

From Risk to Resilience: The critical importance of liquid-filled annuli

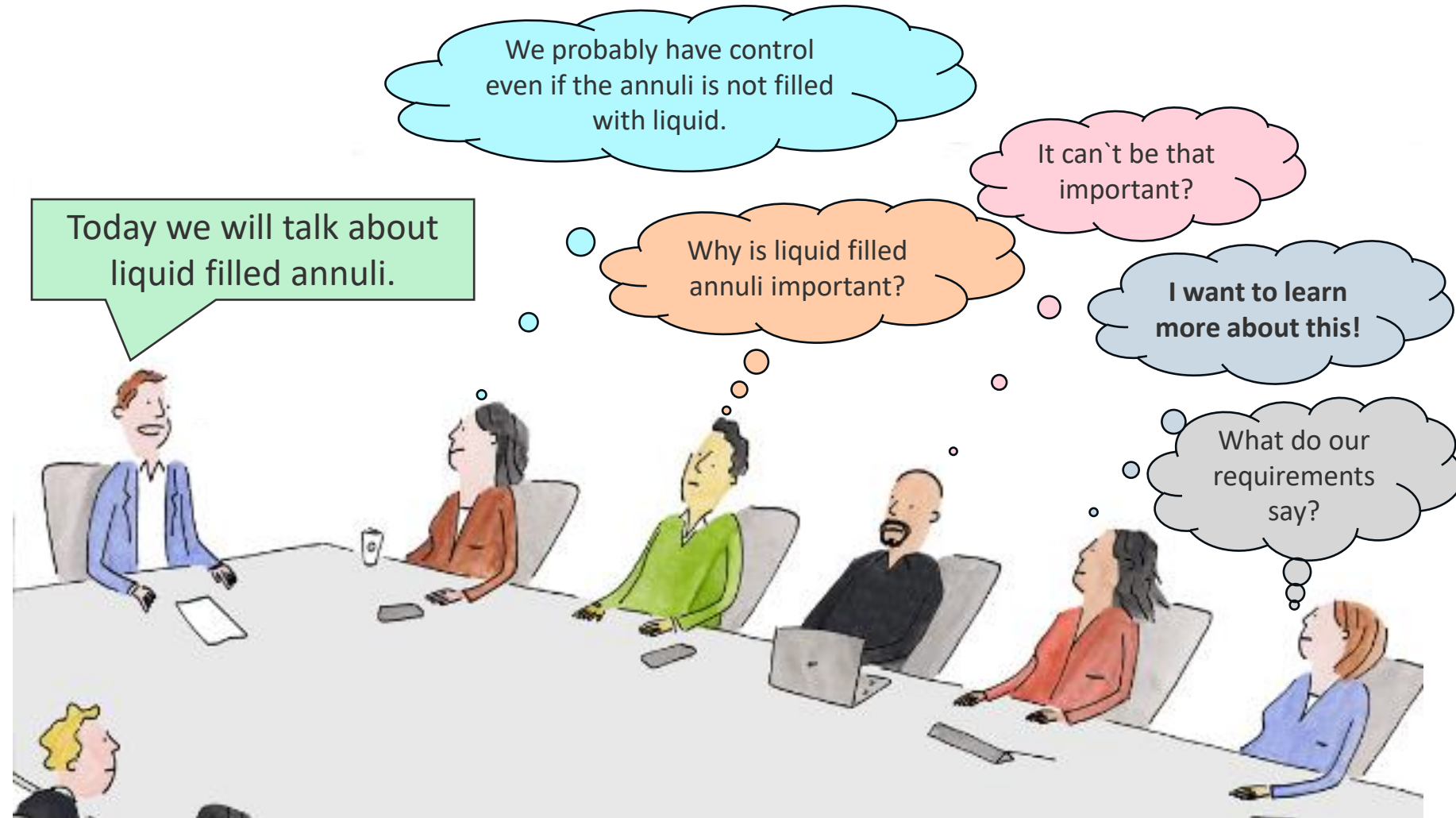


Liquid Filled Annuli

**Christer Andresen
Well Integrity Engineer**

Agenda

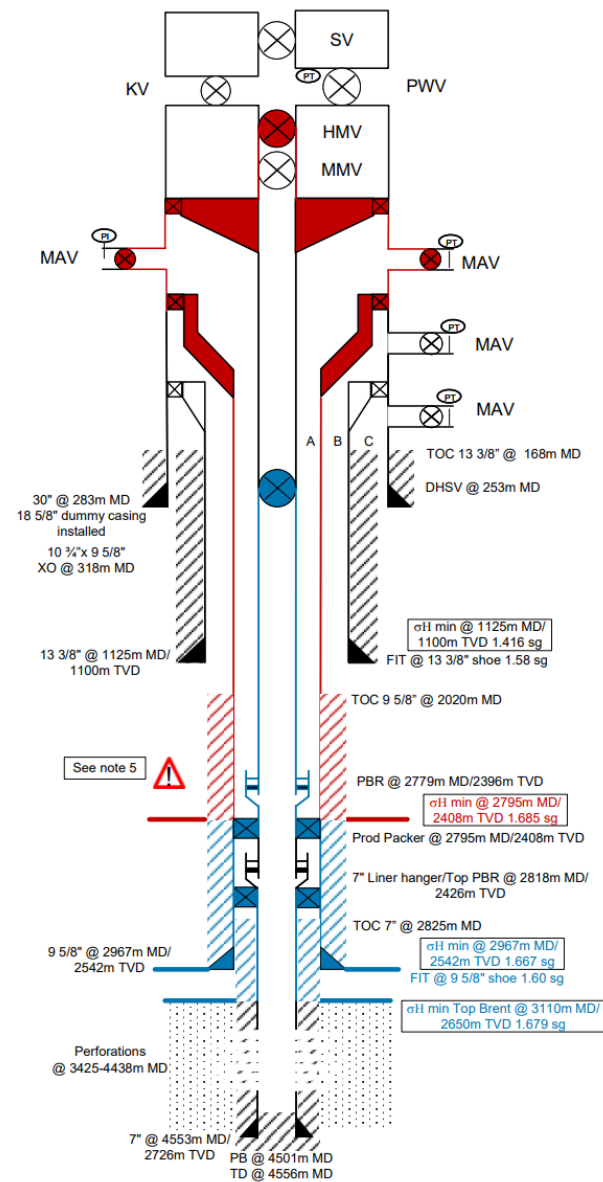
- Introduction.
- Meaning of color code for well integrity status.
- Requirements to liquid filled annuli.
- Trending and group tasks.
- Diagnostic phase and the unknown condition of the well.
- Learning.



Status

April 2023

- Oil/gas producer since 1993.
 - +30 years old
 - Most important producer on the installation.
- None failed/FOF PM tests last 12M.
- Positive pressure on all annuli.
 - Nitrogen used to pressurize.
- Stabile well – No verification of liquid filled annuli performed for many years.
- Green integrity status.
 - Primary and secondary barrier intact.



Well barrier elements	WBEAC tables	Verification	Monitoring						
PRIMARY									
Formation at Cap rock	51	σH min 1.679 sg. Method: ref see Note 4.	n/a after initial verification						
7" Liner cement	22	Length: 285m MD > Cap rock Method: see Note 1.	n/a after initial verification						
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Production packer	7	PT: 280 bar with 1.06 sg (DBR 21.04.1993)	Continuous pressure monitoring of A-annulus						
Production tubing (w/ PBR)	25 (29)	PT: 280 bar with 1.06 sg (DBR 21.04.1993)	Continuous pressure monitoring of A-annulus						
DHSV Control line	8	IT: 27 bar (DBR 21.04.1993) PT: 570 bar (DBR 21.04.1993)	Periodic leak testing. AC: Max 3.2 bar/30 min						
SECONDARY									
Formation at Prod packer	51	σH min 1.685 sg. Method: ref see Note 4.	n/a after initial verification						
9 5/8" Production casing cement (above packer)	22	Length: 700m MD > packer Method: see Note 2.	n/a after initial verification						
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Notes:									
1. 7" TOC at LH depth: single barrier for operation phase considered "intact". Pumped 34 m3, lost 4,5 m3 (15% loss), cement to top liner. Cement shall be evaluated during next re-entry.									
2. 9 5/8" cement: re-evaluated old CBL log which indicate potentially good cement intervals above packer of 18 and 48 m (report not uploaded to DBR, but available on teamsite). Two independent cement jobs acting as a barrier against reservoir.									
3. 13 3/8" TOC: Ref Hydro FWR, well drawing 3.1. TOC up to cellardeck, 18 5/8" dummy casing installed.									
4. Sh calibrated by XLOT, minifrac, mudloss B and vE Mohr (2010).									
5. PBR part of primary barrier, but status is continuously monitored.									
Well Risk Status Code (marked X): Detailed information in iWIT									
<table border="1"> <tr> <td>Well Risk Status Code</td> <td>Green</td> <td>Yellow</td> <td>Orange</td> <td>Red</td> <td>X</td> </tr> </table>				Well Risk Status Code	Green	Yellow	Orange	Red	X
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Integrity Status

Color code

- Color code used by operator and the authorities.
- Describes status of barriers in well.
- Orange and red wells are outside the authority's minimum requirement of barrier performance.

Well Integrity Status	
Red	One barrier failure and the other is degraded/not verified, or leak to surface.
Orange	One barrier failure and the other is intact. Or a single failure may lead to leak to surface.
Yellow	One barrier degraded, the other is intact.
Light Green	Barriers intact. Minor integrity issue.
Green	Healthy Well.

Management system

Operate wells

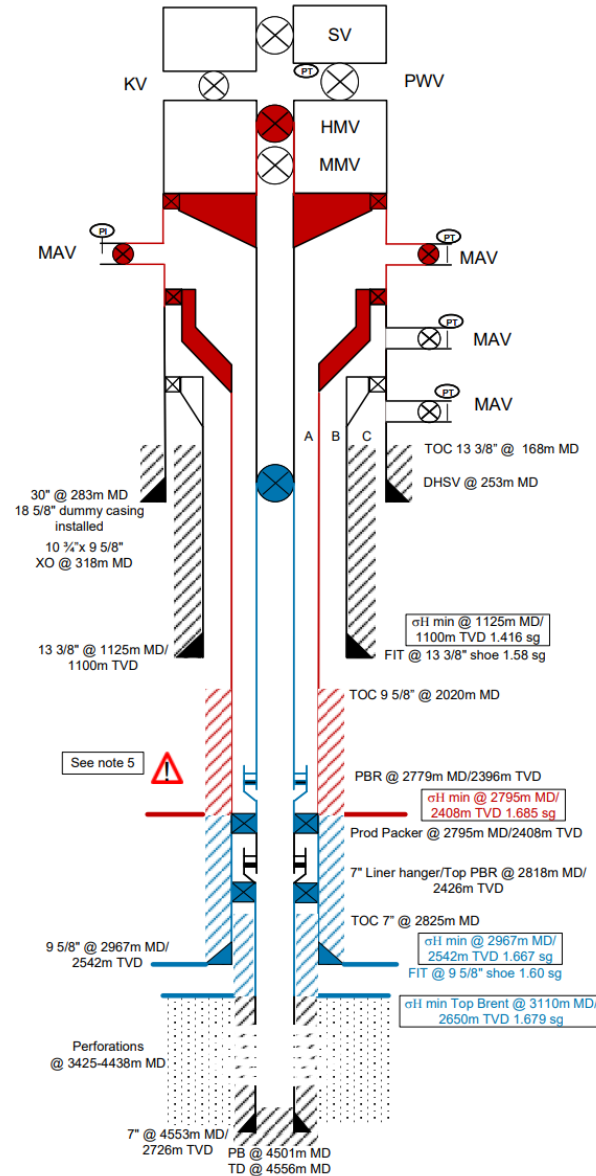
- Operate well and monitoring.
 - Operate well safety.
 - Maintain well integrity.
- Req. 1 – Liquid filled annuli.
 - Detect leak.
- Req. 2 – Monitor pressure changes.
 - Detect leak.
- Req. 3 – Use of alarm limits for monitoring well.
 - Alarm to detect leak.
- Req. 4 – Well barrier condition.
 - Condition of well barriers shall be known.



Status

April 2023

- Well has all barriers intact and positive pressure on annuli.
 - Is it important to do a verification if annuli is liquid filled?
 - Is it important to pressure trend?

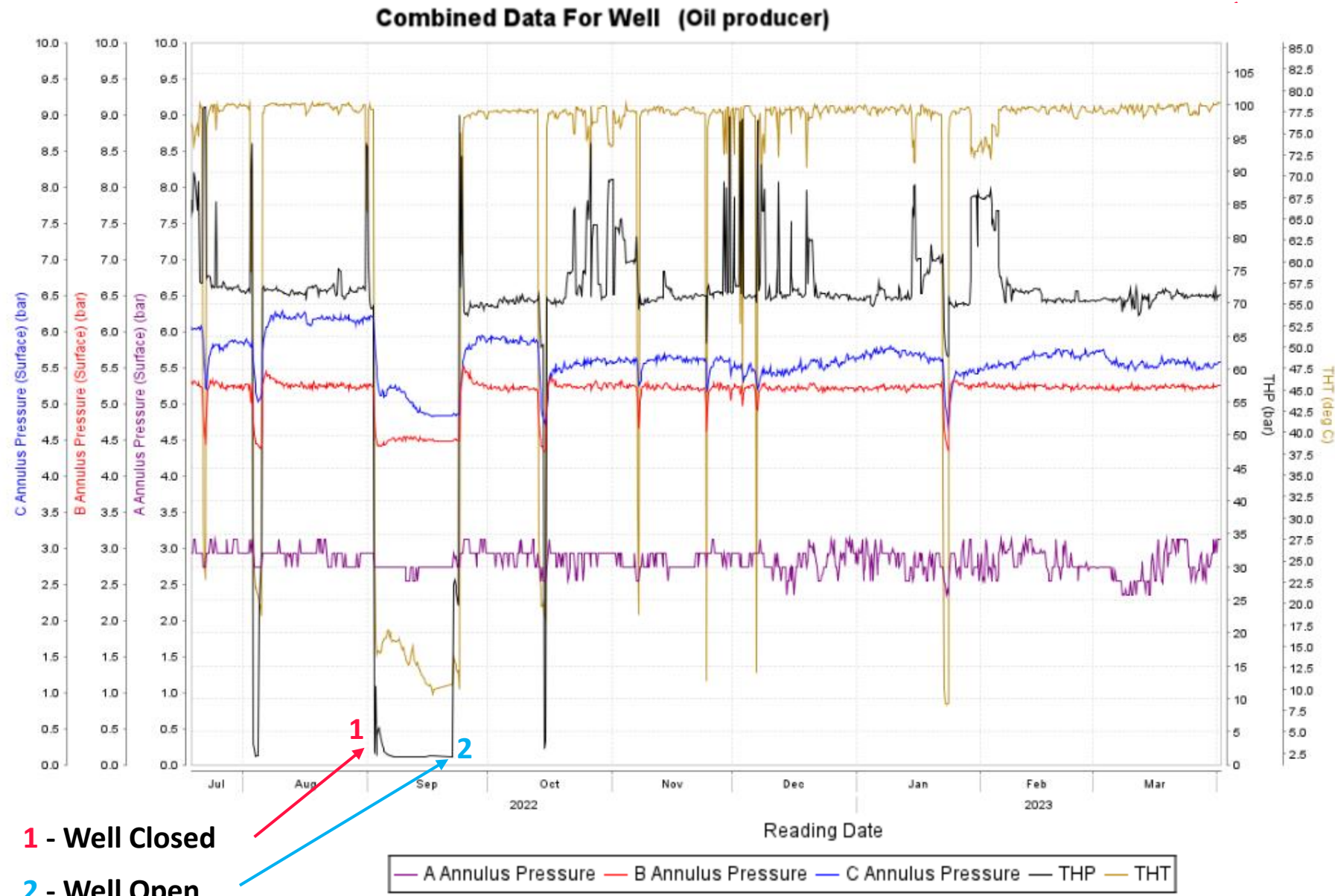


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5. PBR part of primary barrier, but status is continuously monitored			
Well Risk Status Code (marked X): Detailed information in iWIT			
A) PBR part of primary barrier			
Open Dispensations	Comment		
Closed Dispensations - Still Valid	Comment		

Status

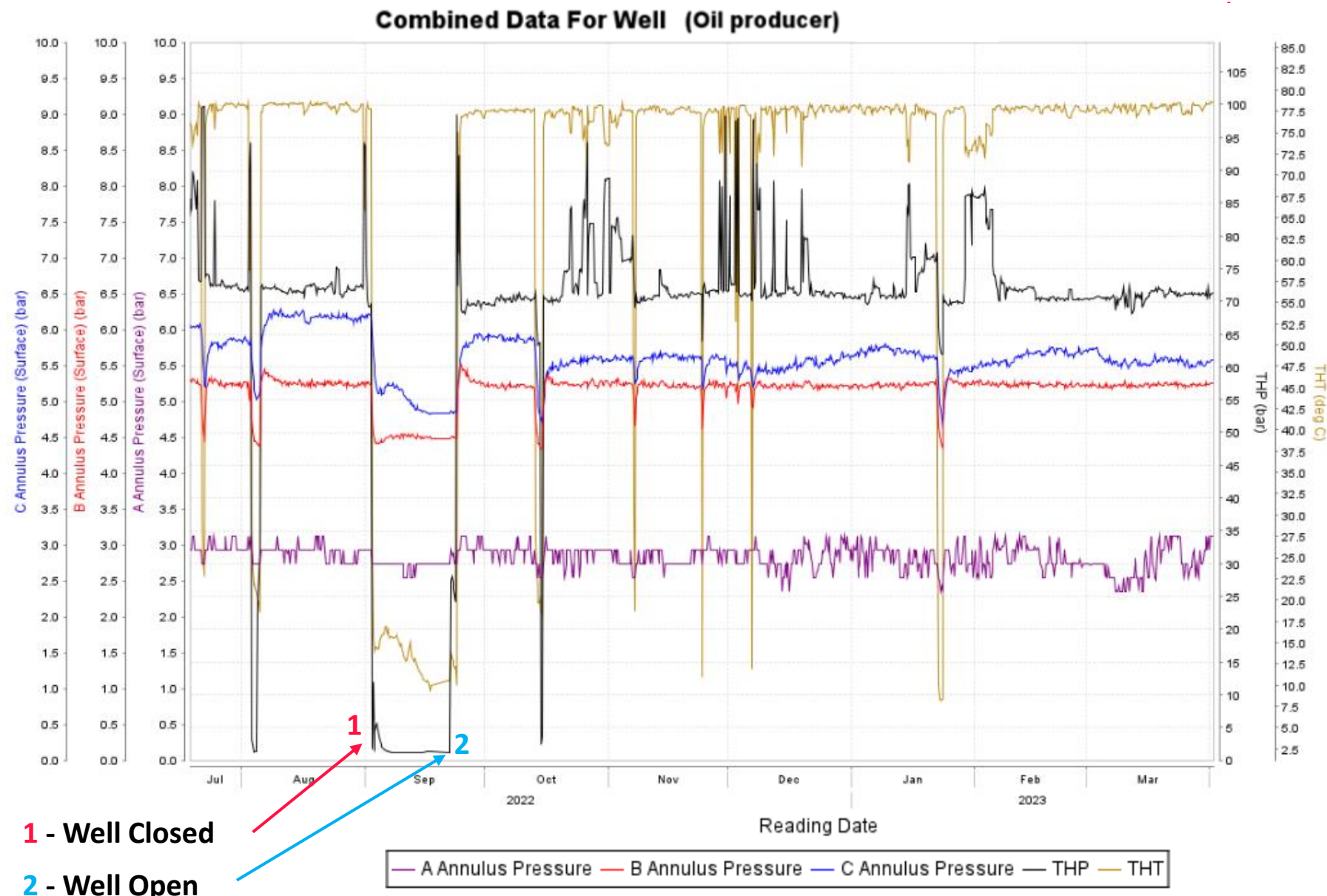
April 2023

- Trending conducted April 2023.
- Trend history 9 months back in time.



Group task

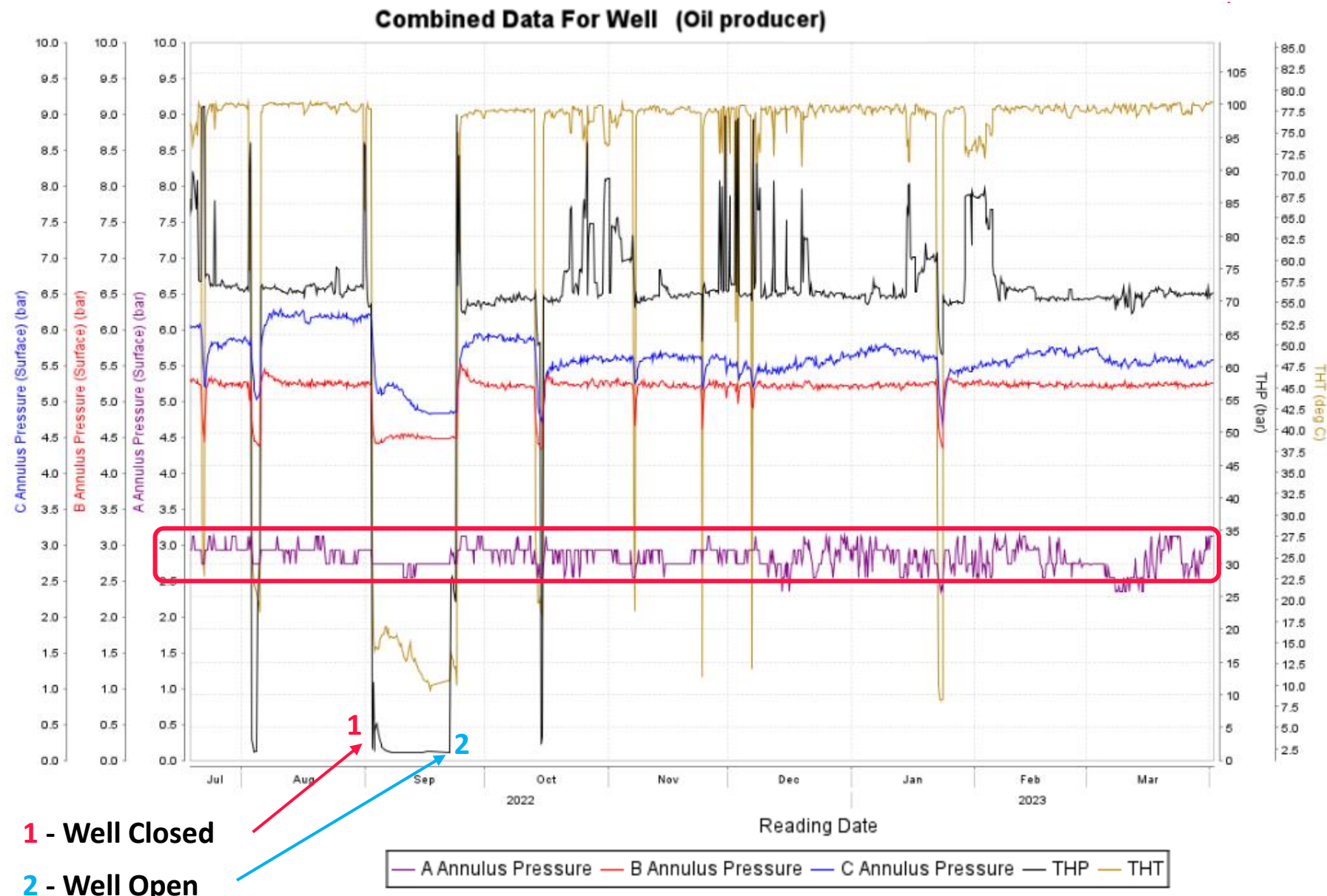
- Any abnormal pressure in this plot?



Interpretation of trend

- Any abnormal pressure in this plot?

- Annulus-A - low and stable pressure for long time.
 - Req. 3 – Use of alarm to monitor well barriers.

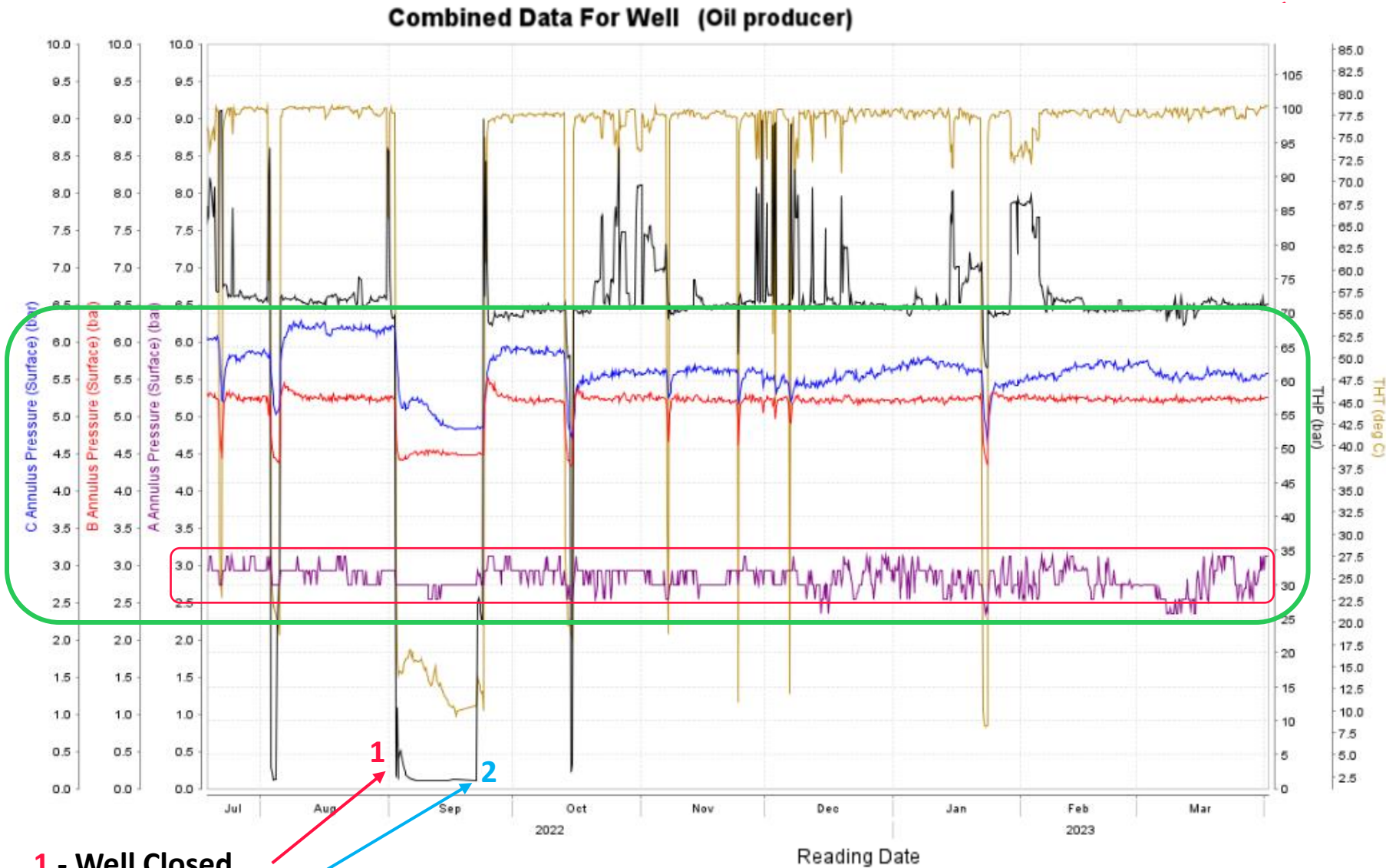


1 - Well Closed
2 - Well Open

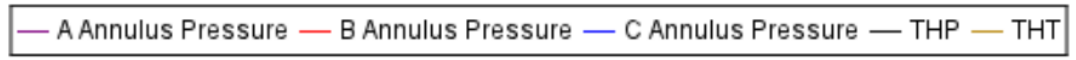
Interpretation of trend

- Any abnormal pressure in this plot?

- Annulus-A - low and stable pressure for long time.
- All annuli had approx. same pressure.
 - Annulus-A: 3 bar
 - Annulus-B: 5.5 bar
 - Annulus-C: 5.8 bar
- Req. 2 – Monitor pressure development.



1 - Well Closed
2 - Well Open



Interpretation of trend

- Any abnormal pressure in this plot?

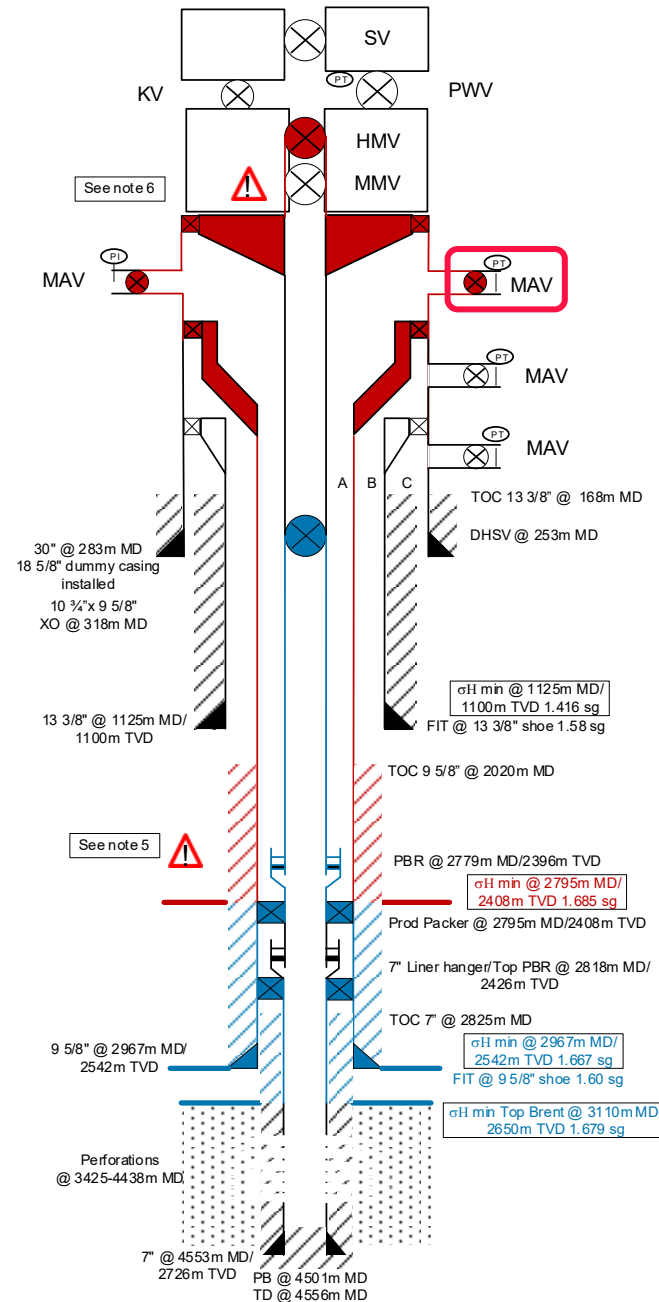
- Annulus-A - low and stable pressure for long time.
- All annuli had approx. same pressure.
- Annulus-A does not react on stop/start of well.
 - Temperature effect.
 - Req. 1 – Liquid filled annuli.



Status

April 2023

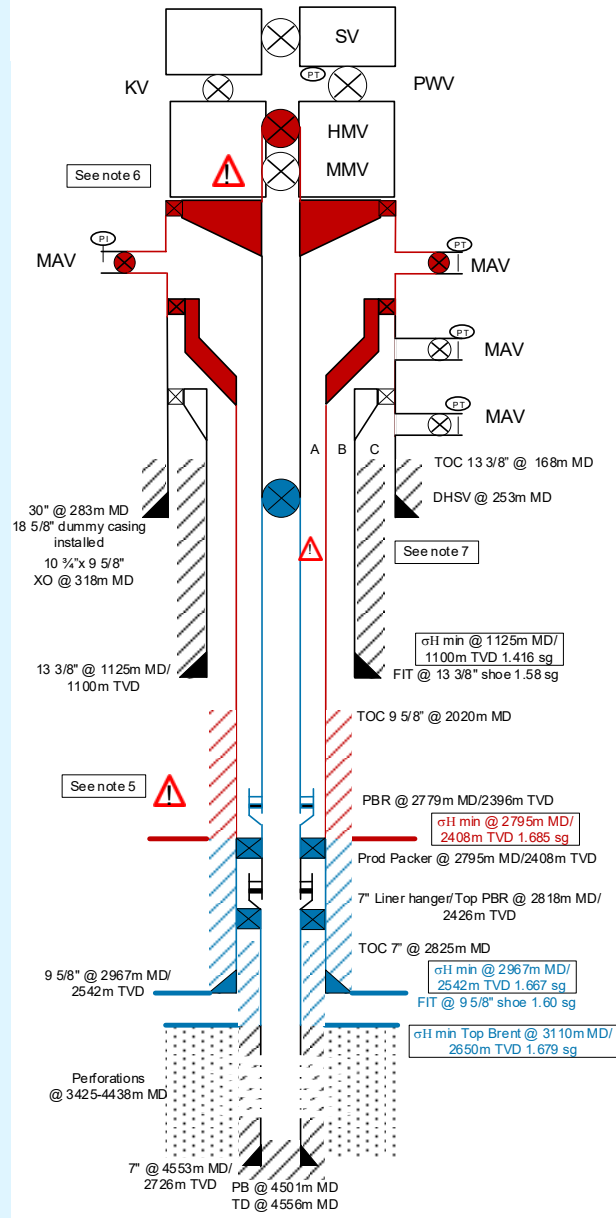
- Further action:
 - Investigate if annulus-A transmitter was defect.
- Result:
 - Annulus-A transmitter functioning.
 - Pressurized annulus-A with nitrogen. Calculated a volume of approx. 20 m³ missing liquid.



Status

May 2023

- Suspected leak in primary barrier.
 - Annulus-A to tubing.
- Further action:
 - Liquid fill annulus-A and apply for dispensation to keep well in production.
- Integrity status changed: Yellow

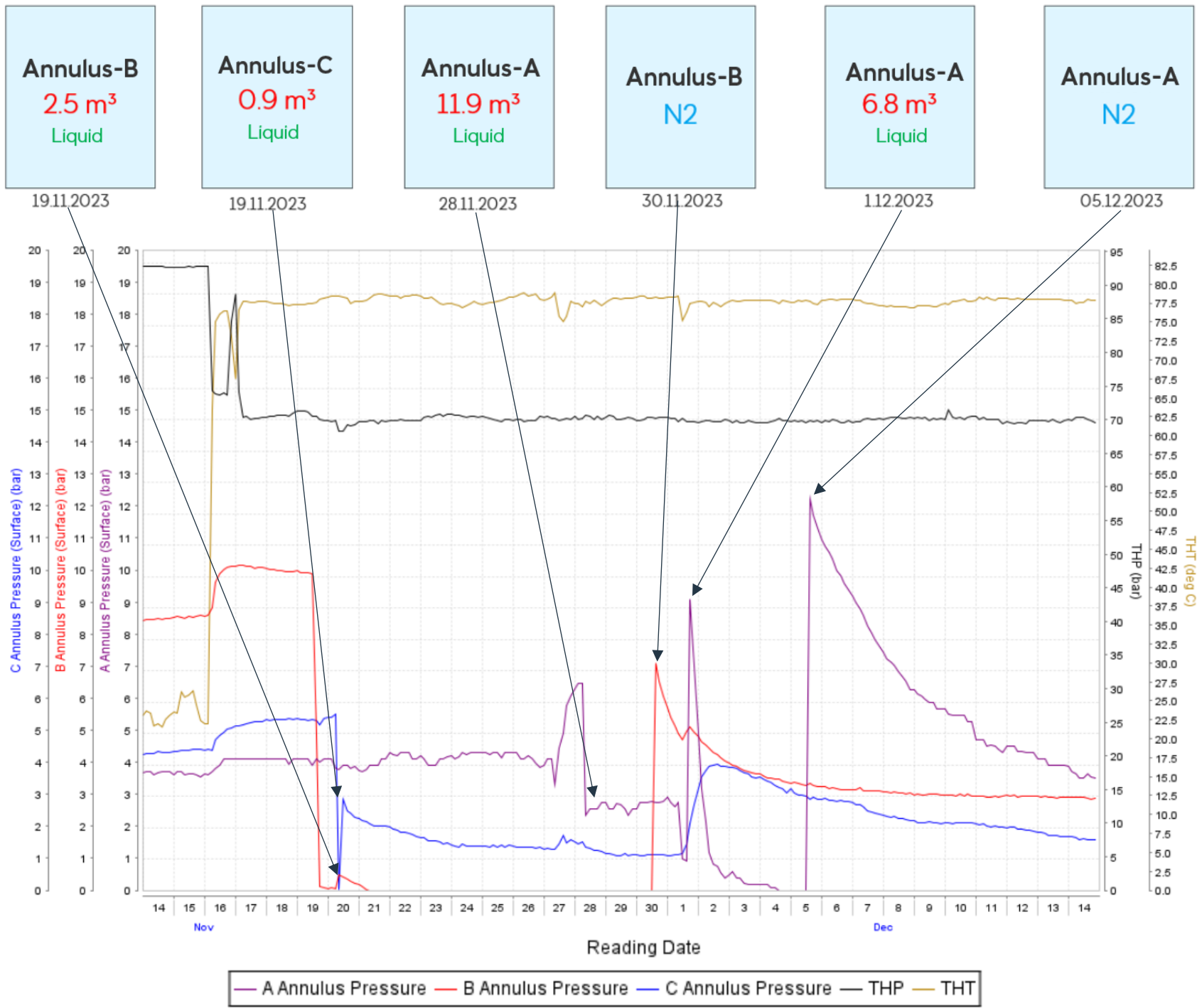


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5. PBR part of primary barrier, but status is continuously monitored			
6. Lokkeja i områdene MMV to be replaced/repaired			
7. A-annulus missing ca. 20 m ³ fluid. Equals 50% of annulus volume.			
Well Risk Status Code (marked X): Detailed information in iWIT			
A) PBR part of primary barrier			
B) Annulus-A missing ca. 20 m ³ fluid. Challenging to monitor primary barrier. Secondary barrier monitored by annulus-B.			
Closed Dispensations - Still Valid			
Comment			

Status

November/December 2023

- Annulus-B:
 - Filled 2.5 m³.
 - Cannot hold pressure.
- Annulus-A:
 - Filled 18.7 m³.
 - Cannot hold pressure.



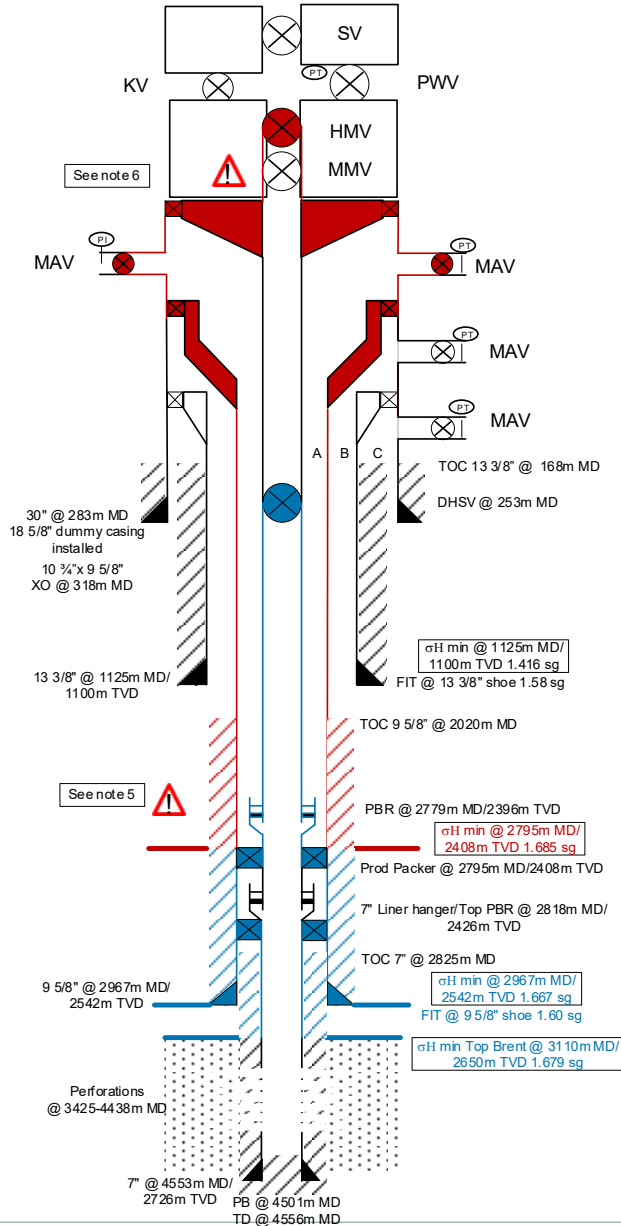
April 2023

Integrity status : Green

Well Status

The unknown condition

- Status April 2023:
 - Green integrity status.
 - No integrity issues to consider.
- Status May 2023:
 - Concluded that 20 m³ liquid is missing in annulus-A.
- Status November/December 2023:
 - Liquid filled annuli.
 - Annulus-A cannot hold pressure, A->T leak?
 - Annulus-B cannot hold pressure, B -> formation leak?



The unknown condition

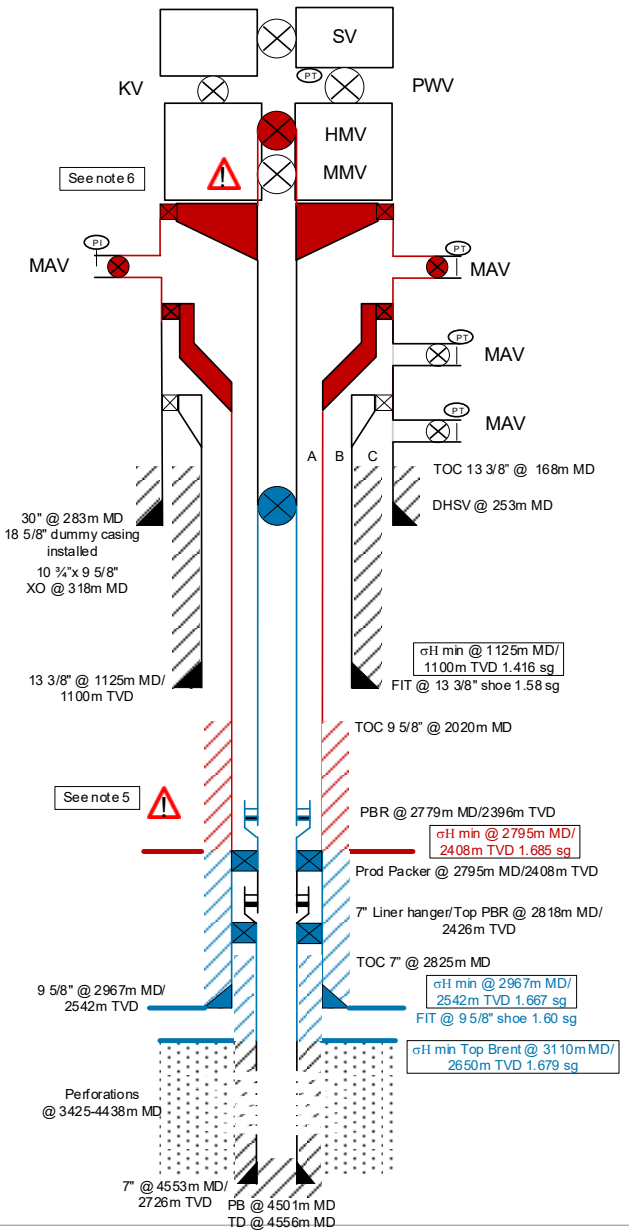


Well Status

The unknown condition

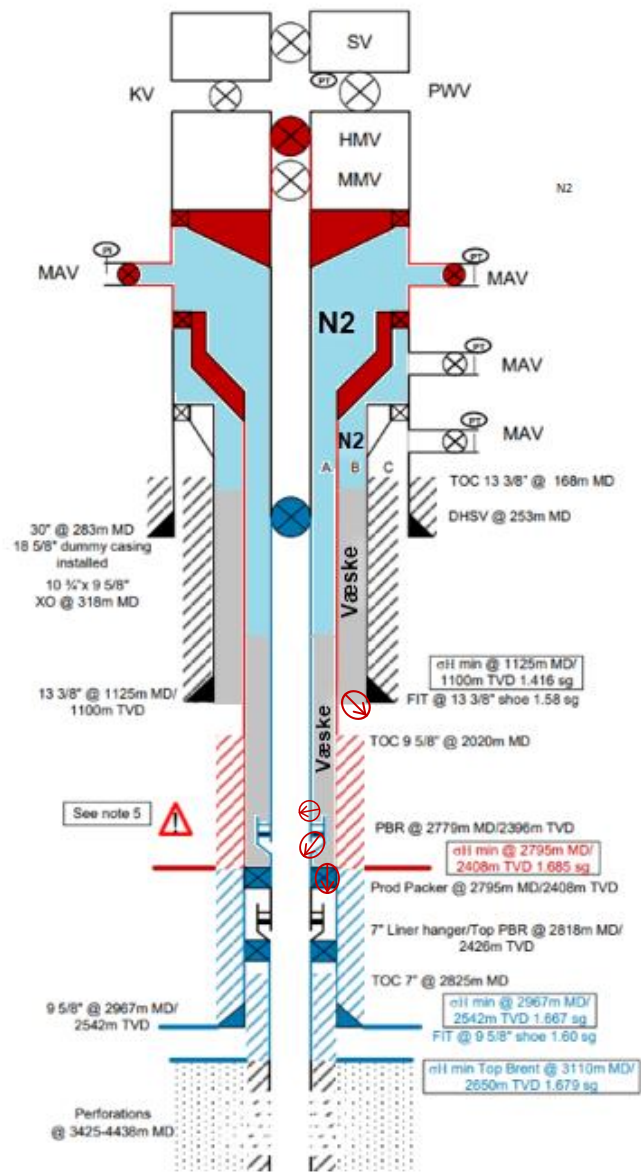
- Conclusion:
 - Leak in primary barrier.
 - Annulus-B cannot hold integrity.
 - One barrier left with unknown status.
 - Risk of potential collapse of secondary barrier.
- Well closed– Huge production loss.
- Well potentially outside of requirements from authority.
- Urgent mobilization of interventions.

April 2023
Integrity status : Green



Possible condition

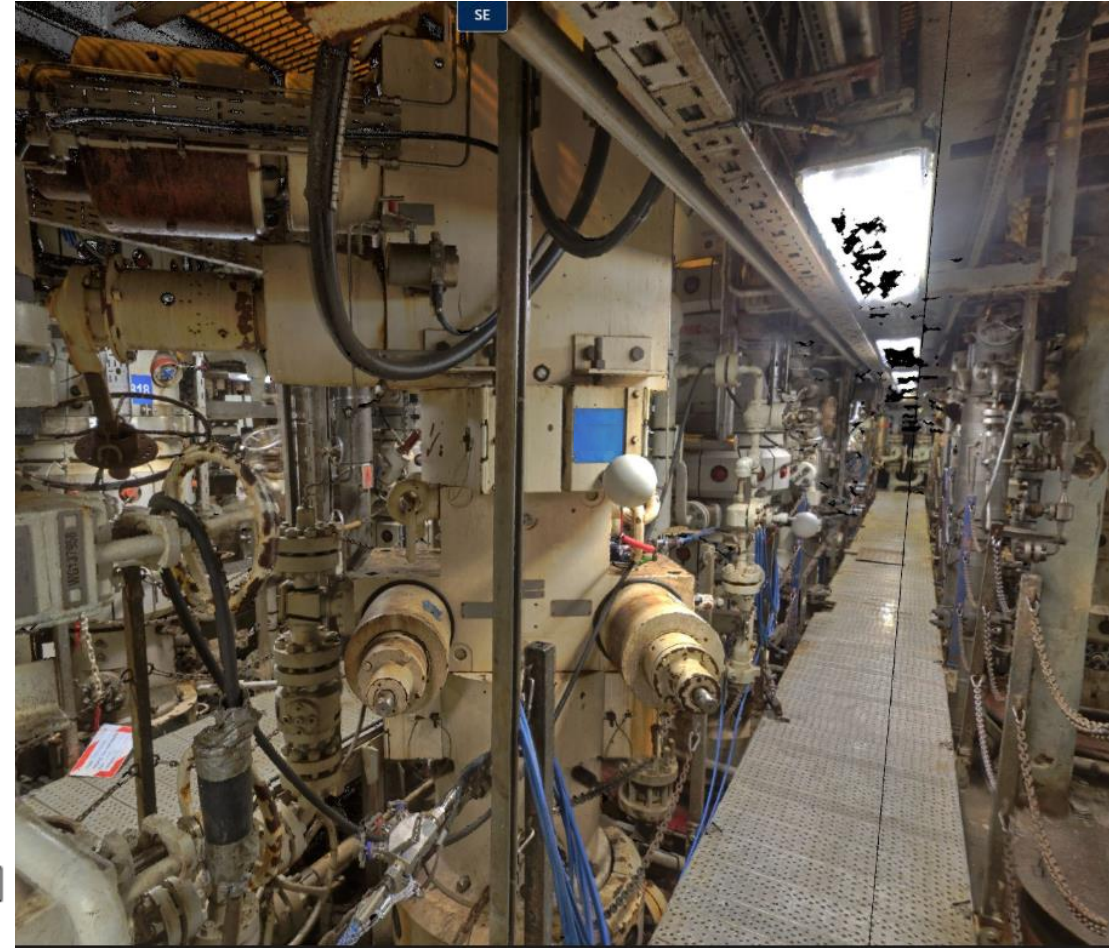
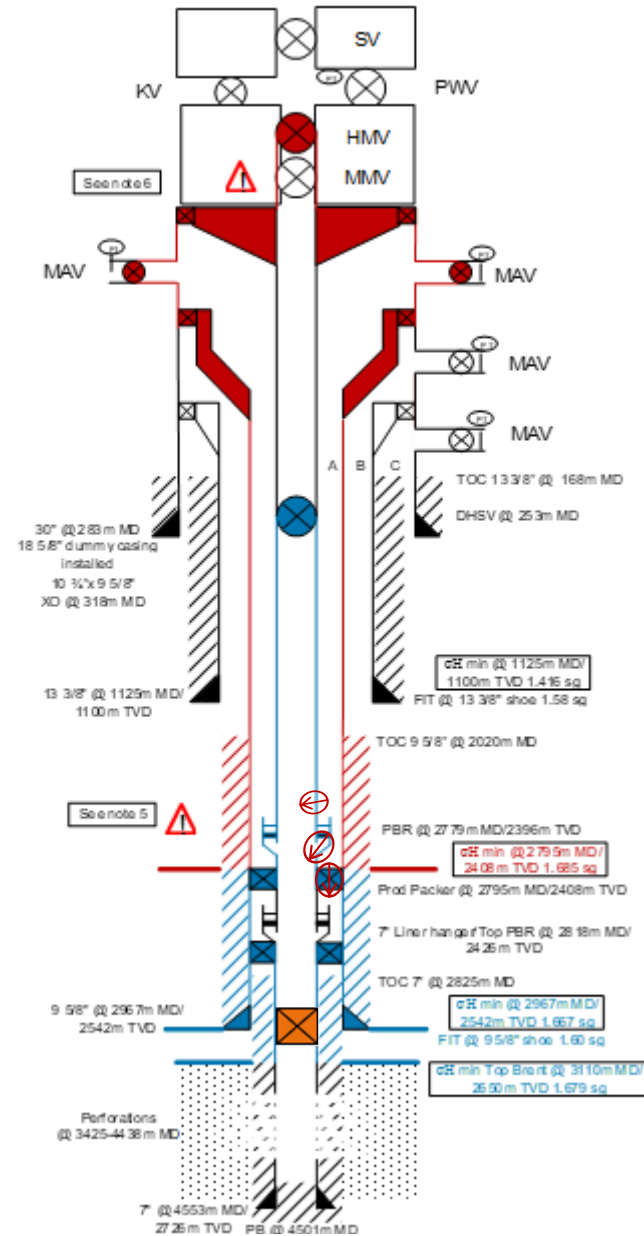
November 2023
Integrity status: Orange



Intervention

Job scope

- Task:
 - Verify condition of tubing.
 - Identify leak depth and WBE.
 - Verify condition of secondary barrier.
 - Consider possibility of straddle.

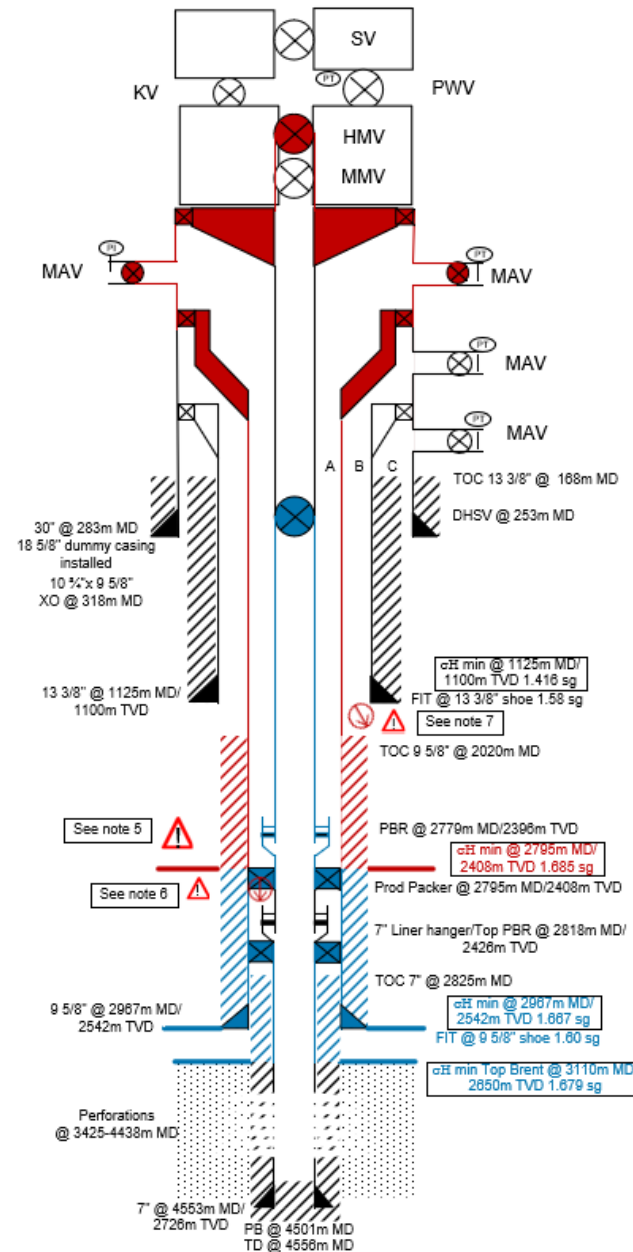


Intervention

March 2024

- Findings:
 - Tubing condition– good.
 - Leak in production packer.
 - Small leak.
 - Secondary barrier – intact.
 - No straddle.
 - Yellow integrity status.

- Applied for dispensation to continue operating well.
 - Implemented measures.
 - Well was put on drilling schedule for workover/re-drill.



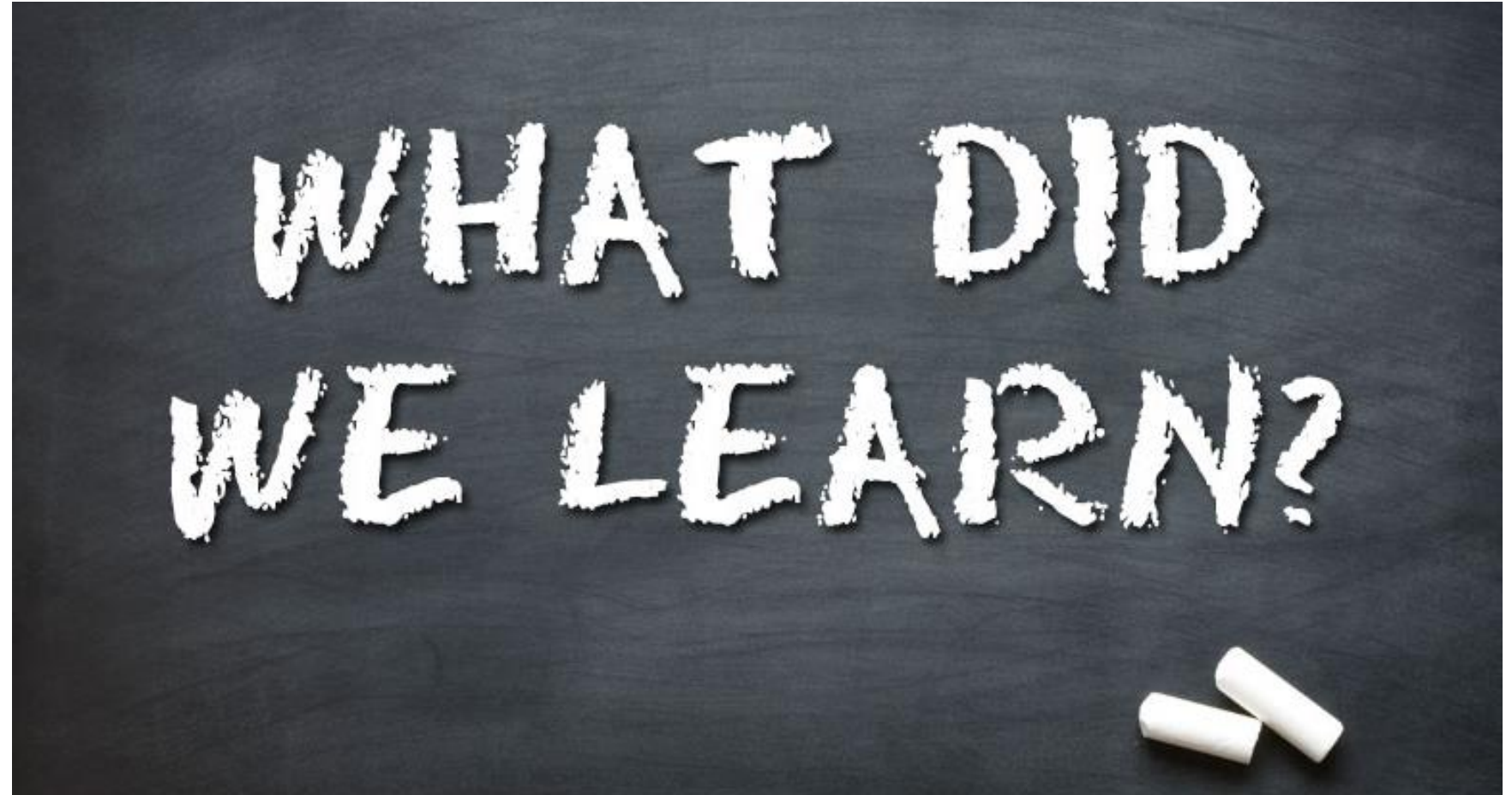
Reflection

- Reflection from audience:
 - Liquid filled annuli.
 - Does your organization/field have focus on this topic.



What did operations learn

- We lose control by regularly filling annulus with nitrogen.
- Implemented 12-24 months PM to liquid fill all annuli on all wells to improve integrity and control.
- Observation of a stable pressure trend over extended time on annuli should be checked.



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- We lose control by regularly filling annulus with nitrogen.
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WHAT DID
WE LEARN?

Low pressure in annuli does not prove
good integrity!



Main learning

- Good cooperation creates results!
- Ask questions and be curious.



Q

&

A

Thanks

Christer Andresen

