Exam PET 675 Spring 2021:

PART A, Well Integrity:

A.1: Well integrity management systems (WIMS) is a procedure that identifies technical, operational and organizational barriers to prevent hazardous occurrences by reducing the risk. This type of system addresses several factors, for instance well barriers and safety critical elements, performance standards, qualification and verification of a well barrier and reporting and documentation. These are only some f the factors used in a WIMS system, but the system is not restricted by the abovementioned factors only.

A.2: During a drilling operation, the main focus in accordance with well integrity issues is to ensure that formation is under control (preventing cave-ins, etc). The drilling fluid alone should be designed to provide enough overbalance to maintain the formation integrity, as well as preventing the reservoir fluids from leaking into the well. If the drilling has these properties during a drilling operation, it can be regarded as an acceptable well barrier element.

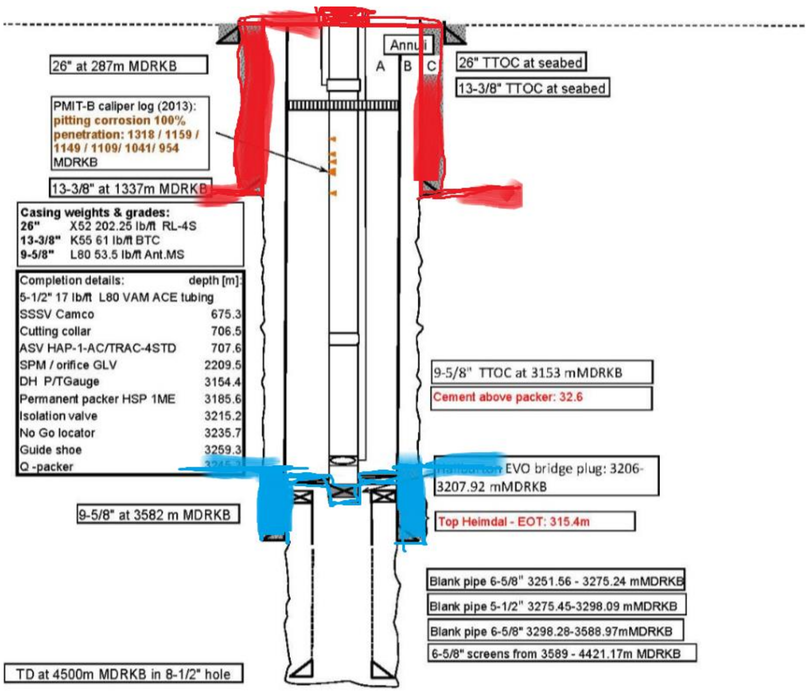
A.3:

- We have 100% pitting corrosion, indicating that there is a tubing leak at surface
- The leak indicates that there is still pressure building from the reservoir, which is an indicator that sustained casing pressure (SCP) is present
- 7m^3 of cement is lost during cement job at 9 5/8" casing, might be poor cement qualities and cause well integrity issue
- 9 5/8" casing is type L80, and should have been L80 Chrome or similar. This choice will most likely lead to a corroded casing due to gas zone in "Balder"

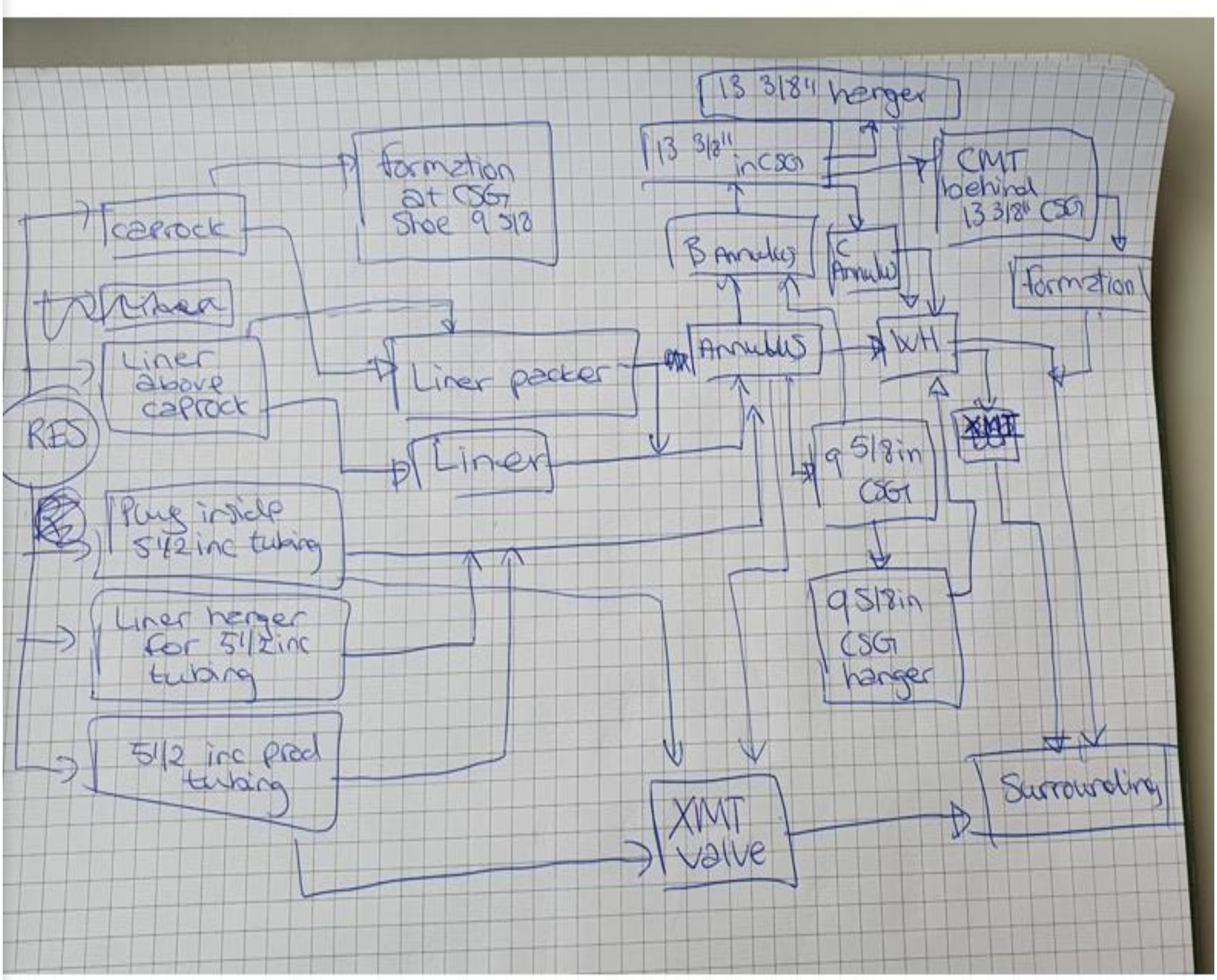
A.4:

Primary Well Barrier:
- Caprock
- 9 5/8" CSG
- 9 5/8" CSG CMT
- EVO Bridge plug
- Production Packer

Secondary Well Barrier
- In situ formation at 13 3/8" Casing shoe
- 13 3/8" CSG CMT
- 13 3/8 CSG
- Wellhead (Not visible on drawing)



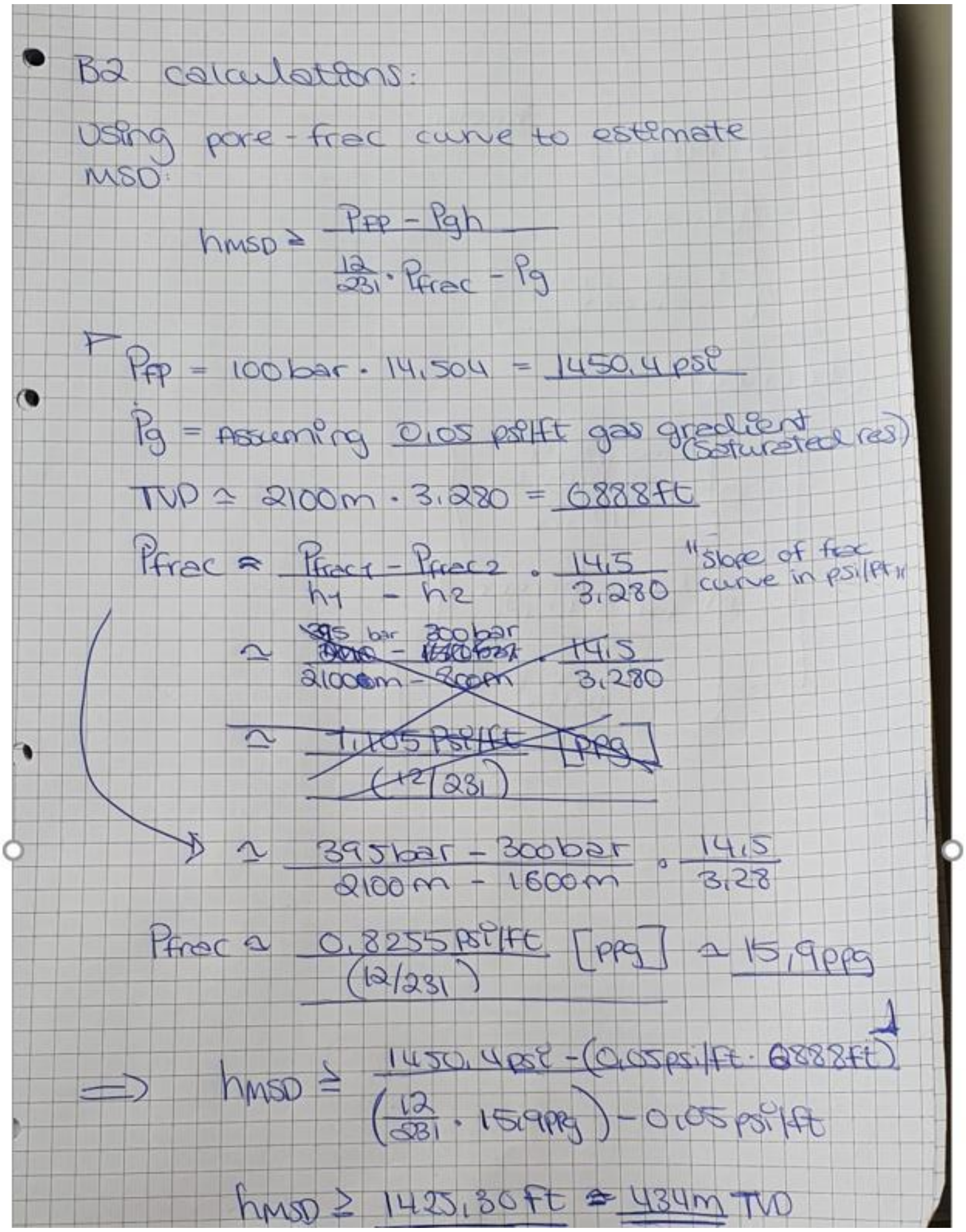
A.5: A well barrier diagram is created as an illustrative purpose so we can see all possible leak paths from the reservoir to its surrounding, and the WBD describes the status of a barrier element after a leak occurs.



PART B, Permanent P&A:

B.1: Phase 0 is considered as an information gathering and inspection phase. Activities that be done in phase zero is:
Inspecting the wellhead to check if it tolerates deration through historical data and fatigue analysis, then we can rig up a wireline (WL) unit. Then the WL unit can be employed to check wellbore access. This can be done by drilling and evaluating the condition of the production tubing by running a caliper log.. The caliper log is used to check corrision scale or similar in the production tubing.

B.2: The minimum setting depth is calculated to be 434mTVD.



B2 calculations:

Using pore - frac curve to estimate MSD:

$$h_{MSD} \geq \frac{P_{FP} - P_g h}{\frac{12}{231} \cdot P_{frac} - P_g}$$

$P_{FP} = 100 \text{ bar} \cdot 14{,}504 = 1450{,}4 \text{ psi}$

P_g = Assuming 0,05 psi/ft gas gradient (Saturated res)

$TVD \simeq 2100 m \cdot 3{,}280 = 6888 ft$

$$P_{frac} \approx \frac{P_{frac1} - P_{frac2}}{h_1 - h_2} \cdot \frac{14{,}5}{3{,}280}$$ "slope of frac curve in psi/ft"

~~$\simeq \frac{395 \text{ bar} - 300 \text{ bar}}{2100m - 800m} \cdot \frac{14{,}5}{3{,}280}$~~

~~$\simeq \frac{1{,}105 \text{ psi/ft}}{(12/231)} [ppg]$~~

$$\simeq \frac{395 bar - 300 bar}{2100 m - 1600 m} \cdot \frac{14{,}5}{3{,}28}$$

$$P_{frac} \simeq \frac{0{,}8255 \text{ psi/ft}}{(12/231)} [ppg] \simeq 15{,}9 ppg$$

$$\Rightarrow h_{MSD} \geq \frac{1450{,}4 psi - (0{,}05 psi/ft \cdot 6888 ft)}{\left(\frac{12}{231} \cdot 15{,}9 ppg\right) - 0{,}05 psi/ft}$$

$h_{MSD} \geq 1425{,}30 ft \simeq 434m$ TVD

B.3: The minimum setting depth is calculated to be 434mTVD. However, plugs are recommended to be installed as close to the reservoir as possible to reduce the amount of differential pressure build up. We have a Lista formation above the reservoir which is a formation that is permeable with flow potential. Therefore, we need:

A primary and a secondary Barrier above the main reservoir, which should be set above the Lista formation as it is permeable. For the primary and secondary barrier above the main reservoir, we can see form appendix A that there is no CMT behind casing, therefore a PWC operation would be beneficial. Then the plug can be verified by dressing off TOC and tagging It, then pressure test to see if the CMT holds.

B.4:

<u>- Perf, Wash and Cement (PWC)</u>

Advantages: Time and cost effective, no milling is required and the metal is left in place.
Cons: Effectiveness of washing procedure must be verified. There does not exist convenient qualification tools or technique to verify the established annular barrier. Perforation size and phasing angles when perforating needs more investigation for cases with eccentricity.

- <u>Upward Milling</u>

Advantages: No HSE issues in terms of swarf handling, its time and cost efficient, steel will no be a part of the permanent well barrier.
Cons: High inclination can cause the swarf to get stuck to the well leg.

<u>- Plasma based milling</u>

Advantages: Rigless operation due to the system being a CT solution, effective due to high ROP, No swarf generated.
Cons: Needs enough electrical power through transfer lines, not field proven yet, need a specific type of CT-reel.

B.5:

There seems to be a gas zone present on the pore-frac curve (by top balder), therefore A primary and a secondary Barrier above the gas zone which is located at "top Blader". For the primary and secondary barrier above the gas zone located at "top balder" we can have back to back plugs were you need 2x30m of CMT in annular space behind the CSG. The primary barrier CMT needs to be 100m. Since the secondary barrier rests on top of the primary (functioning as a mechanical foundation), we only need a minimum of 50m CMT for the secondary barrier. These barriers can also be tagged and pressure tested for verification purposes. The proposed depth of plugs is 1200mTVD to 1000mTVD.

We also have a water bearing zone, which need to be plugged. This can be done using a bridge plug and having CMT poured on top of it, acting as a primary barrier. Since we have a Leak of test in the appendix, we can verify if the plug holds by pressure testing the plug to 35 bar above the LOT as a this is recommended in NORSOK D010. Proposed depth I 400mTVD to 200mTVD.

B.6: The reason we need to have an environmental plug is to isolate our openhole annuli from the external environment. We also need to minimize the amount of swabbing fluid from the ocean or near surface fresh water that can seep into the formation through the created annuli, and we need to prevent possible leak paths from near surface sources. It should be named as an environmental plug and not a barrier, because there are claims that the environmental barrier does not provide a well barrier envelope as the surrounding formation can’t withhold large pressures and there exists a possibility for getting fluid getting around the barrier. Therefore, the functionality of the surface plug is often defined as “plug” rather than a “barrier”.

B.7: There are some changes I would have like to make. As previously mentioned, I would have used a chrome coated casing for the L80 9 5/8” casing. I also see that there has been used BTC threads, which I believe is not gas tight. I would have changed that with threads that are actually gas tight.