Application of Asheim Stability Criteria for Troubleshooting Gas Lift Instability

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Presentation Outline

01 Introduction

02 Asheim Stability Theory

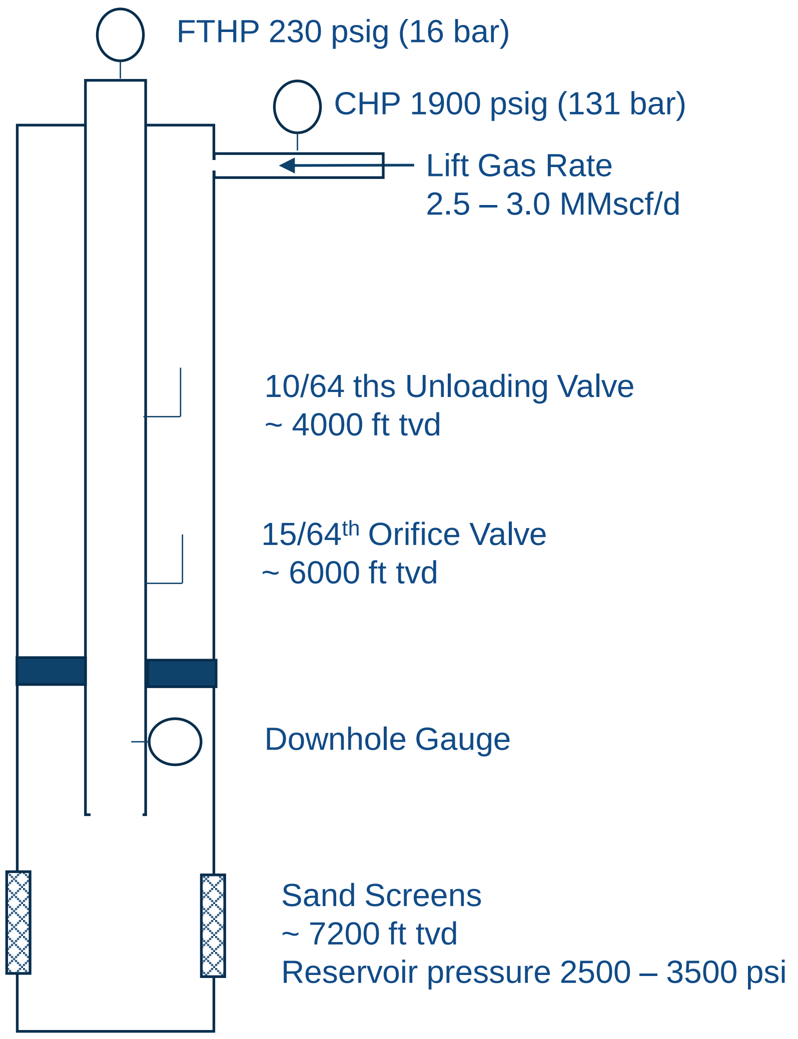
03 Field Examples

04 Conclusions

05 Questions?

Introduction

- UK North Sea undersaturated oil field with water injection pressure support
- All wells completed with gas lift, typically an injection pressure operated unloading valve and a orifice valve
- During the course of 2019-2020, several wells developed intermittent instability
- Deep dive investigations were completed to determine the cause:
  - Multi-pointing?
  - Gas lift valve failure?
  - Inherent (Asheim) instability?



Ashiem Stability Criteria Theory

Inflow Response:
stability promoted by high PI, small orifice port size:

$$F1 = \frac{\rho_{gsc} B_g Q_{gsc}^{2}}{Q_{lsc}} \frac{J}{(EA_i)^2} > 1$$

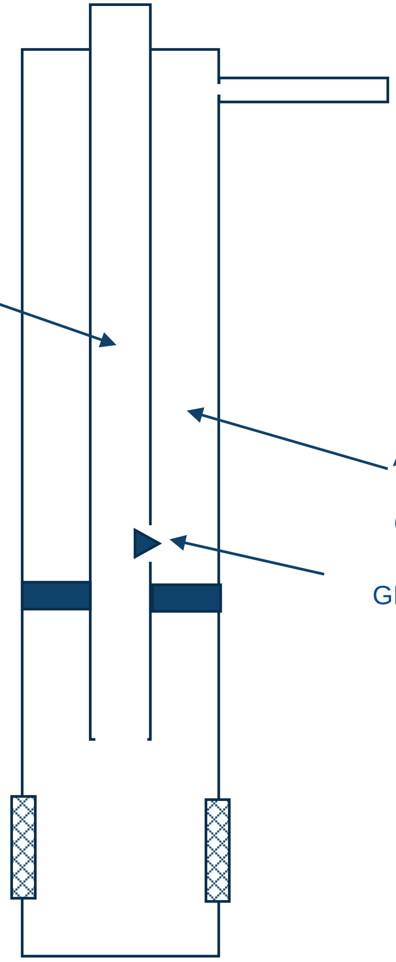
- Gas lift rate @ SC
- Productivity Index
- Liquid flowrate @ SC
- Port size
- Orifice efficiency = 0.9*

*Prosper uses a fixed Orifice efficiency = 0.9, higher efficiency will make F1 value lower

Pressure Depletion Response:
stability promoted by shallow injection point, higher THP:

$$F2 = \frac{V_t}{V_c} \frac{1}{gD} \frac{p_t}{(\rho_{fi} - \rho_{gi})} \frac{Q_{fi} + Q_{gi}}{Q_{fi}\,(1 - F1)} > 1$$

- Tubing vol above GLV
- THP
- Liquid rate @ injection point
- Gas lift rate @ injection point
- Annulus vol down to GLV
- Vertical depth to GLV



Either F1 or F2 > 1 to be in a stable condition

Reference: Criteria for Gas Lift Stability, H.Asheim, SPE 16468 (1988)

Ashiem Stability Benefits & Limitations

- Both reservoir inflow and gas lift rate respond to a decrease in tubing pressure
  - Inflow response (F1) becomes unstable if the reduction in tubing pressure/ increased drawdown from gas lift exceeds the reservoir inflow capacity to keep the tubing full of fluid.
  - If the inflow response is unstable but the increase in gas rate through the orifice depletes the annulus pressure faster than the tubing pressure, the gas lift flow rate will reduce and stabilise the well if (Depletion response (F2) >1)
- Easy to determine how to restore stability by adjusting the gas lift operating parameters or design
- Mathematically simple and programmed into widely used nodal analysis software

Limitations

- Several simplifying assumptions to be mathematically solvable:
  - Transient inflow responses are neglected
  - Gas lift orifice is operating under isothermal flow i.e. a relatively small pressure drop through it
  - Casing pressure varies but gas rate through the surface choke is assumed to be constant
  - Variation in tubing pressure at orifice is same as variation in BHFP (only valid if orifice is close to perforations)
  - Tubing response is dominated by gravitational effects, acceleration and friction are ignored
- Not a transient (multi-pointing) solution.

Recommended further reading: Continuous Gas-Lift Instability: Diagnosis, Criteria and Solutions, Alhanati et.al. SPE 26554 (1993)

Well A Instability

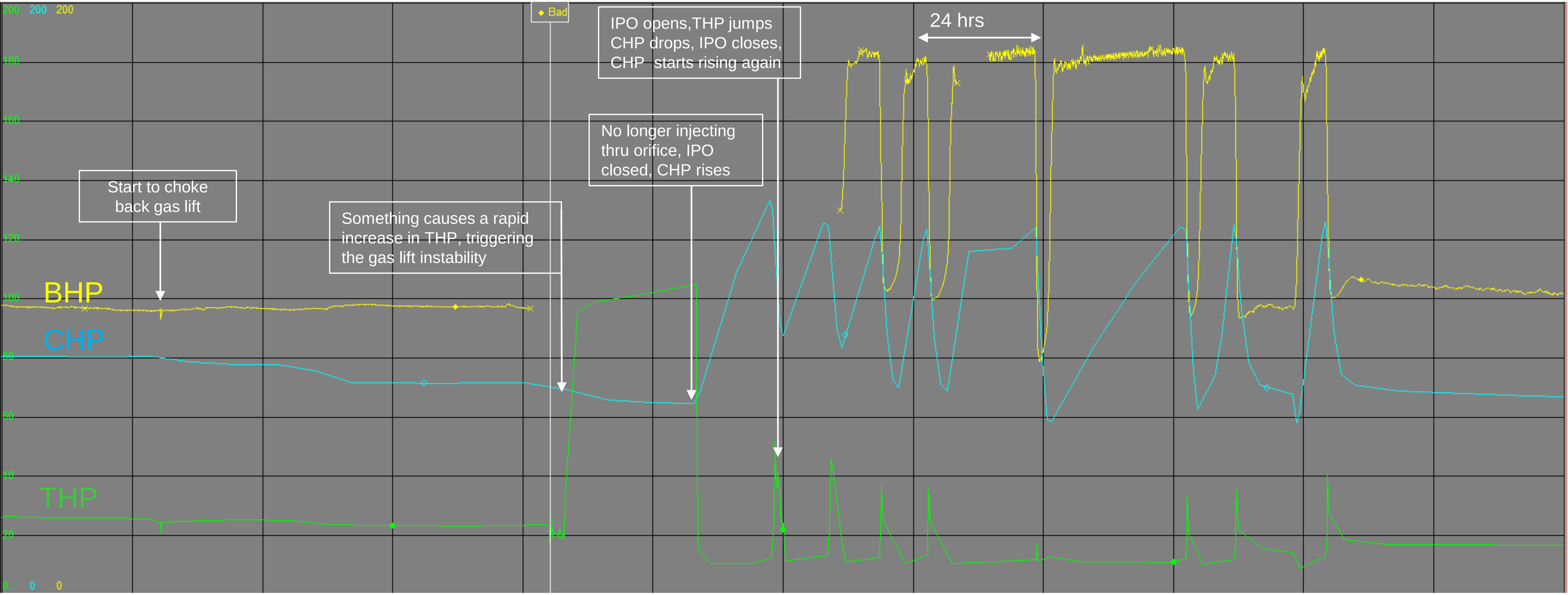
Instability cycle is constant and repeatable, and triggered by an increase in gas lift rate

Well A Summary

- The Asheim criteria are met so design is fundamentally stable.
- Well becomes unstable whenever the gas-lift rate is increased > 2.5 MMscf/d.
- Orifice port size is small, so CHP has to be increased for lift gas rates > 3 MMscf/d
- Instability is caused by the casing pressure exceeding the IPO valve opening pressure.
- This results in the unloading valve opening, causing a surge in lift gas, until the casing pressure drops and the unloading valve closes, repeating every 20-30 minutes.

		Design	2020
Pr	psig	3000	3020
PI	STB/d/psi	18	9
Qgl	MMscf/d	2.5	2.5
Ql	STB/d	14,000	13,980
CHP	psig	1885	2060
FTHP	psig	210	180
F1	-	0.76	0.65
F2	-	2.50	1.53

Well B Instability



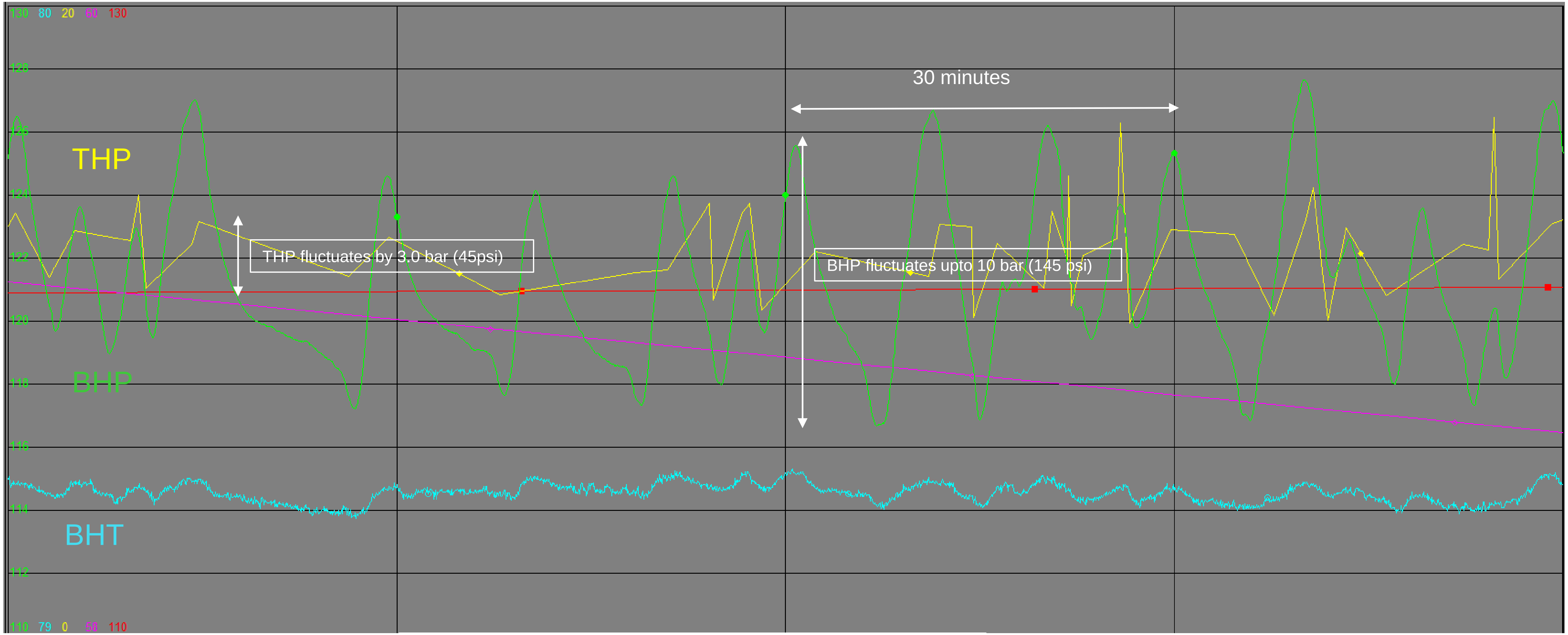
Instability is erratic, BHP drops when the IPO valve opens then rises when the IPO closes

Well B Analysis

- Instability triggered after a series of gas lift choke moves to reduce the gas lift rate.
- At first glance, the instability is due to the IPO valve opening but that is actually a consequence, not the cause.
- PI, liquid flowrate and gas lift rate are all lower than the design assumptions. As a result, the Asheim stability criteria are no longer being met.
- A stable design can be restored by reducing the port size or changing to a single shallow orifice valve.

		Design	2019
Pr	psig	2500	3500
PI	STB/d/psi	14	1.3
Qgl	MMscf/d	2.5	1.75
Ql	STB/d	10,000	2,500
CHP	psig	1950	1030
FTHP	psig	232	332
F1	-	1.12	0.35
F2	-	-3.08	0.58

Well C Instability



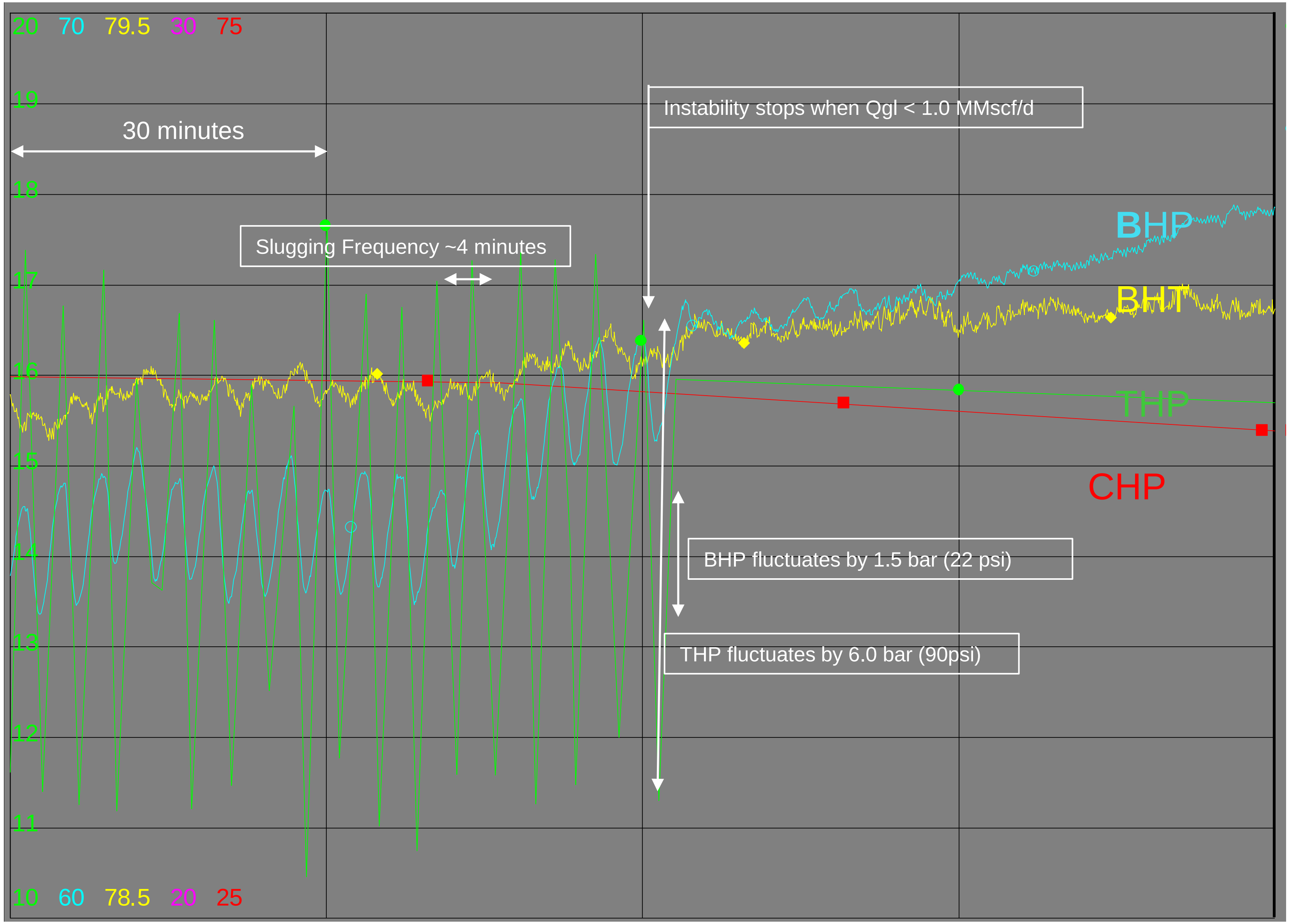
Instability is erratic, cause not determined

Well C Analysis

- Instability occurs intermittently and usually after re-starts.
- Asheim inflow response stability criteria (F1) is not met, but the pressure depletion response criteria (F2) is met, so the gas lift design is inherently stable.
- The orifice port is correctly sized for the gas lift rate and operating close to critical flow.
- The CHP is ~300 psi lower than IPO opening pressure, and there is no evidence of IPO opening.
- The gas lift design is suitable for the well conditions and is not thought to be the trigger for the instability events.

		Design	2020
Pr	psig	3000	3000
PI	STB/d/psi	20	6
Qgl	MMscf/d	2.5	2.75
Ql	STB/d	16,500	8,100
CHP	psig	1900	1800
FTHP	psig	232	160
F1	-	0.68	0.85
F2	-	2.09	3.14

Well D Instability



A gas lift instability event occurred whilst bring the well back after a platform trip

Well D Analysis

- The reservoir pressure, PI, and gas lift rate are much lower than the basis of design.
- Consequently, the Asheim inflow response stability criteria are not met and the gas lift design is inherently unstable
- The orifice port size is too large for a gas lift rate of < 1MMscf/d, but if the rate is increased above this, the BHFP drops below bubble point
- Choking back the well to increase the THP helps to restore stability, but as the design is inherently unstable a longer term solution would be to recomplete with a smaller port size or shallower valve depth

		Design	2020
Pr	psig	3000	2400
PI	STB/d/psi	20	1.1
Qgl	MMscf/d	2.5	0.9
Ql	STB/d	13,700	1200
CHP	psig	1944	820
FTHP	psig	232	300
F1	-	1.38	0.25
F2	-	-1.28	0.64

Conclusions

Well A
- Asheim criteria are met
- Instability caused by CHP exceeding IPO valve opening pressure

Well B
- Asheim criteria not met
- Productivity index and flowrate are lower than the gas lift basis of design

Well C
- Asheim criteria are met
- Cause of instability undetermined

Well D
- Asheim criteria not met
- Reservoir pressure, PI and flowrate are lower than the gas lift basis of design