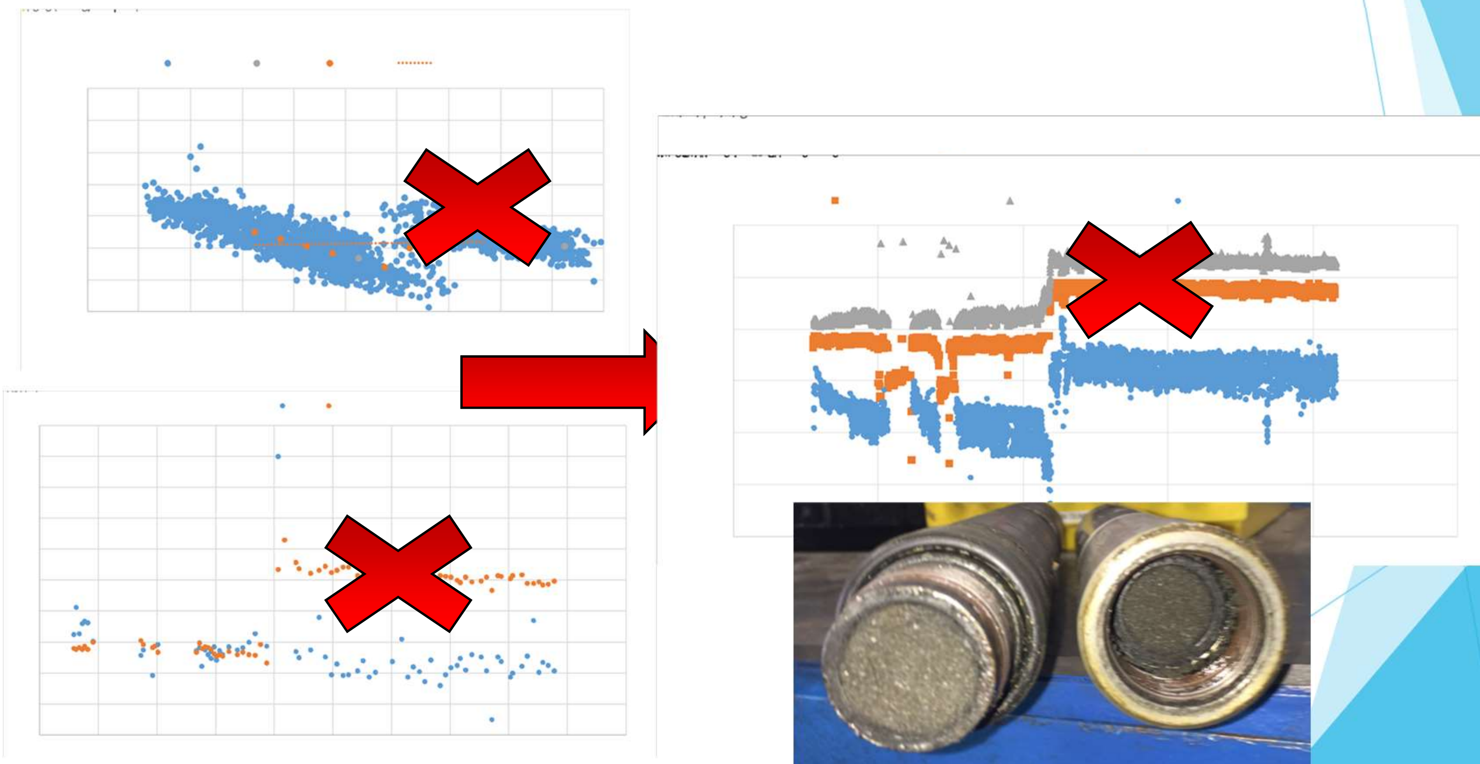
Pilot Valve Troubleshooting



Rock/Surge the well

Pilot Valve Troubleshooting – Plugging

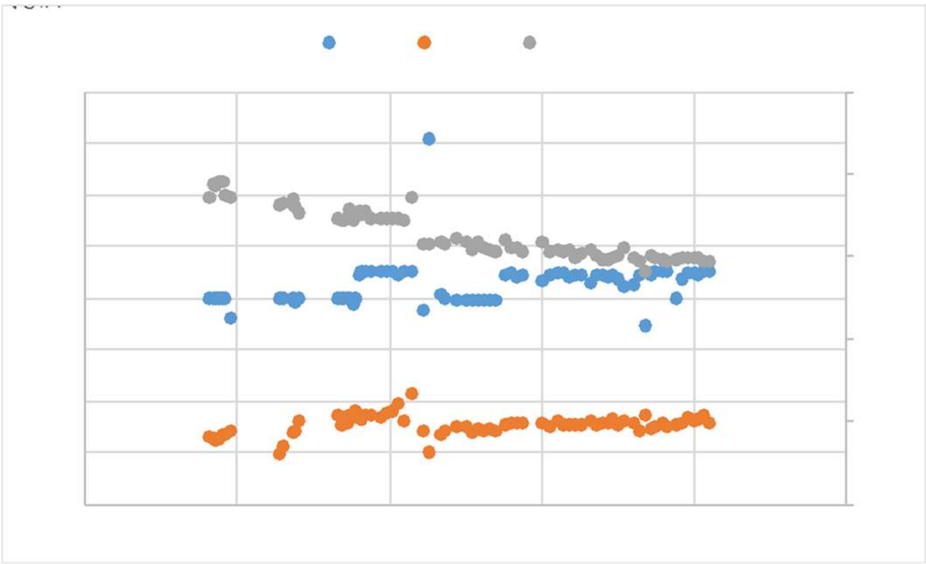
Plugging (Example Well SAU 320LH)
Realized Bellows Pressure approx. 795# initially.
Then Psc/Pso shift up, however Pso below that required for next valve above
Pso adjusted for depth * F1 equals Pb initially, and Psc appears to be a differentially stuck case
This indicates something preventing the valve from sensing the tubing load



Pilot Valve Troubleshooting – Paraffin/Solids

Paraffin/Solids

Example SAU 320 – Realized incrementally smaller kicks at surface with the same spread



Pilot Valve Design - Recommendations

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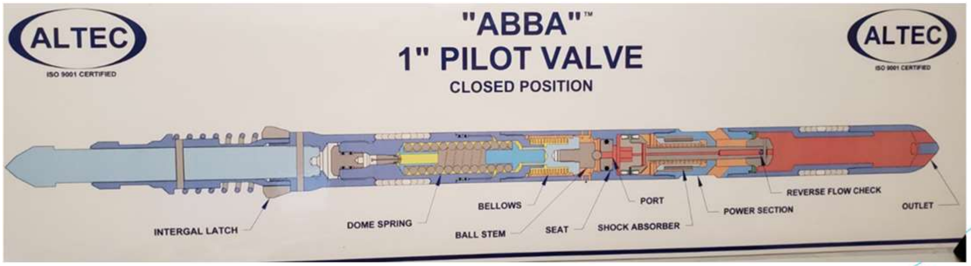
Design Recommendations

Utilize Sam's design sheet w/ Altec as your initial valve design

- **Desired Pso -** 75# less than Psc of unloading valve above
- **Tbg Load at Pilot** - ~550#
- **Port Size -** Start with 24 for 2-7/8" & 20 for 2-3/8"; test stepping down on 2nd valve design
- **Backpressure -** 175# (Function of spread)
- **Fallback -** 3% (Function of spread / tbg roughness)

Adjust PTRO & port size on second valve based upon actual Pso, Psc, bbl/kick, etc,..

			load	kickT				
			5.54	15				
design	inj rate	min	vol/cycle	FB/1000'	FB	net load	cycles	daily prod
prop. 20 port	400	30	12,000	4.00%	39%	3.39	32	108
curr. 24 port	400	50	18,000	1.00%	10%	5.00	22	111
prop. 20 port	200	60	12,000	2.50%	24%	4.19	24	101



Chamber Lift Installations

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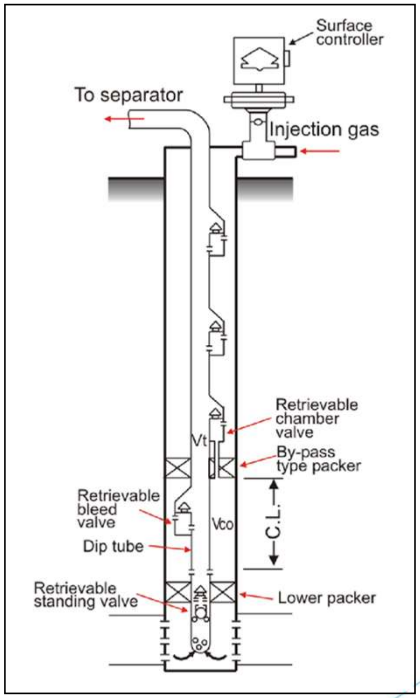
Chamber Lift

- Operation
  - Liquid enters chamber through standing valve.
  - Liquid fills the tubing and annulus of the chamber.
  - Bleed valve, or port, allows gas to vent to tubing to prevent gas lock.
  - At pre-determined time, time cycle controller opens
  - Injection pressure increases.
  - Chamber valve opens and evacuates the fluid to the tubing and lifts it to the surface.
  - Standing valve prevents fluid from flowing back into the reservoir.
  - Well stabilizes and the cycle begins again.



Insert Chamber Installation

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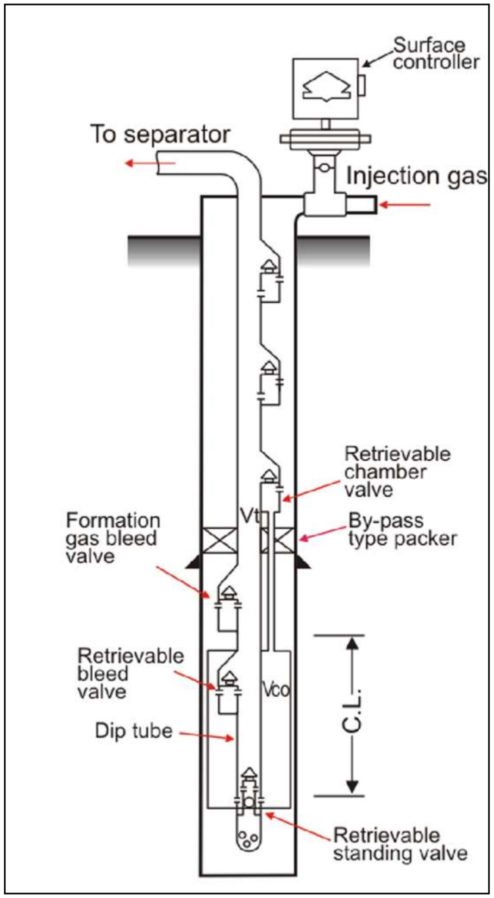

Chamber Lift in Horizontals

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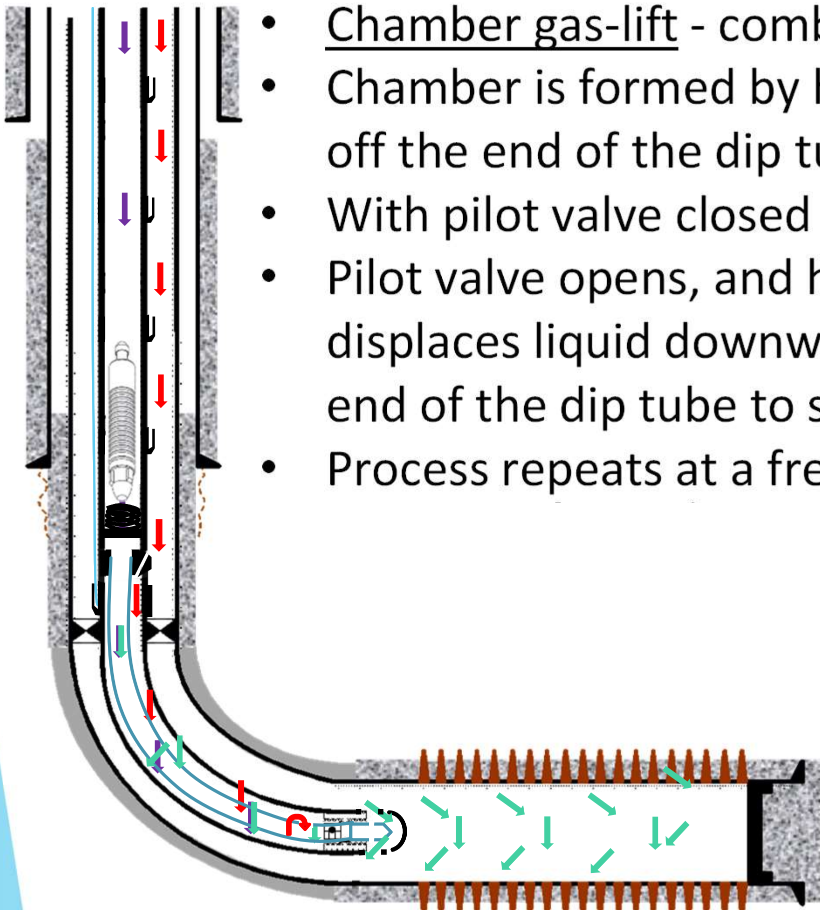
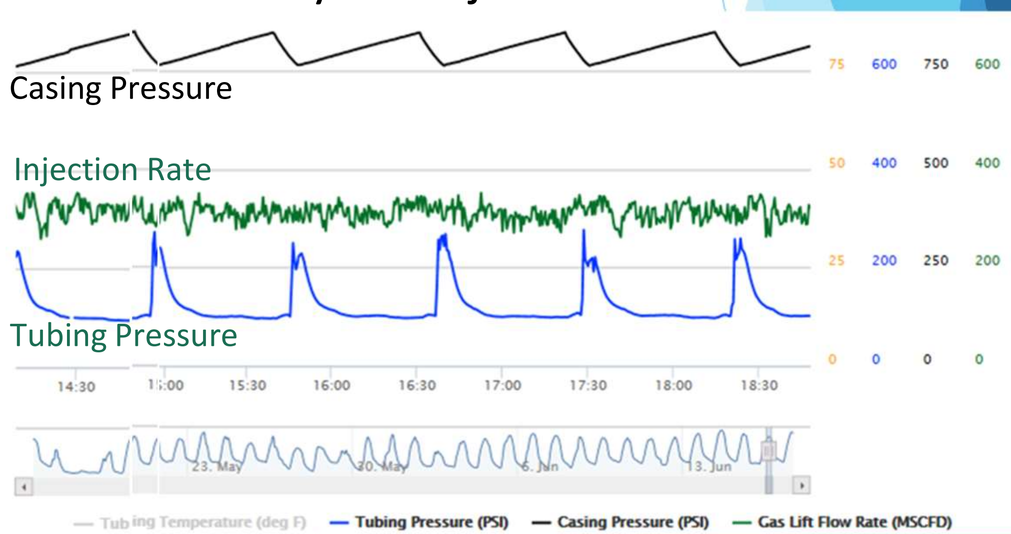
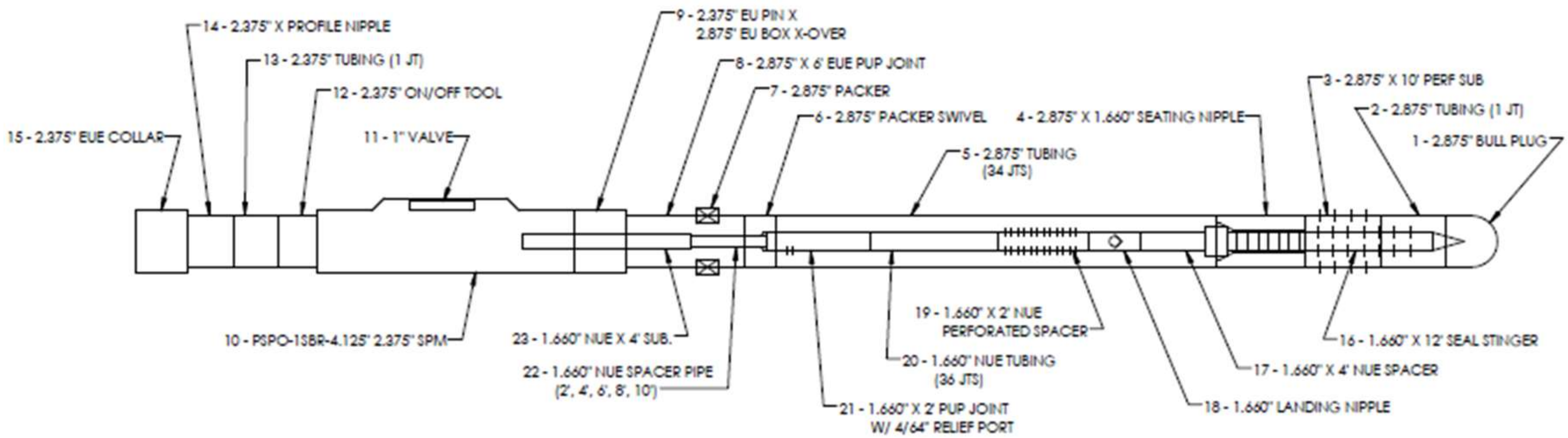
- Chamber gas-lift - combination of deep gas-lift and intermittent gas-lift
- Chamber is formed by hanging a dip tube above the injection point, and sealing off the end of the dip tube in the tail pipe with a standing valve and sealbore
- With pilot valve closed ad casing pressure building, chamber fills with liquid
- Pilot valve opens, and high-pressure gas enters the chamber annulus and displaces liquid downward, closing the standing valve. Liquid routes around the end of the dip tube to surface at high velocity
- Process repeats at a frequency determined by the injection rate





Chamber Lift in Horizontals



- See SPE 190923-PA, “Chamber Gas Lift in Horizontals”, C.N. Hardegree, B.A Gerrard, S.L. Wildman, K.S. McKenzie

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