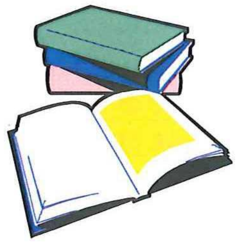
Drilling and Production Engineering (AES1330)

Written Examination

14 April 2014

- Write your name and personal student number ***clearly*** at the top of ***each*** page.
- Decimal points and comma's in this examination paper are used in the *English* manner,
- thus, for example 100,000 is hundred thousand, <u>not</u> 100 with three decimals !
- It is important to supplement all your answers with your personal calculation sheets, as points are also awarded for the actual method being applied.
- Use sketches and drawings freely if this will facilitate your calculations and / or make it easier to understand the actual situation in the exercise. (Note this also assists the examiner in judging the level of understanding in the event of an incorrect arithmetical answer)
- With this exercise, a simple and quick to use handout with ***tables*** has been given to you to speed up the search for the required capacities, buoyancy's, weights, etc.
- The exam is open book. This means that you are allowed to use the lecture notes and hand-outs given by the lecturers. Any other materials those mentioned above are forbidden. In particular any material with (your) hand written annotations are forbidden. It is also not permitted to use electronic devices with wireless function. Any student caught in violating these rules will be requested to leave the examination room immediately without prejudice of further disciplinary measures.



Marks allocation

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*Total*
Question 1	2	3	3	2					**10**
Question 2	2	3	2	5	1	2	2	1	**20**
Question 3	5	4	2	4					**15**
Question 4	2	5	8	5					**15**
Question 5	4	6	4	6					**20**
Question 6	2	5	8	2	3				**20**

Total : *100 pts.*

EXAM QUESTIONS

1. Tripping [10 pts.]

The following data is available:

Mudweight	1.68 sg
Drill pipe capacity	0.00915 m^3/m
Drill pipe metal displacement	0.00425 m^3/m
Casing capacity	0.0436 m^3/m
Average stand length	30 m
Slug weight	1.83 sg
Slug volume	3.0 m^3

2.1 Calculate the reduction in BHP if 5 stands are pulled wet [2 pts]
2.2 What pressure would the annular pressure gauge read if a heavy slug is pumped and the annular preventer shut in directly after pumping the slug [3 pts]
2.3 Calculate the drop in level in the drillpipe if the annular preventer is opened [3 pts]
2.4 Calculate the returned volume after pumping the heavy slug [2 pts]

2. Well control [20 pts.]

We are now drilling the 6" hole section with high uncertainties in terms of reservoir pressures. At a depth of 3800 m AHD/TVD, the well kicks and the Driller closes in the well.
The following information has been pre-recorded:

Drill String (from bottom up)	
- 26 pcs 4-3/4" OD by 2-1/4" Drill Collar (each Drill Collar is 10 m)	Capacity: 2.57 l/m
- 145 pcs of 3-1/2" OD Drill Pipe (each Drill Pipe is 9 m)	Capacity: 3.37 l/m
- 5" OD Drill Pipe to surface	Capacity: 9.05 l/m
Annulus	
- Annular Capacity between 4-3/4" Drill Collar and 6" Open Hole	Capacity: 6.80 l/m
- Annular Capacity between 3-1/2" Drill Pipe and 6" Open Hole	Capacity: 11.70 l/m
- Annular Capacity between 3-1/2" Drill Pipe and 7" Liner	Capacity: 12.80 l/m
- Annular Capacity between 3-1/2" Drill Pipe and 9-5/8" Casing	Capacity: 31.60 l/m
- Annular Capacity between 5" Drill Pipe and 9-5/8" Casing	Capacity: 24.90 l/m
Casing	
- 7" OD Liner: 423 N/m	Set between 3000 – 2300 m
- Leak-Off Pressure	5000 kPa
- Drilling Fluid Gradient during Leak-Off	12.8 kPa/m
Drilling Fluid and Pump	
- Current Drilling Fluid Gradient	12.8 kPa/m
- Slow Circulation Pressure at 25 Strokes/min	3600 kPa
- Mud Pump Output (at 97% efficiency)	15 litres/stroke

Closed in well information:

- Stabilised Shut-In Drill Pipe Pressure or SIDPP [P_{DP}]: 4500 kPa
- Stabilised Shut-In Casing Pressure or SICP [P_{ANN}]: 6000 kPa
- Influx volume: 2715 litres

2.1 Calculate the Reservoir Pressure at 3800 m. [2 pts.].
2.2 Calculate the Formation Strength Gradient in kPa/m at 3000 m [3 pts.]
2.3 Calculate the Kill Mud Gradient (round off value to one decimal behind point). [2 pts.]
2.4 Calculate the Strokes for Phase 1 and the Strokes from Bit to Surface. [5 pts.]
2.5 How many minutes would it take to pump Phase 1 [from Surface to Bit] if we use a circulating rate of 25 strokes/min. [1 pt.]
2.6 If we apply the Wait and Weight Method, what would be the Circulation Pressure from Phase 2 onwards. [2 pts.]
2.7 When the well is closed in, where is the top of the influx? [2 pt.] and what is the influx gradient [2 pts.]
2.8 Briefly explain how we observe migration of the influx [without circulation]? [1 pt.]

3. Liner cementation [15 pts.]

8-1/2" hole has been drilled to a section TD of 3858 mAH (along hole). The 9-5/8" shoe is at 3367 mAH. The 7" liner is ran to 3857 mAH, the liner hanger is at 3265 mAH.

The following data is available:

Depth of 8-1/2" hole	3858 mAH
7" liner data	
Depth of 7" liner	3857 mAH
Top of liner hanger	3265 mAH
Shoetrack length	30 m
Weight of liner	423 N/m
9-5/8" casing data	
9-5/8" shoe depth	3367 mAH
Weight of 9-5/8" casing	686 N/m
Capacity data:	
Capacity of liner	19.38 l/m
Capacity of 5" drill pipe	9.05 l/m
Annular capacity 8-1/2" hole / 7"liner	11.80 l/m
Annular capacity 9-5/8" casing / 7"liner	13.35 l/m
Annular capacity 9-5/8" casing / 5" drill pipe	24.90 l/m
Cement data:	
Planned top of cement	Liner top
Excess cement slurry over open hole	20%
Spacer data:	
Water spacer ahead of slurry	5 m^3
Water spacer after slurry	1 m^3

3.1. Calculate the required volume of cement slurry [5 pts.]
3.2. Calculate the volume of drilling fluid required to bump the top plug, released after the cement has been pumped [4 pts.]
3.3. Why is often a liner used instead of an entire surface casing string? [2 pts.]
3.4. Calculate the pressure difference between the shoe and the annulus after the cementation [4 pts.]

4. Casing Design [15 pts.]

The following API data is given for 9 5/8" C-75 casing.

C-75 9 5/8 inch casing		
	Nominal weight lbs/ft	
Minimum collapse pressure (psi)	36.00	
	40.00	2980
	43.50	3750
	47.00	4630
	53.50	6380
Maximum burst pressure (psi)	36.00	
	40.00	5390
	43.50	5930
	47.00	6440
	53.50	7430
Maximum allowable tensile load (1000 lbs)	36.00	
	40.00	975
	43.50	975
	47.00	1032
	53.50	1173

4.1. What are the usual "collapse" design criteria for a casing? [2 pts.]

4.2. A vertical gas production well has the 9 5/8" intermediate casing string set at depth 7000 ft. The pressure gradient for water is 0.4335 psi/ft, and the specific gravity of the drilling mud down to 7000 ft is 1.4. Calculate the collapse gradient for the 9 5/8" string. [5 pts.]

4.3. It is found that the burst criterion is satisfied for all casings under consideration. Design the 9 5/8" casing string using the collapse criterion, using the API data given above. [8 pts.]

4.4. Calculate the total weight of the 9 5/8" casing string, and check that the designed casing can satisfy the tensile load criterion, with a design factor of 1.6 [5 pts.]

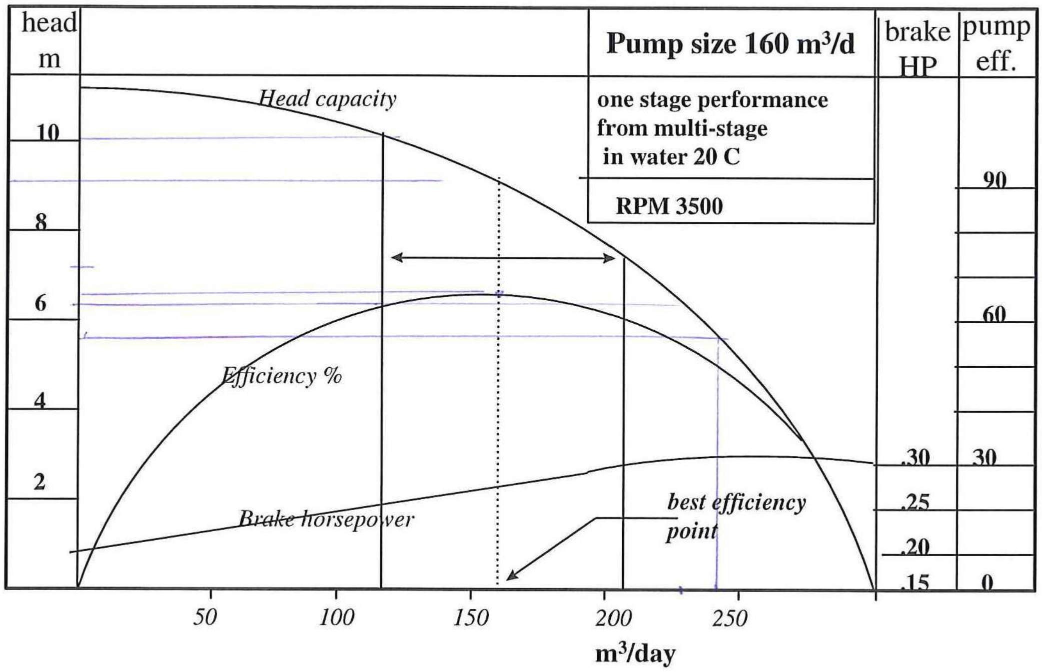
5. Artificial lift [20 pts.]

In an oilfield it is planned to produce oil from a well at 1500 bbl/day. No water is produced from the wells. The oil reservoir is at a depth of 10000 ft. The reservoir pressure is 3000 psi and the Productivity index of the well is 3.5 bbl/day/psi.

An ESP is installed at the bottom of the well. The required pressure at the outlet of the ESP is 2400 psi, in order to achieve the required tubing head pressure.

5.1. Compute the pressure difference that must be supplied by the pump at the planned production rate (1000 bbl/day). [5 pts.]

5.2. Determine how many stages should the ESP have, based on the following performance curve (1 psi = 6.89 kPa, 1 bbl = 0.159 m3) [5 pts.]



5.3. According to the performance curve, what are the maximum and minimum flow rates at which the pump operates efficiently? What are the pressure increases supplied by the pump at the minimum and maximum rates? [5 pts.]

5.4. The speed of the pump can be changed by altering the driving frequency. How does the flow rate vary with frequency? If the frequency is changed from 50 Hz to 60 Hz, what will be the new minimum and maximum operating flow rates and the corresponding pressure increases supplied by the pump. [5 pts.]

6. Stimulation [20 pts.]

In an oil field it is planned to stimulate a well drilled into a sandstone reservoir matrix acidizing treatment. The wellbore has diameter 20 cm. The interval to be treated is 50 m in height.

One of the minerals present in the reservoir is kaolinite. The sandstone has porosity 0.25 and it contains 2% of kaolonite ($Al_4Si_4O_{10}(OH)_8$). The molecular mass of kaolinite is 516.4 g/mole and its density is 2800 kg/m^3

Mud-acid, that is an HF/HCl acid blend, formed of 1.5% by wt HF and 13.5% HCl is used to do the acidizing treatment. and of HF 20 g/mole. The density of the acid blend is 1070 kg/m^3 and of kaolonite. We recall that the primary dissolution reaction for kaolinite is given by

$$Al_4Si_4O_{10}(OH)_8 + 24\ HF + 4H^+ \leftrightarrow 4AlF_2^+ + 4SiF_4 + 18H_2O$$

6.1. What is the goal of the pre-flush, the main flush and the post-flush in matrix acidizing of sandstone formations. [2 pts.]

6.2. Compute the Volumetric Dissolving Power of HF for the above primary reaction. [5 pts.]

6.3. The damaged interval is treated with 60 m^3 of mud-acid. Assuming that the acid penetrates uniformly into the formation compute the depth from the wellbore for which all the mud-acid will react with all kaolinite. [8 pts.]

6.4. Indicate three potential problems in pumping acid into long open-hole intervals and how they can they be avoid. [2 pts.]

6.5. list three possible causes for the failure of a mud-acid with high HF concentrations. [3 pts.]