A Life of Field Approach to Gas-Lift Design

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Agenda

- Elements of a robust life of field gas-lift design
- Input data: scenarios / cases / QA / QC & workflow
- Natural flow and gas-lifted well performance screening
- SPM depth prediction & stress testing
- IPO unloading valve status & specification
- ΔP over operating valve
- Orifice sizing for life of field
- Additional considerations
- Conclusions

Elements of a Robust Life of Field Gas-Lift Design

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- Gas-lift valve spacing that is suitable throughout the life of well
- Detailed gas-lift valve specifications that cater for the life of well
- Stable gas-lift system performance
- Optimised production whilst also considering gas-lift availability
- Robust in case of uncertain data / changing well conditions
- Eliminates (or minimises) intervention requirements for valve change-outs

- This requires:
  - Good input data
  - A running dialogue and transparency with the operator
  - Full understanding of equipment functionality and limitations

Input Data: Scenarios / Cases

- Sensitivity cases:

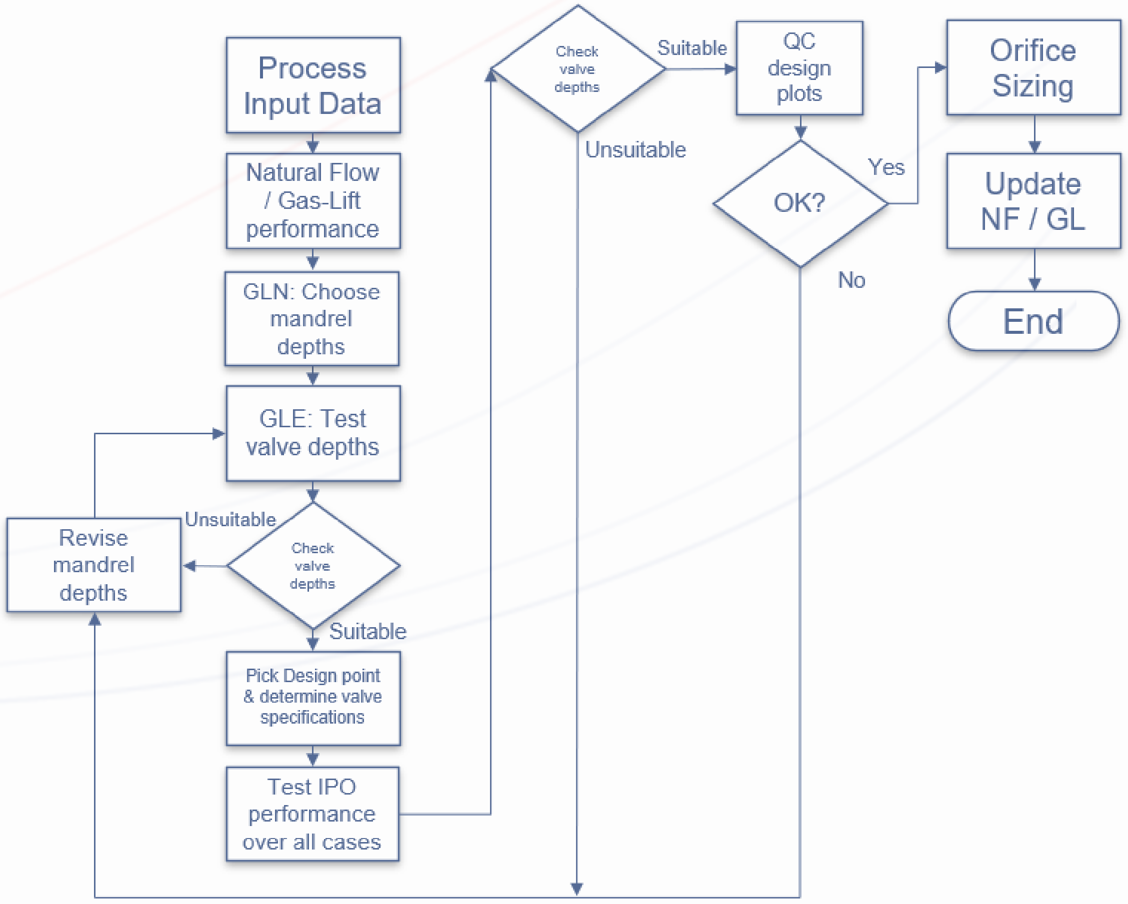
Well	Case	Pres (psig)	PI (stb/d/psi)	GOR (scf/stb)	WC (%)	Max operating liftgas available (MMscf/d)	Max liftgas available during unloading (MMscf/d)	Max Liftgas supply pressure under operating conditions (psig)	Max Liftgas supply pressure at kickoff (psig)	Lift gas SG	UTHP (psig)	FTHP (psig)
	1. Late life (Design case)		40		95							472
	2. Early life		168		0							741
	3. Mid life	3200	64		20							652
	4. Low PI/low WC (e.g. Punt only, early life)		6		0							420
	5. Low PI/high WC (e.g. Punt only, late life)		3	382	85	2.5		2030		0.68	400	334
	6. Mid life (under voidage)	2800	64		20							573
	7. Mid Life (good voidage)	3600										746
	8. Late life (under voidage)	2800	40		95							432
	9. Late life (good voidage)	3600										526

- Condensed Reservoir Simulator Profile:

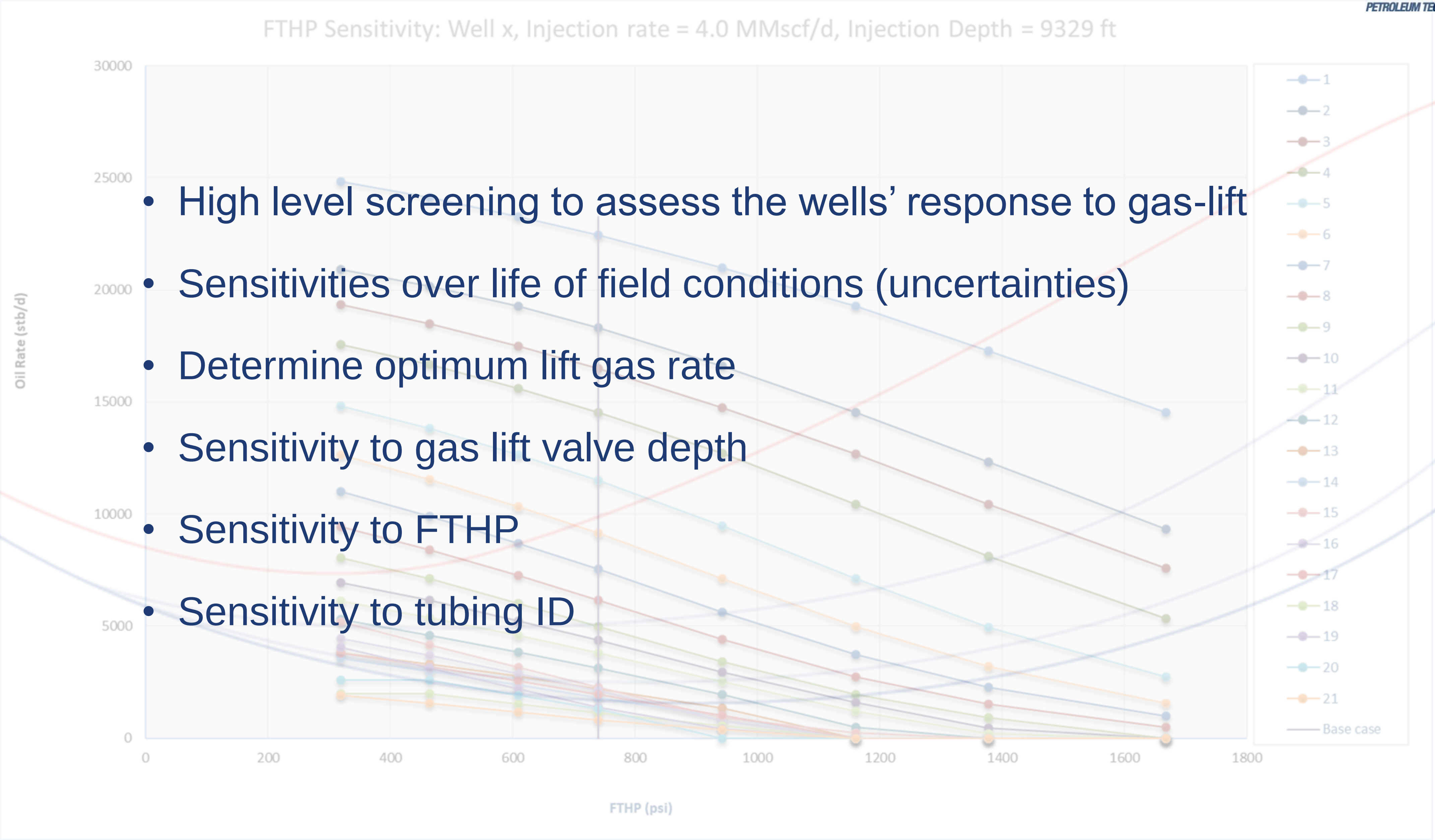
Well	Case/Date	Pres (psig)	PI (stb/d/psi)	GOR (scf/stb)	WC (%)	Max operating lift-gas available (MMscf/d)	Max lift-gas available during unloading (MMscf/d)	Max Lift-gas supply pressure under operating conditions (psig)	Max Lift-gas supply pressure at kickoff (psig)	FTHP (psig)	UTHP (psig)	Lift Gas SG	Load Fluid SG
	Jun-18	4433	54	1545						1108			
	Dec-18	4209	22	1448						1299			
	Jun-19	4048	21	1332						1157			
	Nov-19	3957	19	1272	0					1086			
	May-20	3872	17	1223						1022			
	Nov-20	3797	16	1190						973			
	May-21	3729	14	1168						936			
	Nov-21	3666	13	1151						908			
	May-22	3609	13	1154						889			
	Nov-22	3550	12	1321	0.1					893			
	May-23	3491	11	1477						900			
	Nov-23	3397	10	1853						809			
	May-24	3331	8	2056	0.3					870			
x	Nov-24	3296	7	2288	3	3	5	2176	2321	848	290	0.755	1.03
	May-25	3210	6	2680	15					774			
	Nov-25	3173		2556	20					739			
	May-26	3131		2380	28					695			
	Nov-26	3101		2219	33					662			
	May-27	3081		1990	36					619			
	Nov-27	3051		1466	41					475			
	Jun-28	3048	5	1264						475			
	Nov-25	3173		2556						739			
	May-26	3131		2380						695			
	Nov-26	3101		2219	70					662			
	May-27	3081		1990						619			
	Nov-27	3051		1466						475			
	Jun-28	3048		1264						475			

Input Data: QA / QC & Workflow

- Significance of the key gas-lift inputs:
  - Consistently achievable injection pressure (for operation and unloading / kick-off)
  - Accurate lift gas SG (any significant variation should also be considered)
  - Achievable flowing THP / unloading THP (network models useful)
  - Reservoir conditions and anticipated variation
  - Well constraints (e.g. drawdown / flow rate limits)
  - Completion constraints (e.g. ASV, DH restrictions, deviation)



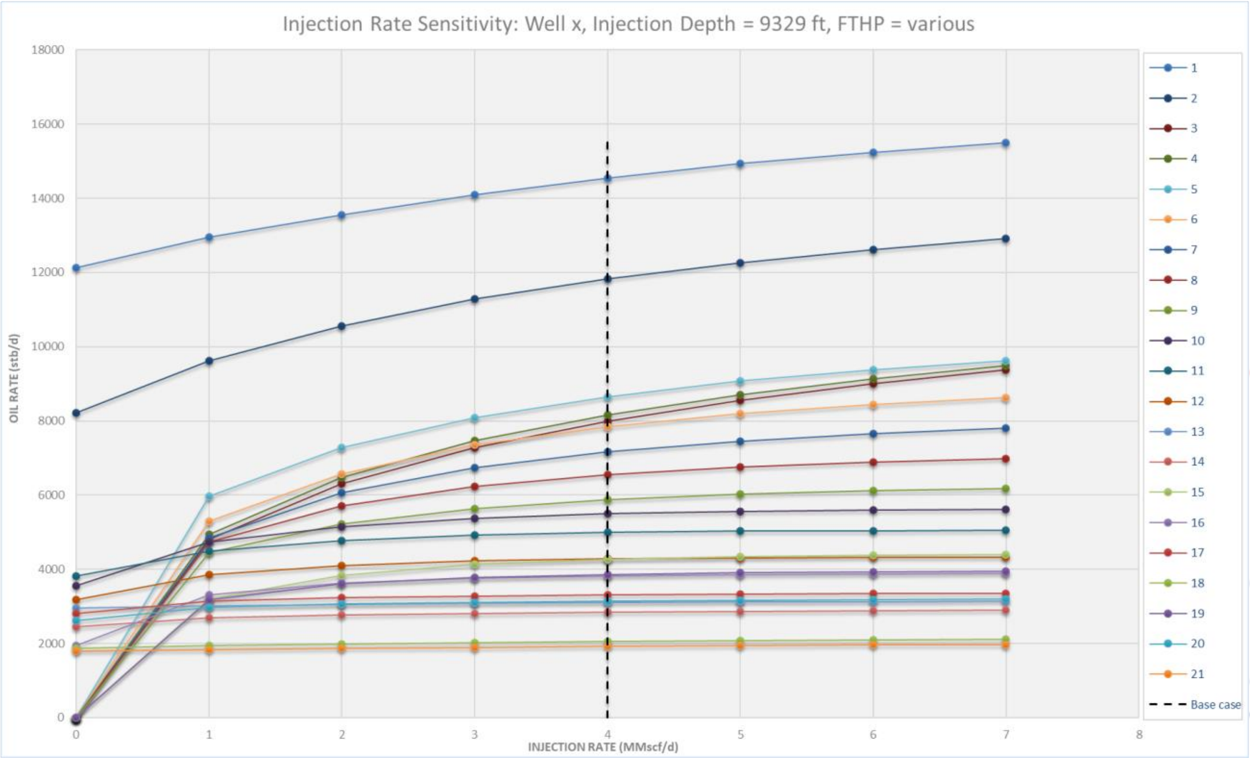
Natural flow and gas-lifted well performance screening



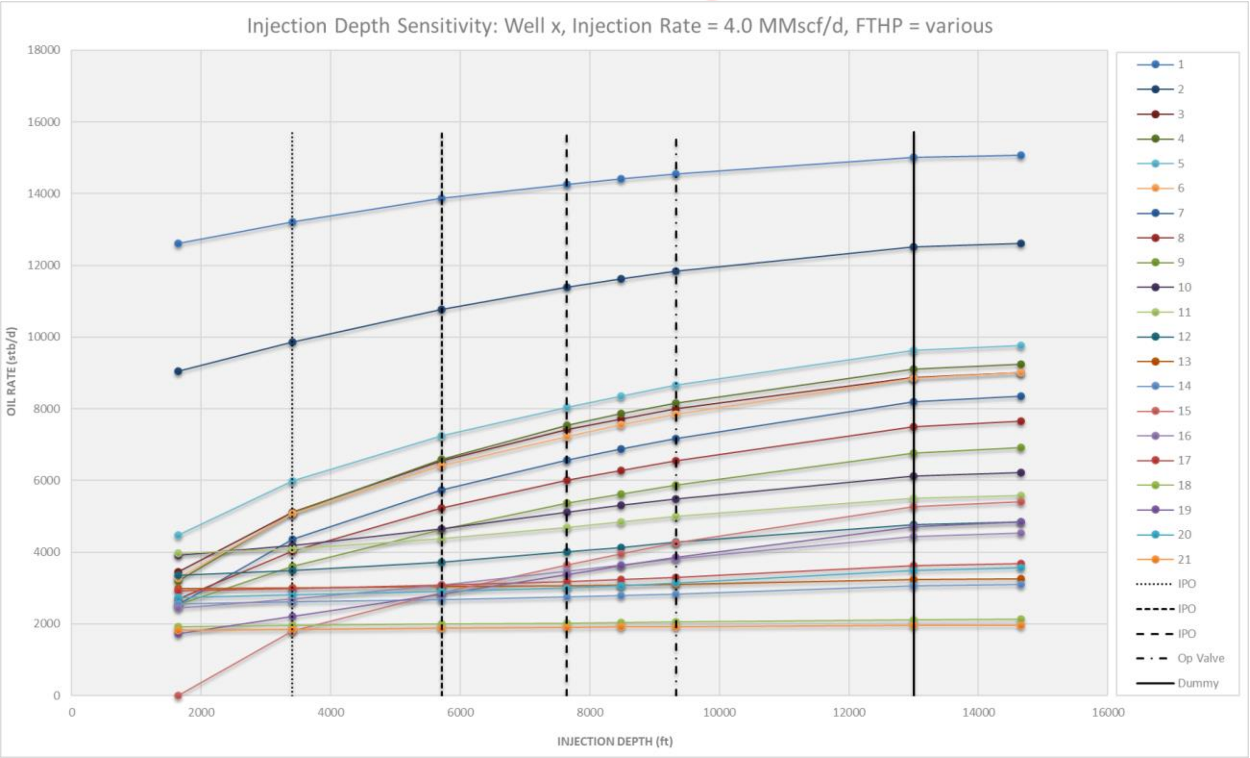
- High level screening to assess the wells' response to gas-lift
- Sensitivities over life of field conditions (uncertainties)
- Determine optimum lift gas rate
- Sensitivity to gas lift valve depth
- Sensitivity to FTHP
- Sensitivity to tubing ID

Natural Flow / Gas Lift screening

- Optimum lift gas rate for each case

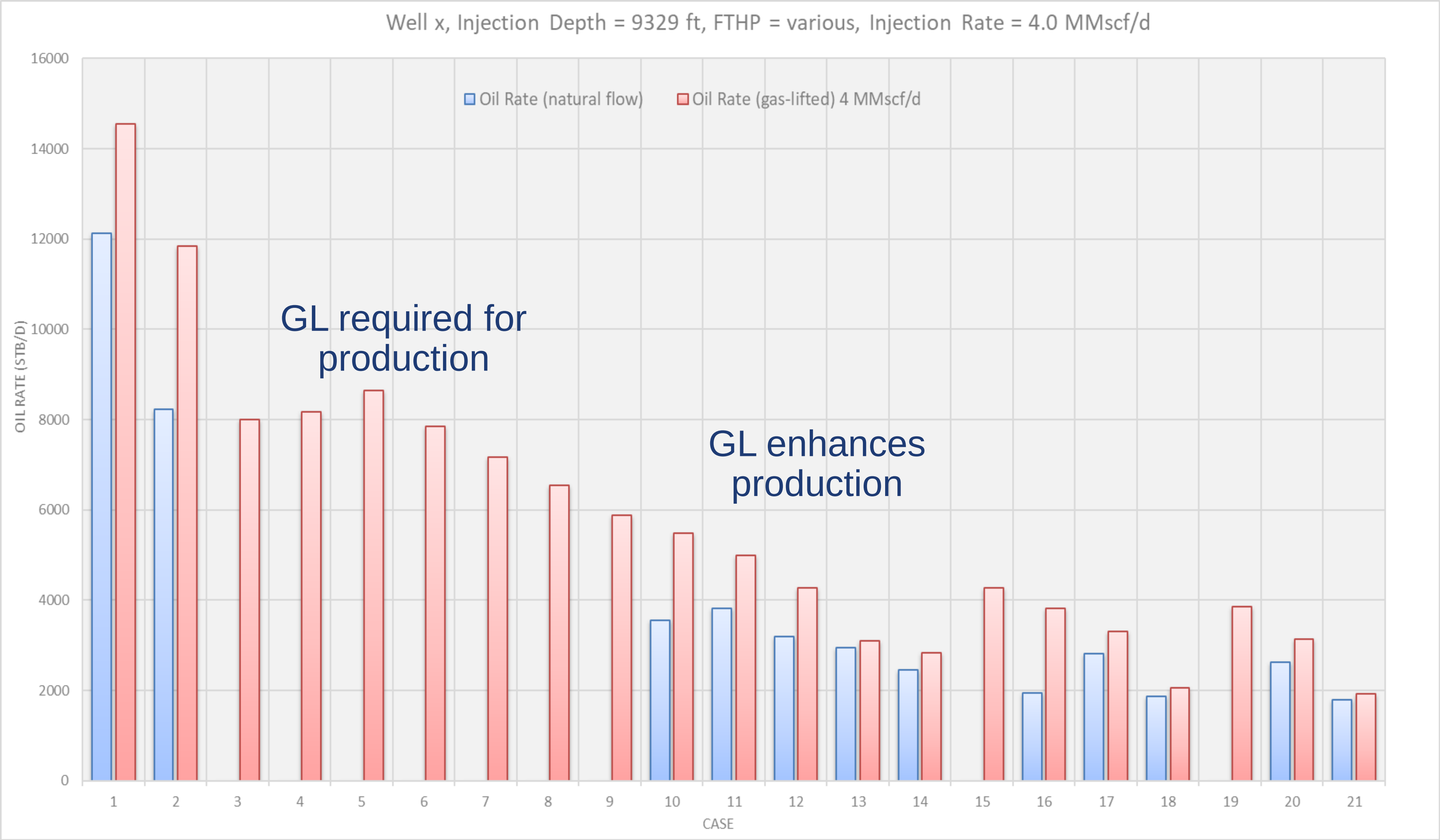


- Production sensitivity to gas lift valve depth



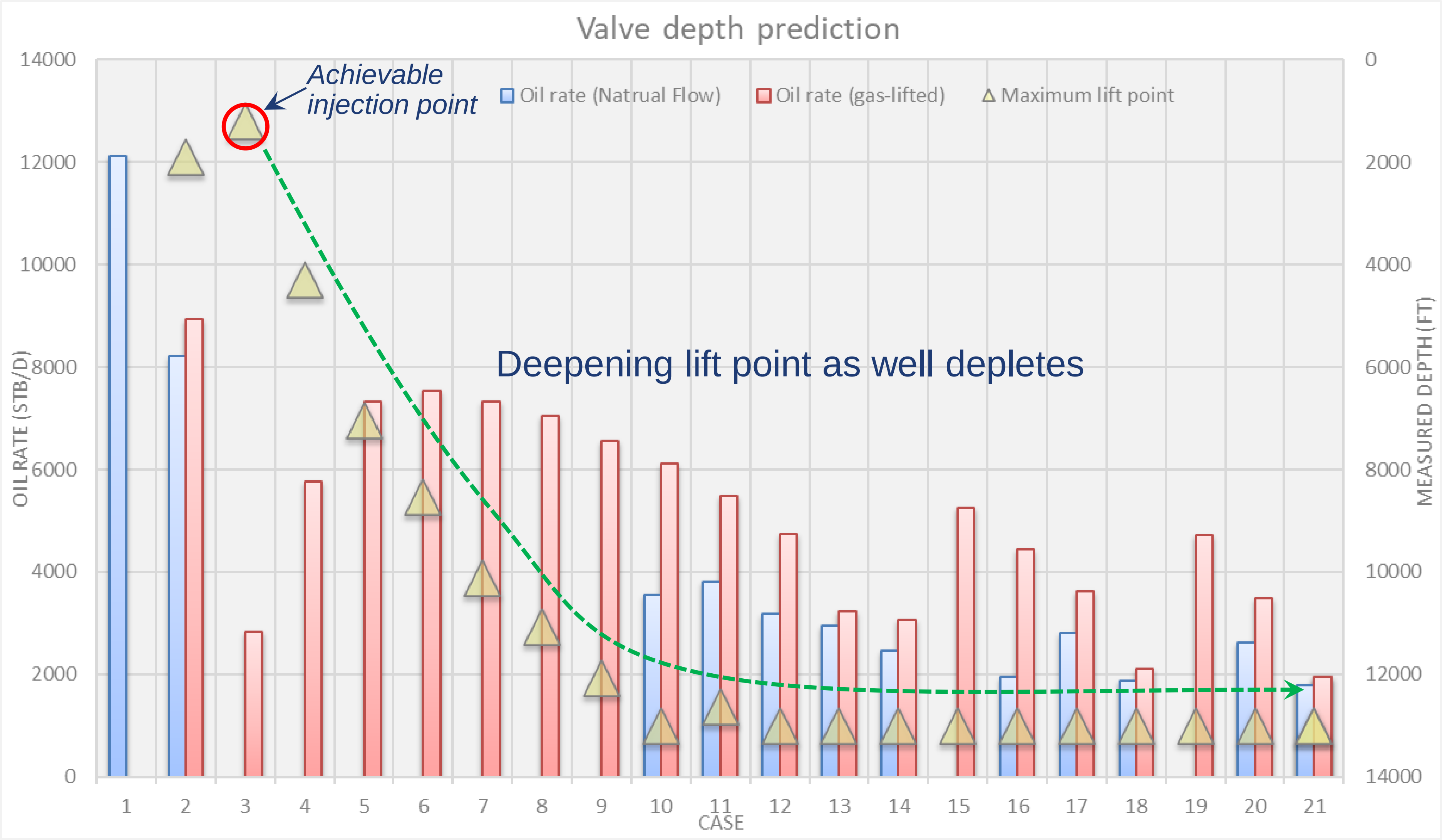
Natural Flow / Gas Lift screening

- Identify where natural flow can occur
- Determine when gas lift will be required (is it beneficial?)



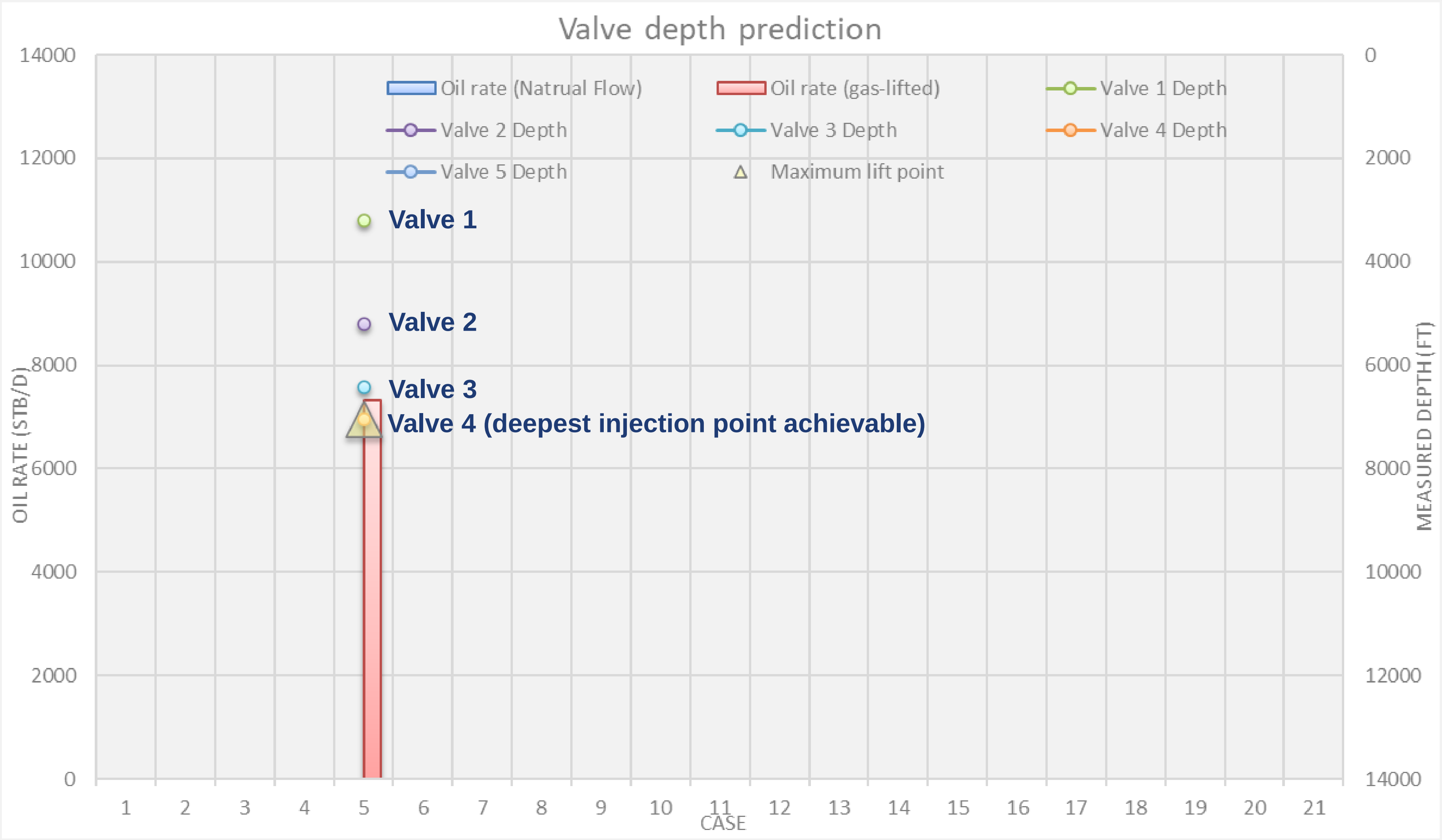
SPM depth prediction

- Many wells exhibit a highly variable maximum lift depth



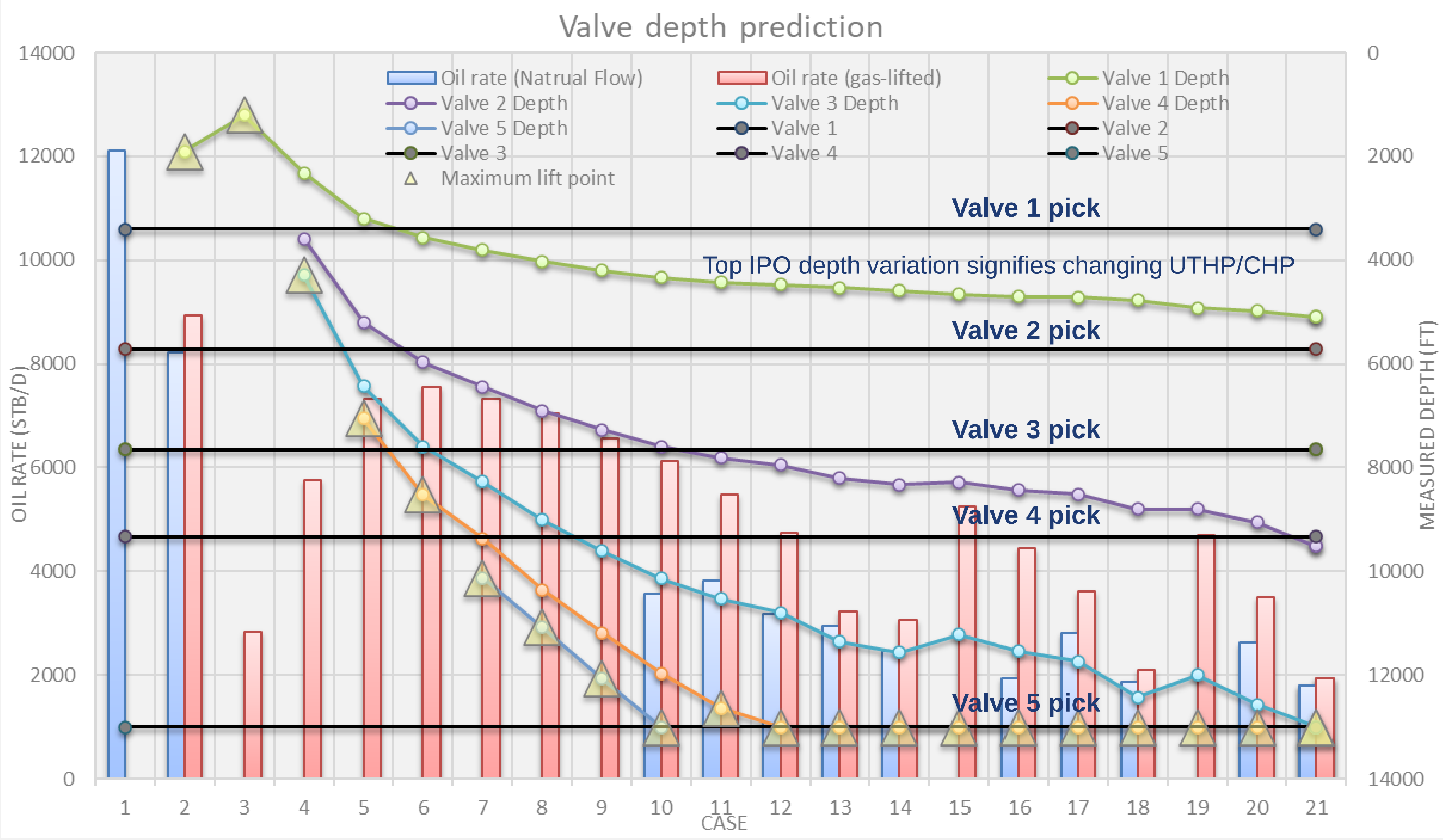
SPM Depth Prediction

- Single case visibility vs Life of Field



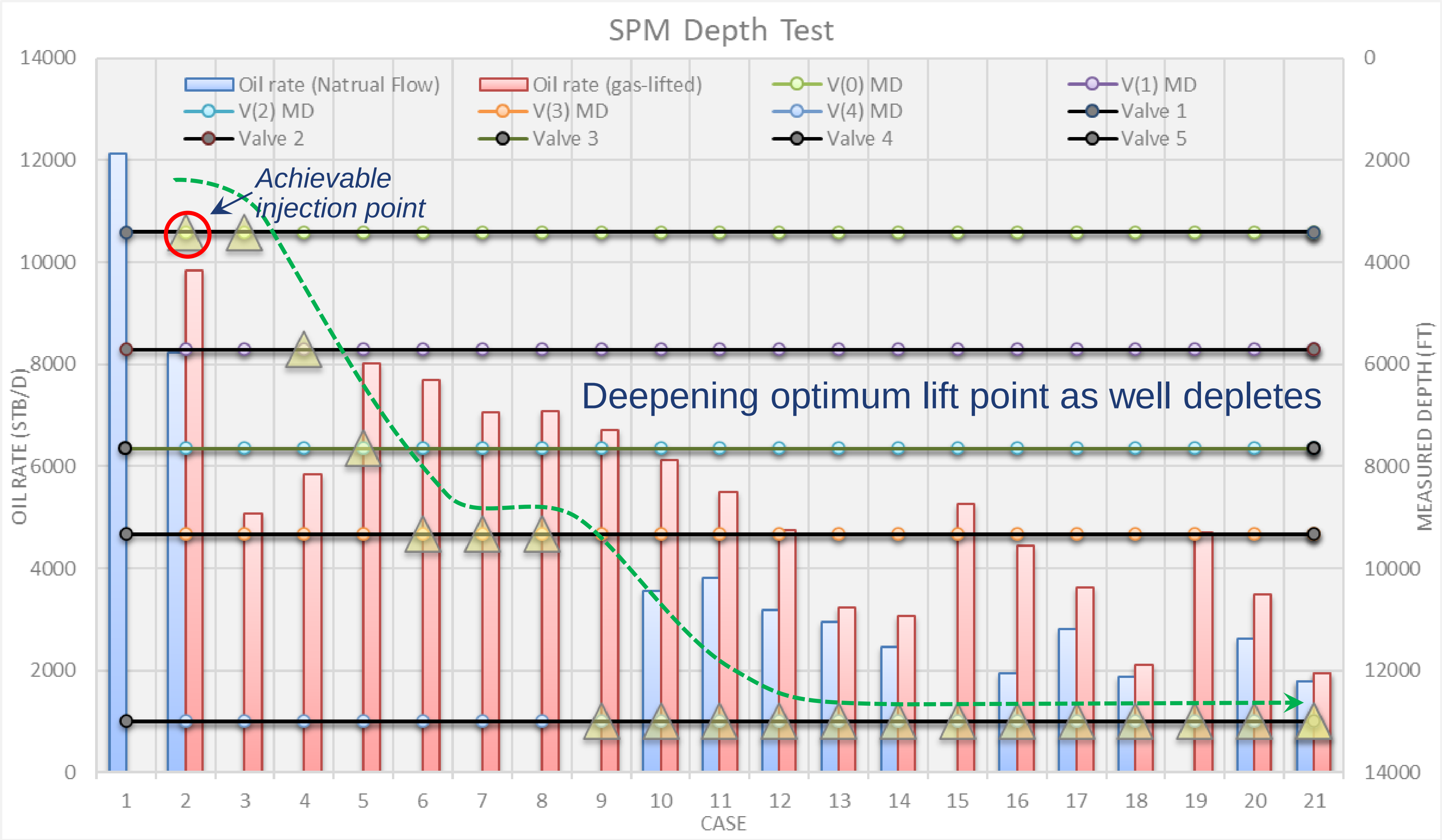
SPM Depth Prediction

- SPM depth selection – can be very subjective, requires testing



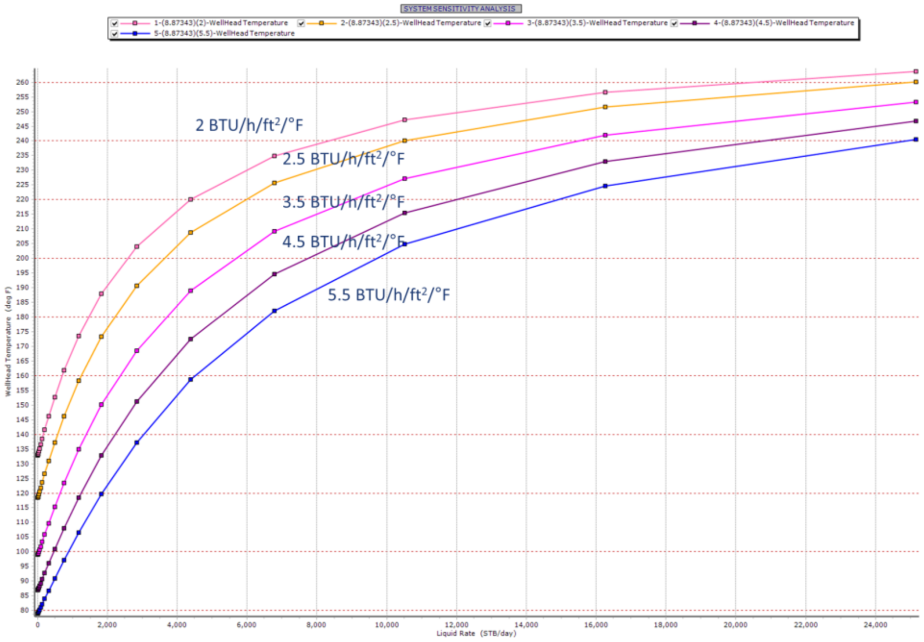
Stress Test SPM Depths

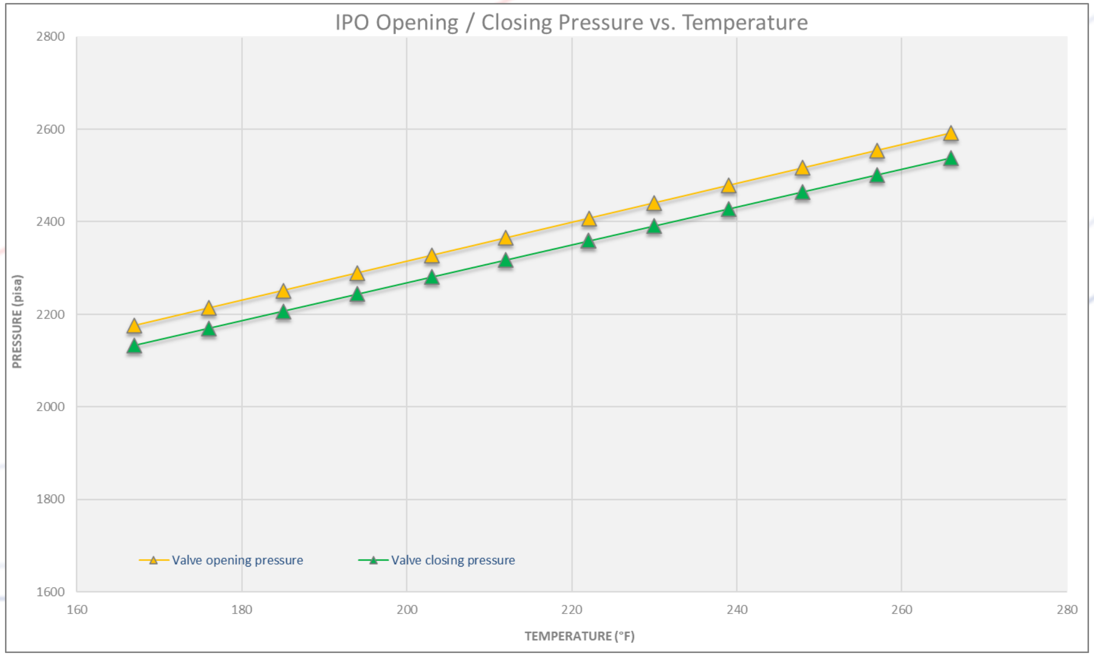
- Identify Potential for dummies for flexibility for future re-optimisation



IPO Unloading Valve Status

- N_2 dome opening / closing pressure varies with well temperature
  - IPO's ideally set up at well temperature & performance verified in FAT
- Characterise IPO behaviour over life of field to avoid re-opening
- Crucial in determining pressure available for injection at the operating valve (avoid multi-point injection & potential valve damage) & subsequent port sizing
- Temperature modelling key – QA/QC of heat transfer input data important

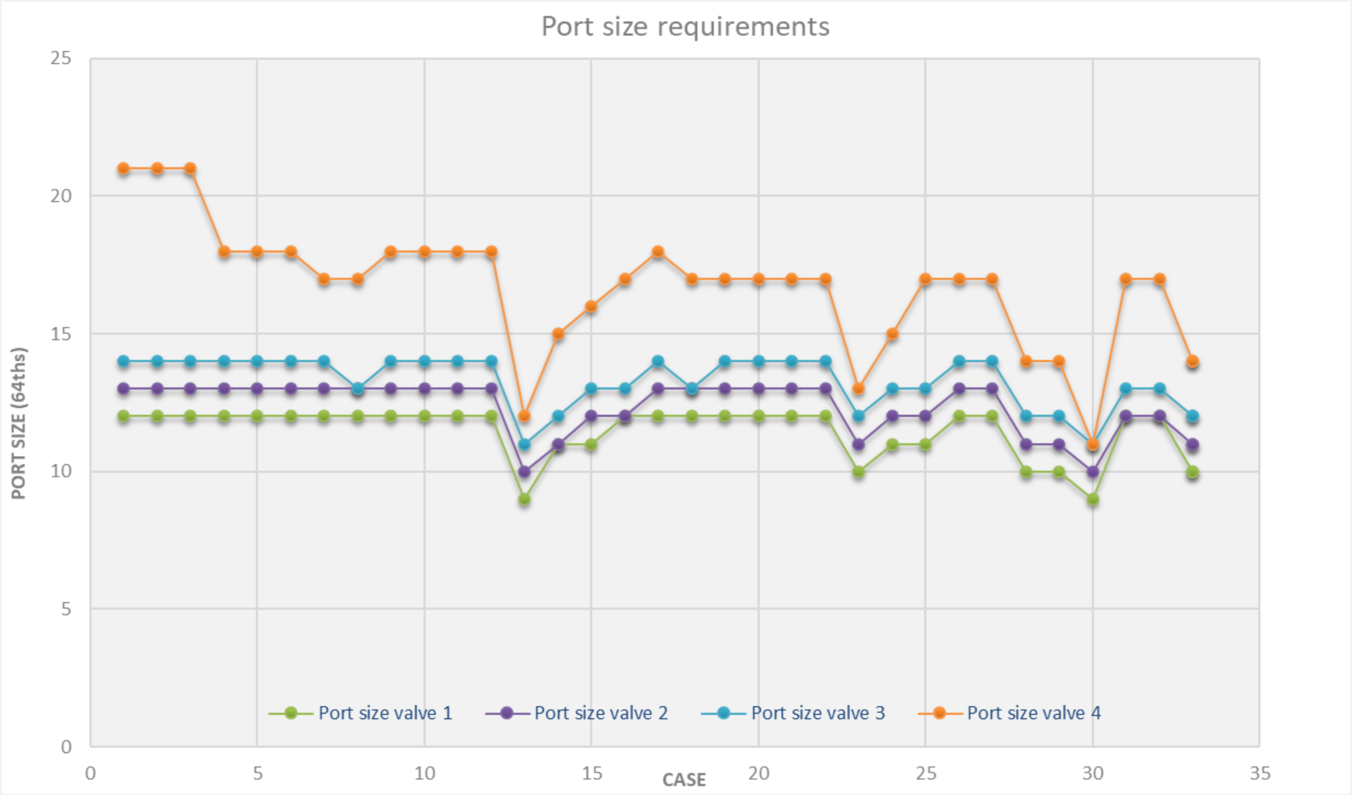




- Operator to monitor and adjust the gas-lift system / models
  - Gas-lift design should be reviewed periodically

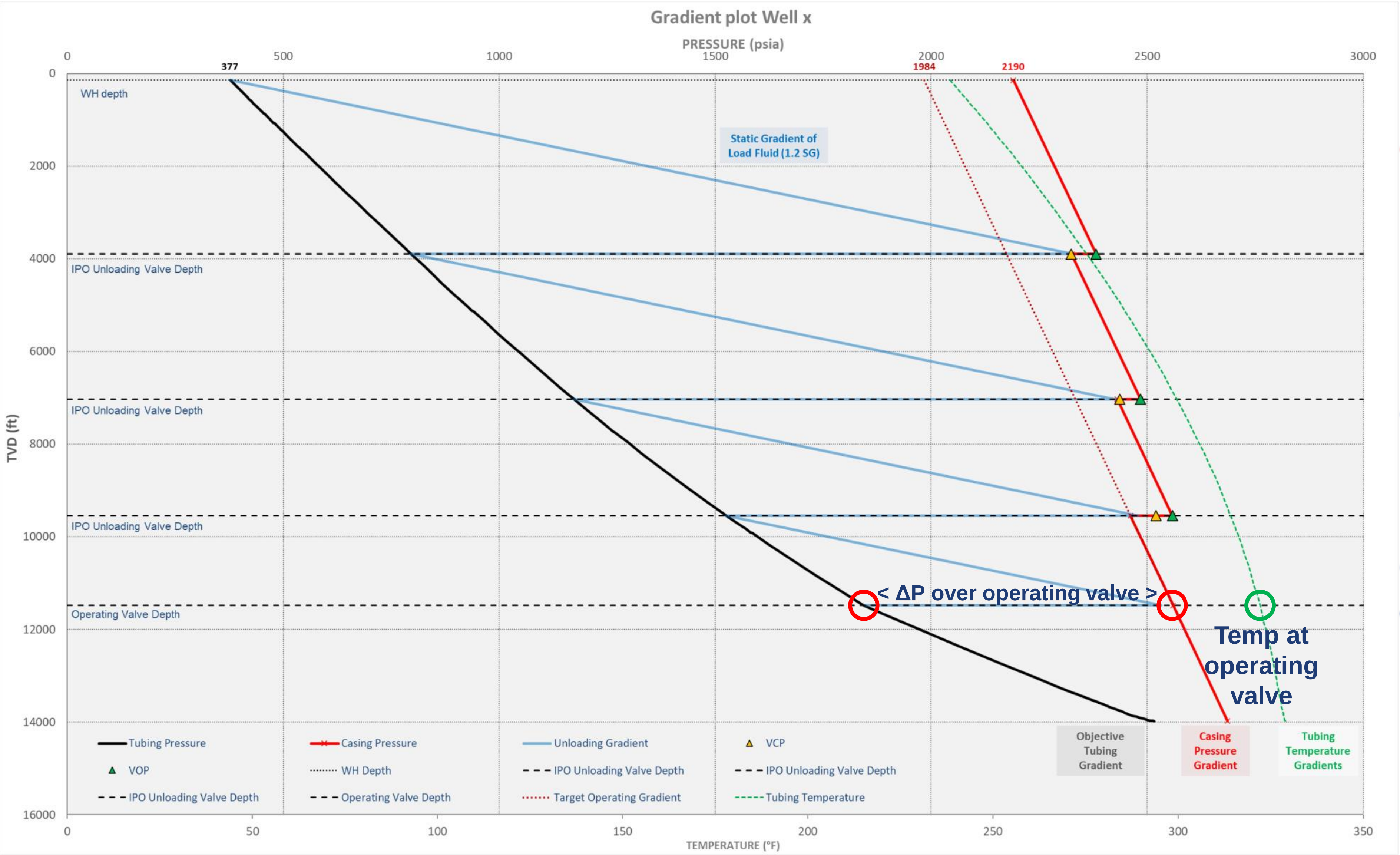
IPO Unloader Specification

- Optimum port sizes can be highly variable with production conditions
- Ensure that the IPO ports are not over-sized as valve spread (VOP – VCP) may be large as a result



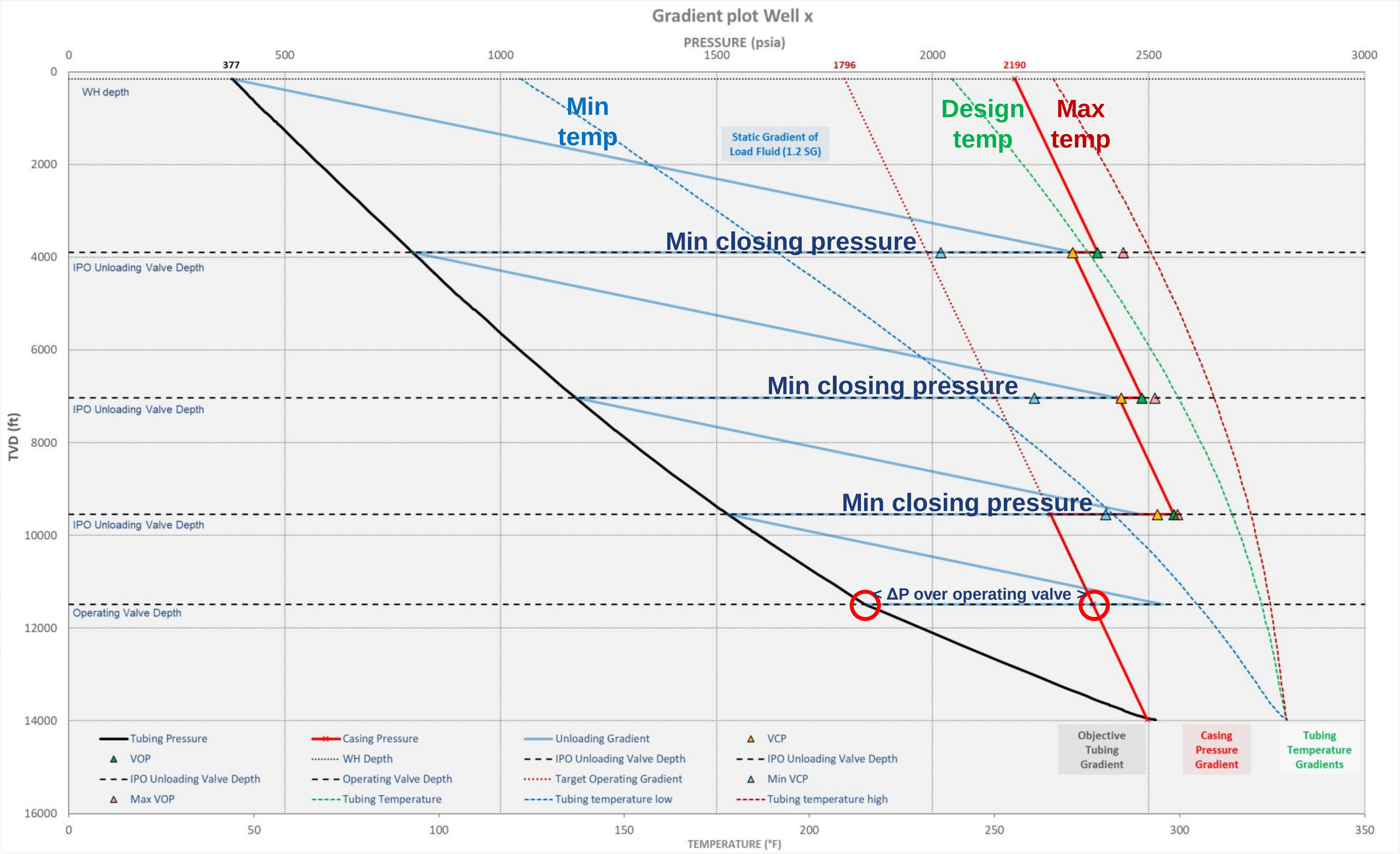
- IPO port sizes must be sufficient to allow the well to unload / kick-off successfully
- Large IPO spread can reduce the ultimate depth of injection as the ΔP over the operating valve is reduced to ensure IPO's close

ΔP Over Operating Valve (Design Case Conditions)



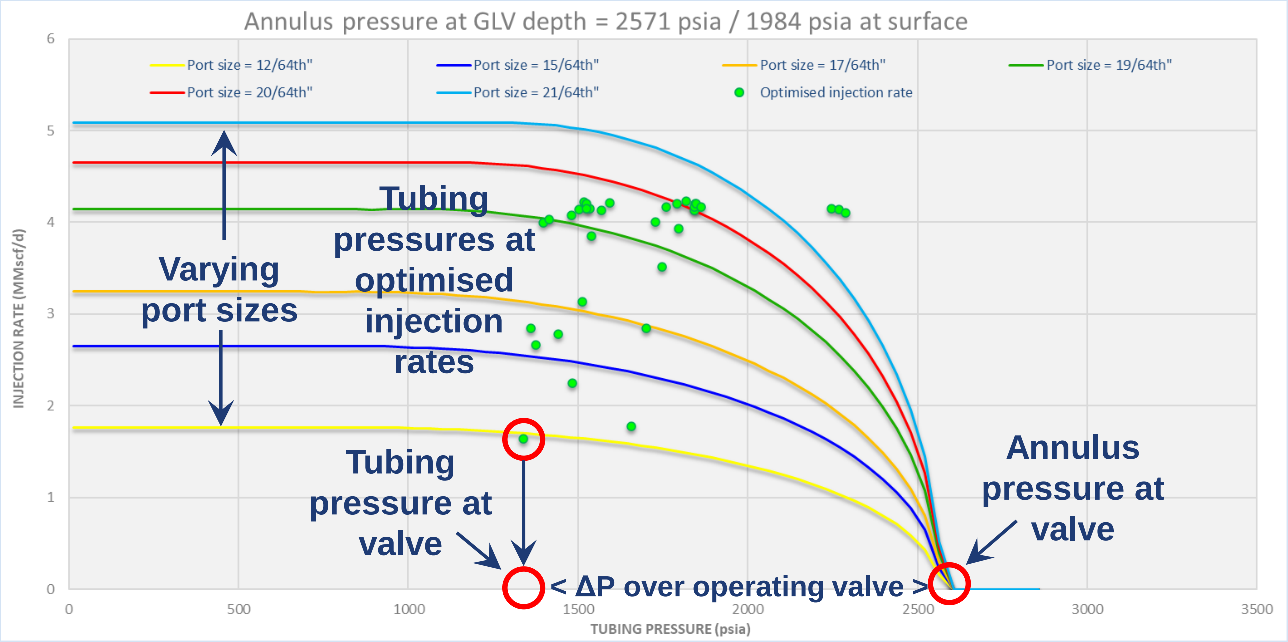
- Identify deliverable ΔP over the operating valve while keeping IPO's closed

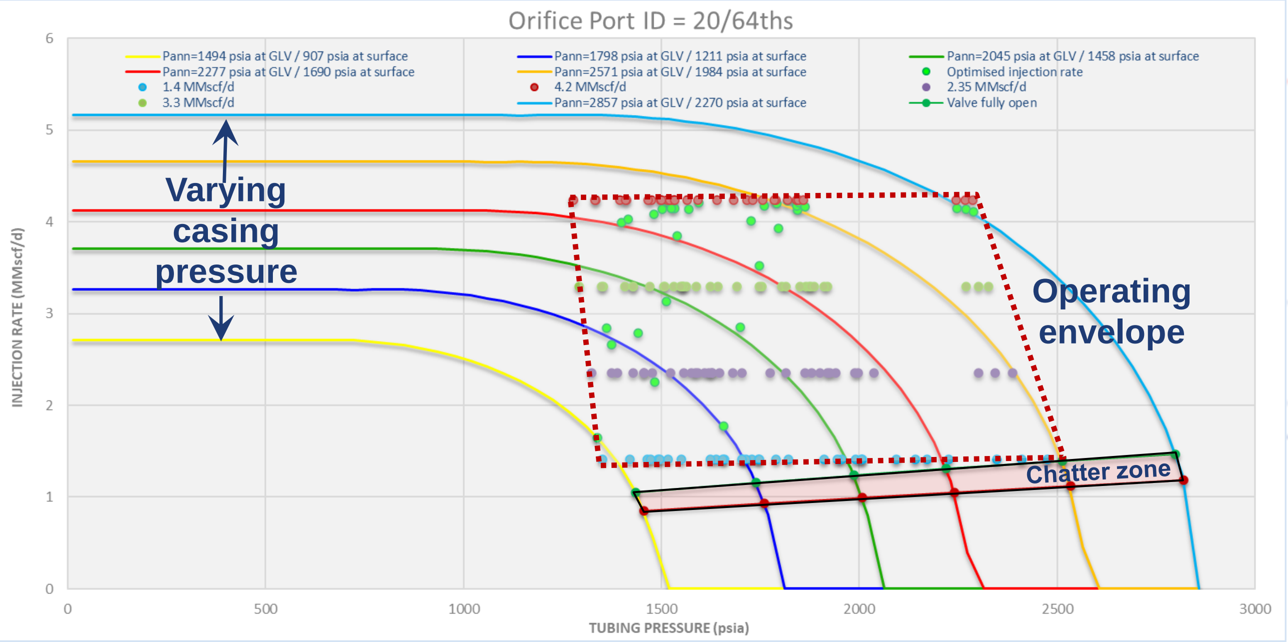
ΔP Over Operating Valve (Max / Min Temperature Conditions)



- Lower temperature scenarios require additional reduction in CHP to close IPO's

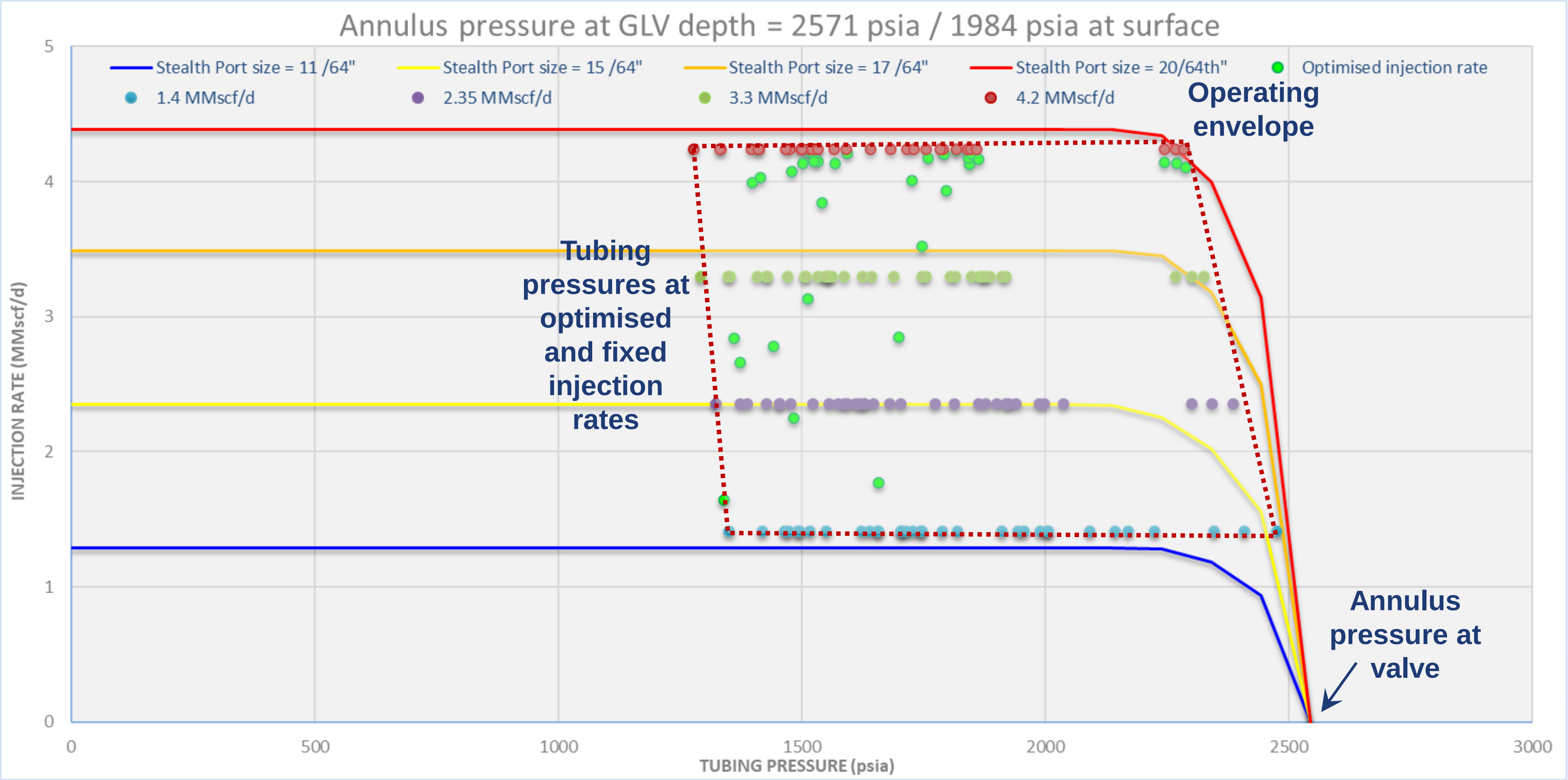
Orifice Sizing for Life of Field (Square Edged Type)





- Use vendor specific valve performance derived from flow loop testing
- Do you size the operating valve for optimised or maximum available lift gas rate? – dialogue with client
- Operators can use these plots when monitoring to understand operating valve performance
- Indicator of injection stability (in addition to further stability tests e.g. Asheim, stability curves etc.)

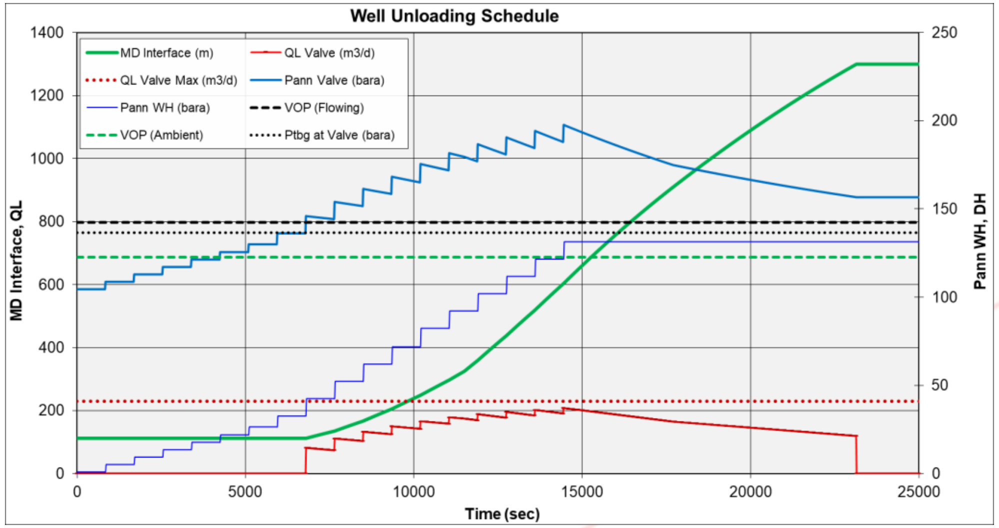
Orifice Sizing for Life of Field (Venturi Style)



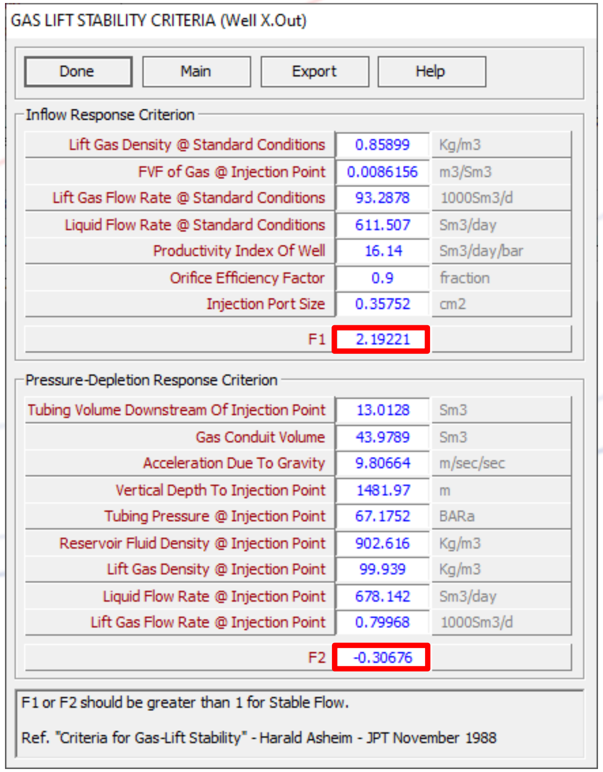
- Venturi style orifice enters critical flow at lower ΔP's than square edged (c. 85% vs. 50%)
  - Limited rate variation / turndown ability (once in sub-critical part of curve at low ΔP's flow can be highly unstable – more susceptible to valve chatter)
  - Assess Venturi vs. square edged orifice suitability for well conditions with operator

Additional Considerations

- Unloading procedure
  - Liquid rate limitations through valve ports
  - API well unloading schedule
  - Transient modelling for a tailored pressure schedule to avoid valve damage
    - e.g. vendor internal software / Prosper, etc.



- Stability analysis
  - Asheim criteria
  - GL stability curves
  - Multiphase flow pattern maps


GAS LIFT STABILITY CRITERIA (Well X.Out)

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Inflow Response Criterion

Lift Gas Density @ Standard Conditions	0.85899	Kg/m3
FVF of Gas @ Injection Point	0.0086156	m3/Sm3
Lift Gas Flow Rate @ Standard Conditions	93.2878	1000Sm3/d
Liquid Flow Rate @ Standard Conditions	611.507	Sm3/day
Productivity Index Of Well	16.14	Sm3/day/bar
Orifice Efficiency Factor	0.9	fraction
Injection Port Size	0.35752	cm2
F1	2.19221	

Pressure-Depletion Response Criterion

Tubing Volume Downstream Of Injection Point	13.0128	Sm3
Gas Conduit Volume	43.9789	Sm3
Acceleration Due To Gravity	9.80664	m/sec/sec
Vertical Depth To Injection Point	1481.97	m
Tubing Pressure @ Injection Point	67.1752	BARa
Reservoir Fluid Density @ Injection Point	902.616	Kg/m3
Lift Gas Density @ Injection Point	99.939	Kg/m3
Liquid Flow Rate @ Injection Point	678.142	Sm3/day
Lift Gas Flow Rate @ Injection Point	0.79968	1000Sm3/d
F2	-0.30676	

F1 or F2 should be greater than 1 for Stable Flow.

Ref. "Criteria for Gas-Lift Stability" - Harald Asheim - JPT November 1988

- Operator feedback on valve performance:
  - Valve installation successful?
  - Well unloaded with no issues?
  - Are the injection rates as expected?
  - Is injection stable?
  - An ongoing dialogue

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Conclusions

- A rigorous life of field approach to gas-lift is recommended which takes account of:
  - Reservoir data uncertainty
  - Changing operating parameters
  - IPO unloader and Operating valve performance envelopes and behaviour under changing conditions
- Vendor / operator collaboration & understanding is key
- The benefits of this approach facilitates a better informed selection of:
  - SPM setting depths
  - Detailed valve set-up parameters
  - Well operational strategy
- This benefits valve integrity and longevity and reduces costs

Thank you for listening

Q & A

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Increase Production,

Enhance Well Integrity

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