University of Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT: PET 600 Well Completion

DATE: 18 Desember 2012

TIME: 0900-1300

AID: Calculator

Some formulas and unit conversion factor can be found in the Appendix.

Separate Attachment: NORSOK D010 rev 3

THE EXAM CONSISTS OF 20 PAGES INCLUDING APPENDIX.

NB: DO NOT WRITE YOUR ANSWERS ON THE EXAM SHEET. YOU MUST USE ORDINARY ANSWER SHEETS SO THAT WE HAVE TWO COPIES OF YOUR ANSWERS ?

PART I

Five short questions with three alternative answers (multiple choice). Please indicate the answer that you think is most correct.
The estimated time consumption is 0.25 hrs. The correct answer gives 2 points. Maximum score is 10 points.

Question I-1:

During an indirect displacement from reservoir drilling or reservoir completion fluid to completion brine ...

Options:

A. ... the annular preventer is closed and brine is pumped through kill or choke line.

B. ... the annular preventer is closed and returns are taken through kill or choke line.

C. ... spacers and chemical pills are not followed by the completion brine, but by available water.

Question I-2:

To achieve sand control in cased and perforated completions, after drilling to TD, and running and cementing the liner ...

Options:

A. ... (oriented perforations) the reservoir section of the well (plus some excess volume) is displaced to weighted perforation fluid, the well is perforated "oriented" in overbalance, guns are pulled and then further completion string(s) are run.

B. ... (cased and perforated with screen) the reservoir section of the well is displaced to brine, screens are run (cased and perforated with sand control), then the well is perforated in overbalance, guns are pulled and further completion string(s) are run

C. ... (frac pack completions) the reservoir section of the well (plus some excess volume) is displaced to weighted perforation fluid, the well is perforated in overbalance, guns are pulled, fluid is pumped to frac at perforation depth, then proppant is pumped, the screens are set and further completion string(s) are run.

Question I-3:

Which of the completion brines below has the highest density in saturated state?

Options:

A. Potassium formate

B. Potassium chloride

C. Sodium chloride

Question I-4:

Sand control in water injectors is about avoiding ... :

Options:

A. ... tubing wear and erosion of surface equipment

B. ... solids hold-up and poor well hydraulics

C. .... hole fill and poor injectivity

Question I-5:

A multipurpose well is according to NORSOK D-010, rev. 3 defined as ...:

Options:

A. ... a well that is used for production and injection purposes.

B. ... a multi-lateral well with at least two laterals.

C. ... a well that has transport of media to or from a formation interval via the A-annulus in addition to transport through the tubing.

PART II

Four short questions. Provide <u>short</u> answers on your answer sheet.
The estimated time consumption is 0.25 hrs. You can obtain 0-3 points for each answer. Maximum score is 12 points.

Question II-1: Displacements

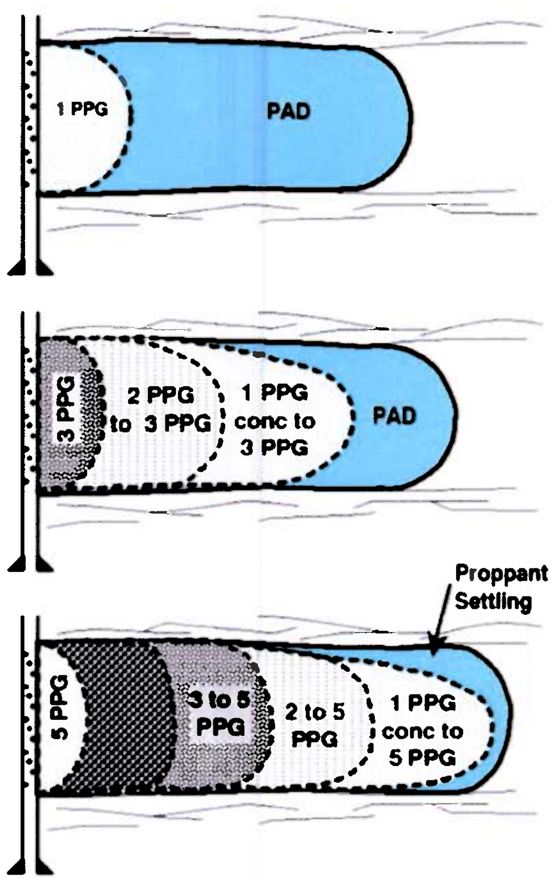
Please explain the method and objective behind performing a "staged displacement". What would be the disadvantages of this displacement method?

Question II-2: General completion

Why would you complete a well with a production packer rather than saving expenses for a packer and completing the well packer-less? Please give at least three (3) reasons!

Question II-3: Frac-packing

Please explain based on the drawing below the basic principles of a frac pack completion!



Question II-4: Rules and regulations

a) What does NORSOK D-010, rev. 3, mean by the term “common barrier element”?

b) What requirements apply according to NORSOK D-010, rev. 3, if common well barrier elements exist?

PART III Lower Completion

The estimated time consumption is 0.5 hrs. The maximum score for this part is 14 points.

Introduction

Consider drilling and completing a well from an integrated drilling rig installed on a wellhead platform with jacket substructure. The water depth is 120 metre. All depth below are with reference to mean sea level (MSL).

Consider the following operations as your basis for further work

- Drill 36 inch section to ~200 mTVDMSL, no inclination, run and cement 30 inch conductor to seabed
- Drill 24 inch section to ~1000 mTVDMSL, 20 deg inclinaton, run and cement 20 inch casing to seabed
- Drill 17½ inch section to ~1500 mTVDMSL, 20 – 60 deg inclination, run and cement 14 inch casing
- Drill 12¼ inch section to ~1900 mTVDMSL, 60 deg inclination, run and cement 9⅝ inch tieback liner
- Drill reservoir section with 8 ½ inch to well TD. Consider underreaming to 9 ½ inch. The horizontal section length of the reservoir section is about 500 meter.
- Run lower completion
- Run tieback casing and upper completion, incl. tubing hanger and X-mas tree.

Torque and drag simulations as well as cement hydraulics simulations have shown that the production casing has to be designed as a tieback solution with two parts, i.e.tieback liner and tieback casing. The upper completion will be designed around a 7" tubing string to allow for high production rates.

Question III.1

Formation evaluation shows that the reservoir sands are highly unconsolidated and require sand control. Based on a risk assessment you will have to choose a lower completion concept. Assume that you can choose between an openhole stand alone screen (SAS) completion and an openhole gravel pack (OHGP). Please list risks (minimum 3) and opportunities (minimum 3) of the OHGP method compared to SAS!

Question III.2

The concept that is chosen in this case is openhole horizontal gravel pack. For your lower completion, consider that sand screens including wash pipe, screen hanger, packer and gravel pack crossover tool have been run in hole to target depth and that the hanger with crossover tool has been set. Also, the wellbore has been displaced to clear brine (the gravel pack carrier fluid).

Consider the following typical steps in an OHHGP pump sequence:

1. Displacement of the clear brine by gravel pack slurry (carrier fluid and gravel) down to the crossover tool
2. Slurry transport along the screens and deposition of an "alpha wave".
3. Backward packing (beta wave) of gravel from bottom to top screen.
4. Screen out and annular pack off.

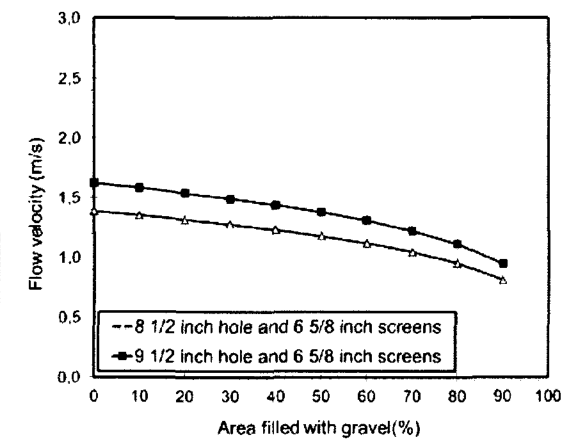
Please draw a diagram with a curve of the surface treating pressure as a function of the elapsed time during the gravel pack treatment. The diagram should show the development of the surface treating pressure during the 4 operational stages listed above! Please explain the pressure response!

Question III-3: Open hole horizontal gravel pack (OHHGP)

For the lower completion 6 5/8" screens will be used to minimize friction losses and drawdown effects along the reservoir section.

To perform a successful OHHGP, the required amount of gravel filled by the alpha wave is by several references given to 50 to 70% of the annular area. At a lower fill percentage, the Beta-wave pack will easily become incomplete leaving voids. At a higher fill percentage, the Beta-wave can be initiated prematurely leaving the lower part of the reservoir section free of gravel.

Based on a set of given fluid and gravel characteristics specialists calculated a relationship of critical velocities and percentage of the annular area fill as presented in the figure and table below.



	Critical Velocity	
	8 1/2 inch	9 1/2 inch
% - Area filled with gravel	(m/s)	(m/s)
0	1,39	1,62
10	1,35	1,58
20	1,32	1,54
30	1,28	1,49
40	1,23	1,44
50	1,18	1,38
60	1,12	1,31
70	1,05	1,22
80	0,95	1,11
90	0,81	0,95

Key parameters for this base case are:

Density carrier fluid (brine)	1300	kg/m^3
Density gravel	2700	kg/m^3
6 5/8 inch screen outer diameter OD	7,3	inch
Effective maximum pump rate	800	l/min
Effective minimum pump rate	400	l/min

Based on this information, please recommend the hole size that should be used in the reservoir section! Explain your answer by comparing actual flow rates during gravel packing with critical flow velocities for both scenarios, 8 ½ inch and 9 ½ inch hole size, respectively!

PART IV Upper Completion and Well Barriers

The estimated time consumption is 0.5 hrs. The maximum score for this part is 14 points.

Question IV-1:

The platform oil producers will be designed with gas lift due to low reservoir pressure and due to the water injection drainage strategy, that will cause water to break through to producers at some point during the life of the field.

The following operational steps present the completion program (i.e. the last two steps in the Introduction).

- Install sand screens
- Run 10¾" tie-back string
- Isolate reservoir section with a middle completion including a preset, deep set
- Install x-mas tree
- Displace well to
- Rig down BOP and
- Retrieve deep-set
- Perform open hole gravel pack
- Scrape production packer and tie-back
- Change out dummy valve to gas lift valve.
- Run upper completion.

TASK: Please sort the steps in correct sequence!

Question IV-2

Gas lift designs for these wells are challenging because of the production tieback casing, that is utilized. At the tieback point different methods may be applied to tie back casing to the 9 5/8 inch tieback liner and to adapt the completion string. Figure IV-1 presents a method without barrier qualified polished bore receptacle (PBR) yet with a mid-string packer between gas lift valves and production packer, while figure IV-2 shows a solution (yet to be verified) with barrier qualified PBR. Gas lift valves are not qualified as well barrier elements!

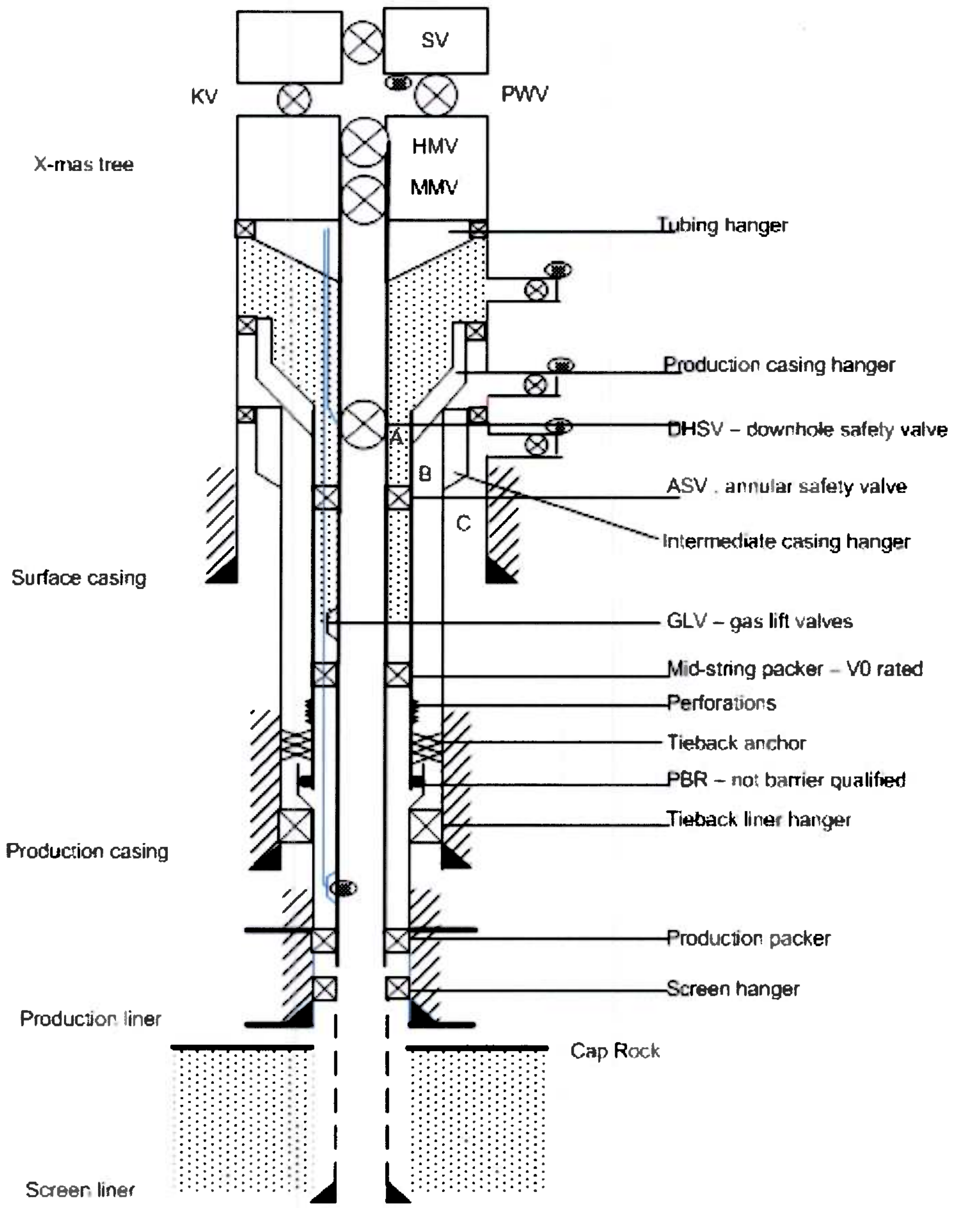


Figure IV-1 – Oil producer with gas lift and tieback production casing. PBR not barrier qualified.

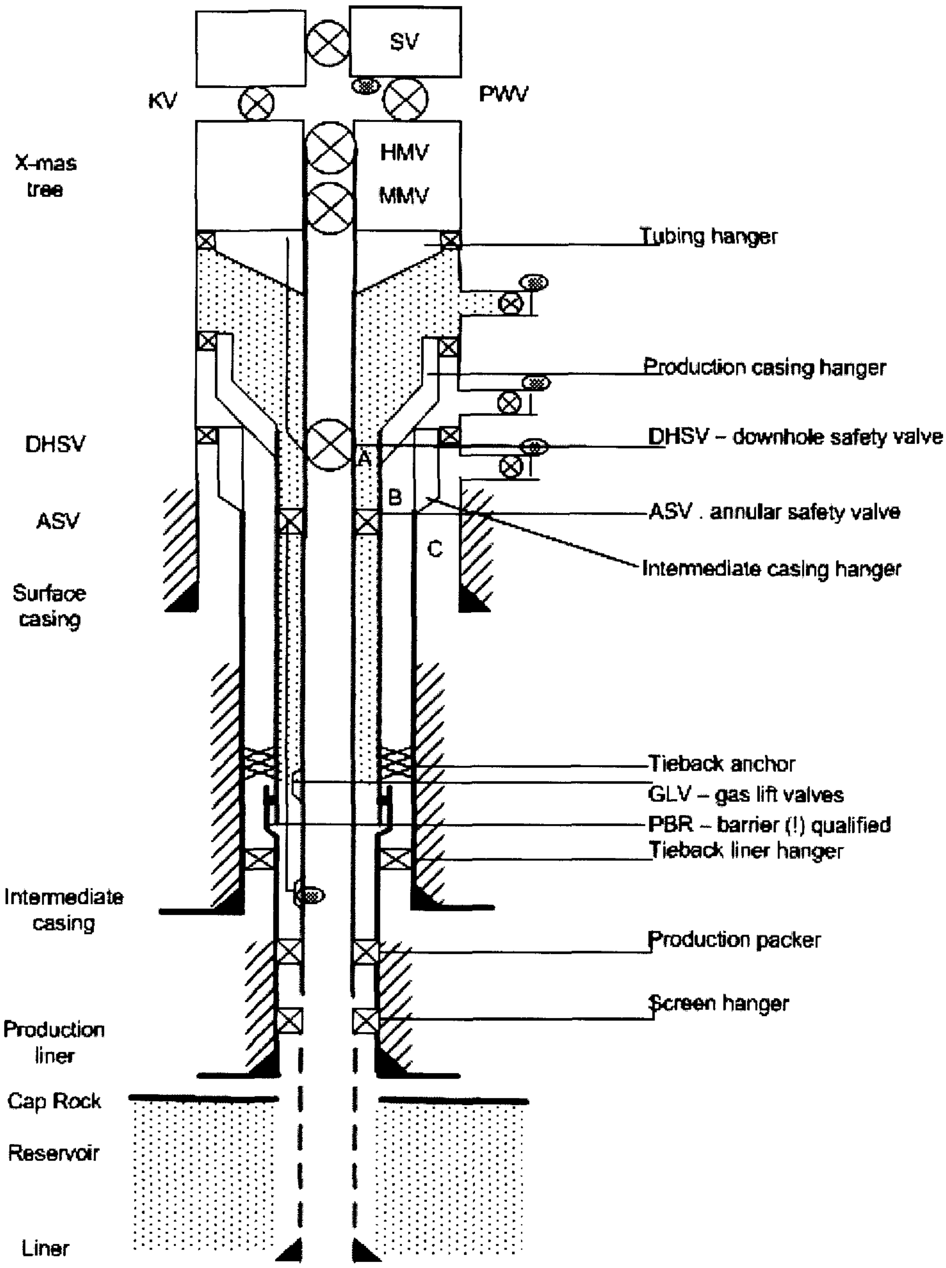


Figure IV-2 – Oil producer with gas lift and tieback production casing. PBR barrier qualified.

a) Please draw well barrier schematics for the primary barrier into Figure IV-1 and IV-2!

b) Set up well barrier tables and explain the primary barrier in both drawings!

Part V Material and grading

The estimated time consumption is 0.5 hrs. The maximum score for this part is 15 points.

Question V.1

From the 2006 well integrity survey performed by petroleum safety authority of Norway (PSA), which part of completion systems recorded a higher integrity problem? How can we detect if the systems shows leakage and how can we repair the leakage part?

Question V.2

Which stainless steel has high pitting resistance, high strength and high heat resistance? How much chromium does it contain at least? In which drilling environment the tubing is suitable to use?

Question V.3

Assume that a tensile test was performed on one of API tubing and the figure below shows part of the stress strain behavior. The test was performed at 75^0F. The dash part is to show the continuation of the Stress-strain curve. Based on these information please answer the following (a to d)

a) Is the stress –strain curve typical steel OR alloyed steel? Give your reason!

b) What is the Young's modulus of the material?

c) Grading of tubing consists of alphabetic and numeric coding. The specimen of Figure V.1 is one of the tubing that is available in the API standard. If the alphabet is C, what is the grade of the tubing? C-_?

d) From the manufacturer it is reported that the yield strength reduction rate of the tubing (Figure V.1) is 0.03% /^{o}F. If we use the tubing in the reservoir having an average temperature of 275^oF, what would be the yield strength of the tubing at this temperature?

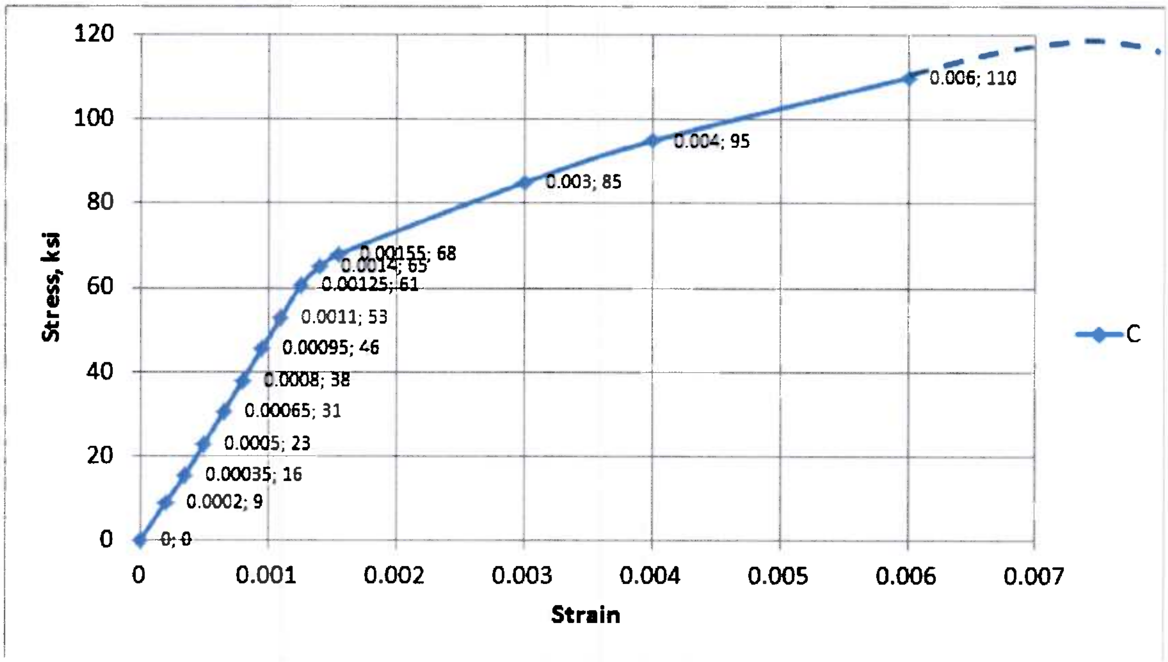


Figure V.1: Stress strain of specimen C

Part VI Completion and Tubing Design

The estimated time consumption is 0.5 hrs. The maximum score for this part is 15 points.

Question VI.1:

A company X has discovered two reservoirs (Carbonate and Sandstone), which are at a certain distance apart in a vertically drilled formation. Using dual packer, the company is planning to produce from these two reservoirs selectively using one tubing from the carbonate and the second tubing from the sandstone reservoir.

Your task is to sketch the completion design based on the company's desire. Remember also to place a blast joint on tubing and tell the reason why you would use a blast joint?

Question VI.2

Figure VI.1 is internally pressurized cylinder with inner and outer radius of *a* and *b* respectively. Assume that ID = 1" and OD = 3" and closed end tube. Based on the information provided, please answer the following questions (a and b)

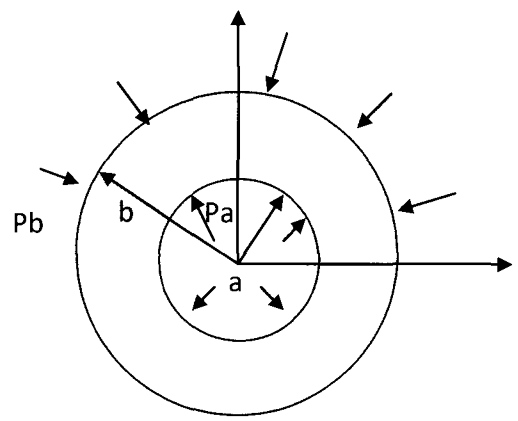


Figure VI.1

a) What kind of cylinder is this? Please tell your reason.

b) Please sketch the stress distribution across the wall thickness

Question VI.3:

Assume the hoop stress; the radial and the axial stress of a thin walled cylinder are given as the following. These stresses are principal stress. Using Von-Mises and Tresca failure criteria, one can determine the maximum allowable pressure ($P = P_y$) to be applied until the cylinder yields (σ_y).

$$\sigma_\theta = P\frac{r}{t} \qquad \sigma_z = P\frac{r}{2t} \qquad \sigma_r \approx 0$$

Applying the failure criterion, the pressure that causes the inner wall yielding to the yield stress ratio is given as: $\frac{P_y}{\sigma_y} = k\frac{t}{r}$

Answer the following by showing your work clearly (here SF = 1)

a) What is the value of "k" according to the Tresca failure criterion?

b) What is the value of "k" according to the Von-Mises failure criterion?

Question IV.4:

From the Wellplan exercise, you were asked to compare the theory and the results obtained from the Wellplan simulator. For this task, the magnitudes of the stresses at the given depth are given in alphabetic parameters as shown in Table VI.1. You are required to answer how you used the Von-Mises to calculate the yield stress. Please show how you did the exercises using the given data! The bended section experiences the following stresses at a given depth x-ft.

Table IV.1

Depth ft	Hoop Stress(psi)	Radial Stress(psi)	Axial Stress(psi)	Bending Stress(psi)	Torsional Shear Stress(psi)
x	h	r	a	b	s

Part VII - 3D Design & API collapse design

The estimated time consumption is 0.25 hrs. The maximum score for this part is 10 points.

Question VII.1:

Figure VII.1 shows the failure envelop of the tubing whose stress-strain is shown in Figure V.1. This tubing is going to be loaded with an inner pressure (P_i), outer pressure (P_o) and axial loads (σ_z) as given in Table VII.2 below. Based on the given data and the failure, does the loading cause any problem? If yes, what kind? Please show your work using the failure envelop!

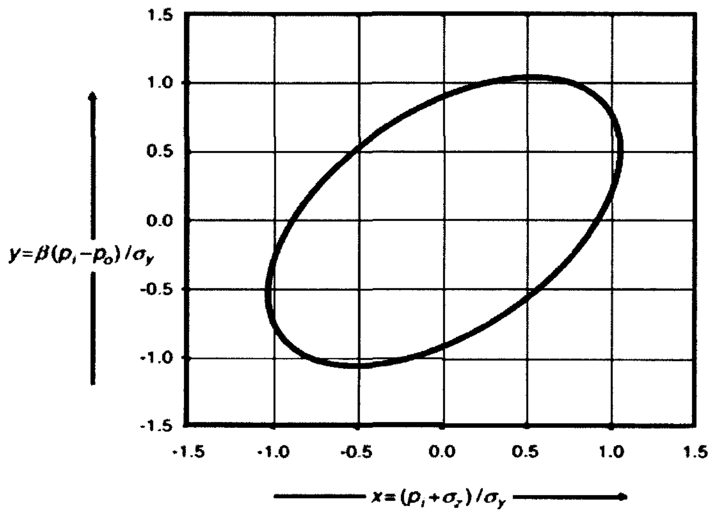


Figure VII.1: Failure envelope for Tubing described in Figure V.1

Table VII.2

β	$\beta.\frac{P_i}{\sigma_y}$	$\beta.\frac{P_o}{\sigma_y}$	$\frac{\sigma_z}{\sigma_y}$
11.36	0	0,68	-0,341

Question VII.2:

What are the Inner (Pi) and Outer (Po) pressures of the tube loaded in the failure envelope, Figure VII.1?

Question VII.3:

Now you are going to compute the collapse rating of the tubing specimen described in Figure V.1 using API formula. Assume that the geometry of the tubing mentioned in Figure V.1 is ID = 8.75 inch and OD =9.64 inch pipe. Please compute the collapse pressure of the tube!

Part VIII Corrosion

The estimated time consumption is 0.25 hrs. The maximum score for this part is 5 points.

a) What are the common types of corrosions in oil well?

b) Please write the common methods to prevent/control corrosion in Oil well

Part V: Conoco-Halliburton company-IO course

The estimated time consumption is 0.25 hrs. The maximum score for this part is 5 points.

a) What does IO stand for?

b) What is the main objective of IO? Please mention at least three elements!

c) To achieve the IO objectives, what are the three main key elements that IO uses?

d) What does SWOT stand for?

e) When planning IO service, one of the most important issues is the reliability of data transfer. Can we ever guaranty nonstop 24hrs data transfer? (YES or NO) If no, how can we minimize the risk? (Mention at least two!)

Formula sheet

Collapse modes				
Grade (ksi)	Elastic collapse (D/t)	Transitional Collapse (D/t)	Plastic Collapse (D/t)	Yield Collapse (D/t)
40	>42.60	27.01-42.64	16.40-27.01	<16.40
55	>37.21	25.01-37.21	14.81-25.01	<14.81
80	>31.02	22.47-31.02	13.38-22.47	<13.38
90	>29.18	21.69-29.18	13.01-21.69	<13.01
95	>28.36	21.33-28.36	12.85-21.33	<12.85
110	>26.22	20.41-26.22	12.44-20.41	<12.44
125	>24.46	19.63-24.46	12.11-19.63	<12.11
140	>22.98	18.97-22.98	11.84-18.97	<11.84
155	>21.70	18.37-21.70	11.59-18.37	<11.59

Transition collapse factors		
Grade (ksi)	F	G
40	2,063	0,0325
55	1,989	0,036
80	1,998	0,0434
90	2,017	0,0466
95	2,029	0,0482
110	2,053	0,0515
125	2,106	0,0582
140	2,146	0,0632
155	2,188	0,0683

Plastic collapse factors			
Grade (ksi)	A	B	C
40	2,95	0,0465	754
55	2,991	0,0541	1206
80	3,071	0,0667	1955
90	3,106	0,0718	2254
95	3,124	0,0743	2404
110	3,181	0,0819	2852
125	3,239	0,0895	3301
140	3,297	0,0971	3751
155	3,356	0,1047	4204

Failure criteria

$\sigma_y = \sigma_{max} - \sigma_{min}$

-
- $\sigma_y = \sqrt{\frac{1}{2}\left\{(\sigma_\theta - \sigma_r)^2 + (\sigma_r - \sigma_a)^2 + (\sigma_a - \sigma_\theta)^2\right\} + 3\tau^2}$

API collapse

Yield strength collapse pressure

$$P_c = 2\sigma_y\left[\frac{D/t - 1}{(D/t)^2}\right]$$

Plastic collapse pressure

$$P_c = \sigma_y\left[\frac{A'}{D/t} - B'\right] - C'$$

Plastic collapse transition pressure formula

$$P_c = \sigma_y\left[\frac{F}{D/t} - G\right]$$

Elastic collapse pressure formula

$$P_E = \frac{46.95x10^6}{(D/t)[(D/t) - 1]^2}$$

Dimensionless failure envelope analysis

$$x = (p_i + \sigma_a)/\sigma_y$$

$$y = \beta(p_i - p_o)/\sigma_y$$

$$SF = \frac{1}{[x^2 - xy + y^2]^{0.5}} = \frac{\sigma_y}{\sigma_{VME}}$$

$$y = \frac{x}{2} \pm \sqrt{\frac{1}{SF^2} - \frac{3}{4}x^2}$$

Temperature dependent yield stress

$$\sigma_y(T) = \sigma_y(T_o)[1 - x\%(T - T_o)]$$