University of Stavanger

Faculty of Science and Technology

Department of Petroleum Engineering

SUBJECT:	**PET 605** **Well intervention and Plug & Abandonment**
DATE:	**21 February 2017**
TIME:	**09:00 – 13:00**
AID:	**Simple calculator**

THE EXAM CONSISTS OF 11 PAGES (including this front page and 1 appendix)

REMARKS: **The exam is divided into two parts**
Part A: Well intervention
Part B: Plug and abandonment
Each part counts 50% of the final grade

EXAM PART A - WELL INTERVENTION

Acronyms, equations and other information at the end of Part A

Maximum score is 100 points

SECTION I

Five short questions with three alternative answers (multiple choice). Indicate on your answer sheet the answer that you think is **most** correct. Please write the letter (A, B or C) and not the wording as your answer for each question.
Maximum score is 20 points.

Question I-1: Lost primary pressure barrier during CT live well intervention
You are running CT at 5000' and 4300 psi WHP when the BPV fails. What next?
Options:

A. Start circulation and pull back to surface with the CT.
B. Deploy the safety head BOP to cut the CT and seal off the wellbore.
C. Bullhead heavy mud through the CT and kill the well.

Question I-2: Lost primary pressure barrier during snubbing live well intervention
You are POOH with your snubbing pipe when the stripper rubber fails. The combination of pipe weight and pressure-area force is such that the pipe would be ejected from the well if unconstrained. What do you do?
Options:

A. Close two pipe rams and change the stripper rubber.
B. Continue POOH using the stripper rams.
C. Regulate the hydraulic pressure on the snubbing jack, pump dart and POOH.

Question I-3: Pipe light condition
While pipe light …
Options:

A. … the pressure-area force is equal to the BOP stripper friction force.
B. … the pipe would fall into the well if unconstrained.
C. … it is necessary to snub the pipe in the hole.

Question I-4: Real axial force and effective axial force
The effective axial force for pipe in a vertical well…
Options:

A. … is the same as the buoyed weight.
B. … is the same as the real axial force.
C. … is the same as the real axial force when the well is dead.

Question I-5: Design of kill-pill
Thermal expansion causes
Options:

A. ... decrease in density and hydrostatic pressure causes increase in density.
B. ... increase in density and hydrostatic pressure causes decrease in density.
C. ... decrease in density and hydrostatic pressure causes decrease in density.

SECTION II

Six short questions. Provide **short** answers on your answer sheet.
Maximum score is 30 points.

Question II-1: Coiled tubing well intervention BOP stack
Make sketch of a quad BOP system used for CT operations. On your sketch indicate the location for the flanged side-outlet that can be used to connect a safety kill line.

Question II-2: High-pressure well intervention using snubbing jack
What is ram-to-ram snubbing and what is the purpose of using this technique?

Question II-3: Buckling of pipe in a snubbing jack
In which two locations in a snubbing jack could buckling occur? Explain what type of buckling this is.

Question II-4: Cable type used in WL well intervention
What are the two main cable systems in use and what is the primary well control barrier for these two systems?

Question II-5: Maximum snub force
<u>Given:</u> TVD = 5000', BHP = 2200 psi, hydrostatic gradient of well fluid = 0.30 psi/ft, stripper rubber friction = 1000 lbs, work string OD = 2⅞", Hydril PH-6 joint OD = 3.687"
<u>Find:</u> What is the maximum snub force?

Question II-6: Axial stress at the bottom of a pipe
<u>Given:</u> TVD = 7000', WHP = 1350 psi, well fluid density = 10 lbs/gal
<u>Find:</u> What is the axial stress at the bottom of the pipe? Is it tension or compression?

SECTION III

Three questions. Provide answers on your answer sheet.
Maximum score is 30 points.

You are rigged up with RAS to mill barium sulphate scale from the inside wall of the production tubing using hydraulic drilling motor. Wellhead pressure is 2200 psi and the well is vertical. The work string is 3½" 15.5 lbs/ft drill pipe with inside diameter of 2.602". The milling fluid density is 9.625 lbs/gal. The annulus space outside the drill pipe is closed using the stripper rams and there is no rotation from the surface. Weight on bit during milling is 10000 lbs. The pipe inside pressure is 1500 psi greater than the outside pressure during the milling operation regardless of depth. Tensile force is positive and compressive force is negative. The length coordinate z = 0' at well bottom and z = 10000' on the surface. Neglect any hydraulic impact force.

Given calculations: $A_o = 9.621128$ in^2 and $A_i = 5.317463$ in^2. During scale milling, calculate at bottom (z = 0') that $p_o = 7200$ psi and $p_i = 8700$ psi.

Question III-1: Real axial force while milling
Consider equation $F_R(z) = a \cdot z + b$, where a has unit of lbs/ft and b has unit of lbs. What are the numerical values for a and b?

Question III-2: Effective force while milling
Consider equation $F_E(z) = c \cdot z + d$, where c has unit of lbs/ft and d has unit of lbs. What are the numerical values for c and d?

Question III-3: Buckled length while milling
What is length of the buckled portion of the pipe? Show calculation and explain your reasoning.

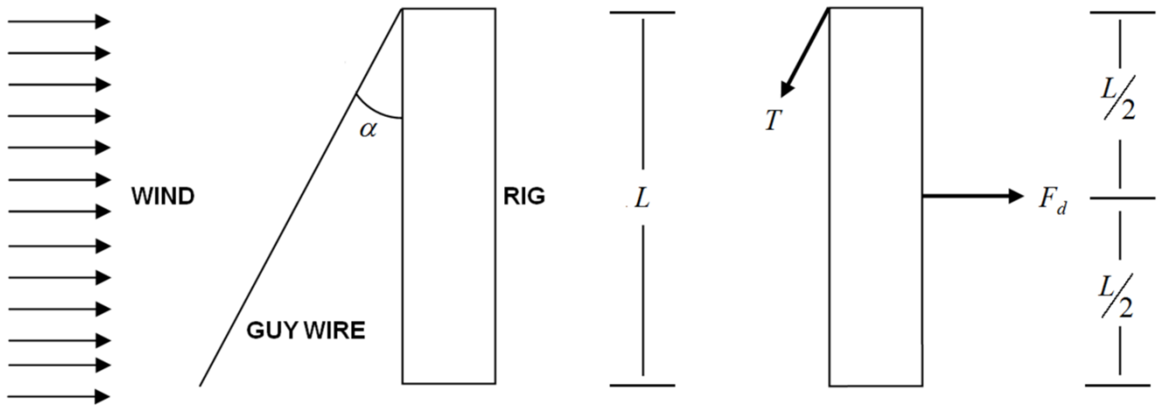
SECTION IV

Two questions. Provide answers on your answer sheet.
Maximum score is 20 points.

Question IV-1: Tripping speed for snubbing jack
Consider a Hydra Rig 225k four-legged snubbing jack with 5" cylinder bore and 3½" piston rods. Output from the hydraulic power pack is 231 gallons per minute.

Question: How many feet per minute does the travelling head move while RIH and POOH.

Question IV-2: Wind loading on rig
Your well site is generally very windy and lately the wind gusts have been picking up as the winter approaches. The well intervention rig is exposed to the wind as shown below and held in place by a single guy wire. As the field engineer on location you would like to determine how much wind velocity is required to break the guy wire. The structure is considered free to rotate at the base (worst case). The guy wire tension is T and α is the angle of the wire measured from vertical.



The drag force F_d caused by the wind is described in equation below. The four RHS parameters are air density, wind velocity, drag coefficient and cross-sectional are of the wall.

$$F_d = \frac{1}{2}\rho V^2 C_d A$$

Question: How do you express the guy wire tension T as a function of ρ, V, C_d, A and α?

Appendix - Part A

Used acronyms

API – American Petroleum Institute
BHP – bottomhole pressure (pressure in the well at reservoir depth)
BOP – blowout preventer
BPV – back-pressure valve
CT – coiled tubing
OD – outside diameter
POOH – pulling out of hole
RIH – running into hole
RLWI – riserless light well intervention
TVD – true vertical depth
WHP – wellhead pressure
WL – wireline

Equations and useful information

$F_E(z) = F_R(z) - A_i p_i(z) + A_o p_o(z)$	$w = \frac{12\rho A}{231}$ | w, lbs/ft | ρ, lbs/gal, A, in^2
$p = \frac{12\rho TVD}{231}$ | p, lbs/in^2 | ρ, lbs/gal, TVD, ft	$w = w_s + w_i - w_o$ $BF = \frac{\rho_s - \rho_f}{\rho_s}$
Density if steel = 65.5 lbs/gal = 7.85 sg 1 sg = 8.34 lbs/gal	231 in^3/gal, 12 inch/ft, 0.3048 m/ft, 2.54 cm/inch, 14.50377 psi/bar, 6894.757 Pa/psi, 0.224809 lbs/N
Short-hand for foot is termed '	Short-hand for inch is termed "

EXAM PART B – PLUG & ABANDONMEMT

Maximum score is 100 points

1. List well abandonment phases and describe them in your own words, briefly. (**5p**)

2. List three cement plug placement techniques and describe two of them in your own words, briefly. (**10p**)

3. What is the main difference between WELL SUSPENSION status and TEMPORARY ABANDONMENT status with respect to NORSOK D-010, third revision? (**5p**)

4. NORSOK Standard D-010 suggests some characteristics for potential permanent well barriers. List five characteristics. (**5p**)

5. Based on the Oil & Gas UK guidelines, issue 4, hydraulic testing is not recommended for verifying a permanent barrier in an open hole. What would be the reason and what technique is recommended? (**5p**)

6. List five critical material properties related to potential failure modes with respect to guidelines on qualification of materials for the suspension and abandonment of wells, Oil & Gas UK, Issue 1. (**5p**)

7. The following gradient curves, Figure 1, have been reported for a well. Based on the given information estimate the minimum setting depth for the plug and propose an interval for the plug placement. Explain the procedure briefly. (**5p**)

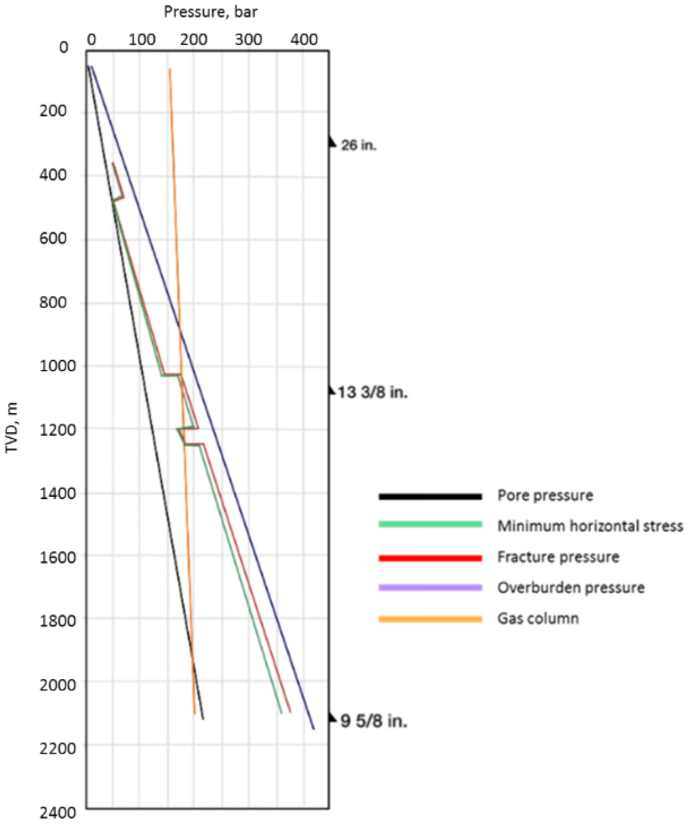


Figure 1 – Pore pressure – Fracture pressure gradient curves.

8. A plugging material sample, 1.5-in diameter and length of 1-in, failed under a tensile load (Brazilian test) of 20 kN (kilo Newton). Calculate tensile strength of the material in psi. (1 N = 0.2248 lbs). (**5p**)

9. A platform well (see Figure 2) has been drilled and completed with the vertical tree in 1985. Apparently, the Top of Cement (TOC) in the B-annulus is below the permanent packer. The well suffers from sustained casing pressure in the A- and B-annulus and caliper log shows big holes along the production tubing (shown with triangle on the well schematic). Operator decided to permanently plug and abandon the well. Through the operation, BOP has been necessitated to control the well pressure.

   a. List the primary and secondary well barrier elements for nippling-down the tree and nippling-up BOP. Write your assumptions if necessary. (**15p**)

   b. Create a decision-making flowchart for permanent P&A of reservoir zone only. Include the contingency plans. (**15p**)

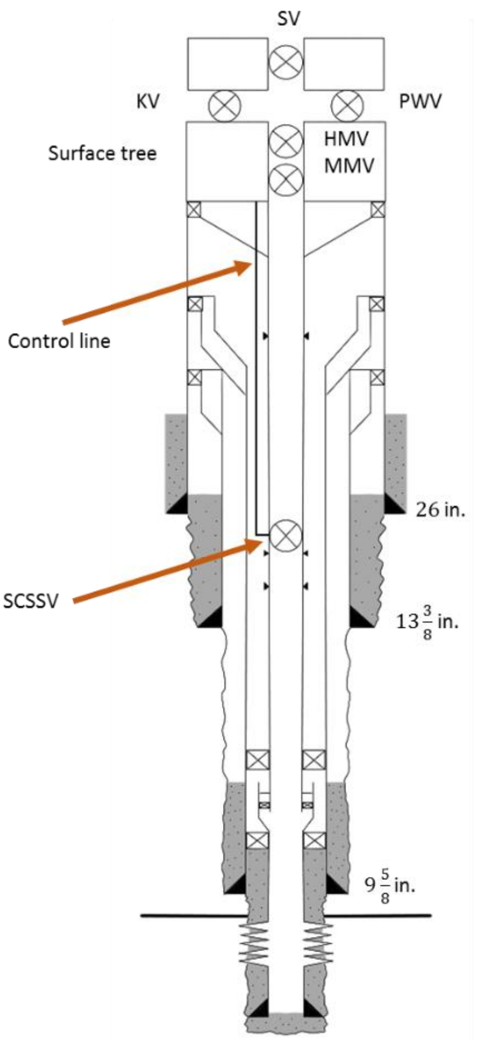


Figure 2 – A platform well completed with the vertical tree.

10. A primary cement job evaluation has been conducted by running an SBT (Segmented Bond Tool), which has been provided in Appendix A. Analyze the interval 2657-2671 meter and write your reflections on the quality of casing cement in this interval. List at least three reasons to support your reflections. Additional information: ATMN: Minimum Attenuation; ATMX: Maximum Attenuation; ATAV: Average Attenuation; CCL: Casing Collar Locator. (**15p**)

11. Which option is correct regarding Young's modulus? (**1p**)
    a. Materials with lower Young's moduli are more susceptible to failure when exposed to the common mechanical stresses
    b. It describes tensile elasticity or the tendency of a material to deform along ab axis when opposing forces are applied along that axis
    c. Young's modulus does not characterize the flexibility of a material
    d. None of the above mentioned options are correct

12. Regarding creep, all the followings are correct EXCEPT: (**1p**)
    a. It is a time-dependent deformation
    b. Material creeps to reduce high shear stresses
    c. Formation creep can lead to collapse of casing
    d. Instantaneous linear deformation under constant load

13. All the following options are correct EXCEPT: (**1p**)
    a. Poisson's ratio is defined as lateral strain to axial strain in a material loaded uniaxially in the axial direction
    b. Poisson's ratio is a unitless parameter
    c. Poisson's ratio allows calculation of shear failure
    d. Poisson's ratio allows calculation of lateral deformation of barrier under a given pressure and under temperature change

14. Which option is not a functional requirement of permanent barriers? (**1p**)
    a. Durability
    b. Position
    c. Placeability
    d. Grouts

15. All the followings are the roots which can cause leak around the bulk material EXCEPT: (**1p**)
    a. Shrinkage and expansion
    b. Chemical degradation
    c. Diffusive leakage
    d. Poor quality of barrier placement

16. All the followings are correct EXCEPT: (**1p**)
    a. In well logging, sound waves are generally characterized by their slowness, which is the inverse of velocity.
    b. A sound wave loses energy as it propagates through a material. This loss of energy is called amplitude.
    c. In cement logging, it is sometimes mistakenly assumed that the transit-time curve says something about the cement. In fact, the most valuable function of the transit-time curve is quality control.
    d. On a CBL-VDL curve, the chevron patterns at the casing collars are visible.

17. Choose the right answer based on NORSOK D-010, Rev. 4: (**1p**)
    a. Multiple reservoir zones/perforations located within the same pressure regime cannot be regarded as one reservoir.
    b. The casing cement between the casing and tubing shall be verified by pressure testing.
    c. It is not necessary to install a deep set plug when removing a horizontal XMT for P&A purposes.
    d. If the casing cement is verified by logging, a minimum of 100 m interval with acceptable bonding is required to act as a permanent external WBE.

18. In CBL/VDL log, the first quantitative measurement that performed on the full wave is the elapsed time between the transmitter firing and the arrival of the first part of the wave exceeding a preset amplitude threshold is called: (**1p**)
    a. Travel time
    b. Attenuation
    c. Transit time
    d. Amplitude

19. Absence of SCP (Sustained Casing Pressure) during the life cycle of the well indicates that … (**1p**)
    a. Poor sealing capability of the casing cement.
    b. Milling operations is necessary.
    c. Running leak off test is necessary.
    d. Good sealing capability of the casing cement.

20. In P&A operations, sometimes section milling is required. Fluids designed for section milling is one of the crucial parameters in section milling. Regarding fluids designed, all the following are correct EXCEPT: (**1p**)
    a. Fluids designed for section milling must have sufficient weight to keep the open hole stable.
    b. Fluids designed for section milling must have sufficient viscosity to suspend and transport swarf and debris to surface.
    c. The required fluid viscosity profile for milling operations can generate Equivalent Circulating Densities (ECD), which exceed the fracture gradient of the exposed open hole.
    d. Sticking of milling, clean out or underreaming challenges are not related to fluids designed for section milling.