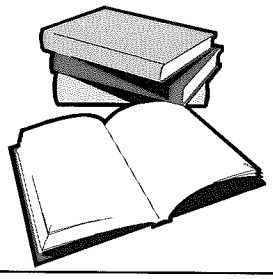
EXAMINATION: AES1330 Drilling & Production Engineering

21 June 2010

- 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, not 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)
- You may consult all your study books and notes. With this exam, 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.
- It is ***not permitted*** to bring old examination papers to the examination room. In the event that the invigilator observes any candidate with an old paper, then the individual involved will be requested to leave the examination room immediately.



Marks allocation

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Total*
Question 1	5	2	2	2	2	2					**15**
Question 2	2	2	2	4	3	2					**15**
Question 3	6	2	2								**10**
Question 4	2	2	2	2	2	2	2	2	2	2	**20**
Question 5	5	6	8	6							**25**
Question 6	2	5	5	3							**15**
TOTAL											**100**

Total : *100 points*

1. Casing Cementation [15 pts]

The 12-1/4" hole has been drilled to section TD (total depth). The 9-5/8" casing is run without problems and the cementation is the next job on our list.

The following data is available:-

Depth of 12-1/4" Hole:	2810 m
Data on 9-5/8" Casing	
- Depth of 9-5/8" Casing:	2800 m
- Weight of 9-5/8" Casing:	79.62 kg/m [53.5 lb/ft]
- Shoetrack Length:	25 m
Data on 13-3/8" Casing	
- Depth of 13-3/8" Casing:	1455 m
- Weight of 13-3/8" Casing:	101.2 kg/m [68 lb/ft]
Cement Parameters	
- Cement Slurry Gradient:	15.6 kPa/m
- Yield Value of Dry Cement:	31.2 litres/sack
- Mix Water for Cement Slurry:	27.1 litres/sack
- Planned 'Top of Cement'	1255 m
- Excess cement slurry over '**open hole**'	20%
Drilling Fluid and Spacers	
- Gradient of Drilling Fluid:	11.8 kPa/m
- Drilling Fluid Buoyancy Factor	0.847
- Gradient of Water Spacer:	10.0 kPa/m
- Water Spacer **Ahead** of Slurry:	5 m^3
- Water Spacer **Behind** Slurry:	1 m^3

1.1 Calculate the required volume of **Cement Slurry** [5 pts].
Capacity data:

Ann. Cap 12-1/4" hole/9-5/8" Casing:	29.10 l/m
Ann. Cap 13-3/8" casing / 9-5/8" Casing:	31.16 l/m
Capacity 9-5/8" Casing:	36.91 l/m

1.2 Calculate the total amount (in metric tons] of **Dry Cement** for this cement slurry. Note that one sack of cement weighs 42.6 kg. [2 pts]

1.3 Calculate the total amount [in m^3 or litres] of **Mix Water** for this cement slurry, including the spacers ahead and behind. [2 pts]

1.4 Calculate total **Volume of Drilling Fluid** required to bump the cementing plugs. [2 pts]

1.5 What is the **reason** for pumping a large volume [5m^3] water spacer ahead of the cement slurry? [2 pts]

1.6 What is the weight of the casing string in mud? [2 pts]

2. Well Control [15 pts]

We are drilling a long 12-1/4" hole section at 2720m MD/TVD. The well kicks quite unexpectedly, because reservoir sections at this depth have been prognosed poorly. But the crew was alert and succeeded in closing in the well timely.
The following information has been pre-recorded:-

	S.I. Units
Drill String (all joints 10m)	
- 12 x 8-1/4 OD x 2-1/4" ID Drill Collars	Capacity: 2.57 l/m
- 18 x 5" HWDP	Capacity: 4.61 l/m
- 5" Drill Pipe to Surface	Capacity: 8.97 l/m
Mud Gradient:	15.2 kPa/m
Leak-Off Pressure:	4375 kPa
Mud Gradient during Leak-Off	12.8 kPa/m
Slow Circ. Press. at 40 SPM	3200 kPa
Mud Pump Output (at 97% efficiency)	16 litres/stroke
13-3/8" Casing, N80, 101.2 kg/m [68 lb/ft]	Shoe at 927m

Closed in well information:
- Stabilised SIDPP [P_{DP}]: 815 kPa
- Stabilised SICP [P_{ANN}]: 1370 kPa
- Influx volume: 3.5 m^3

2.1 Calculate the **MAASP** [2 pts].

2.2 Calculate the **Reservoir Pressure** at 2720m [2 pt]

2.3 Calculate the **Kill Mud Gradient** (round off value to one decimal behind point) [2 pts]

2.4 Construct the **Kill Graph on scale** [4 pts] for a 'Wait and Weight Method' and a kill rate of **40 SPM**, clearly showing:
- SIDPP [P_{DP}]
- PL (= P_{C1} at 40 SPM)
- ICP [P_{ST}]
- FCP [P_{C2}]
- Strokes for Phase 1

2.5 The influx height across the Drill Collars/HWDP has been calculated to have a TV height of 83 m. Calculate the **influx gradient**. What type of influx have we encountered? (water, oil or gas) [3 pts]

2.6 What would be the **Circulation Pressure** from Phase 2 onwards [2 pts]

3. Well Design [10 pts]

3.1 A deviated exploration well is drilled through a hydrocarbon trap (inclined limestone layer). The top of the reservoir is found at 3288m AH (2795m TVD). The following information is available.

- Top Oil Water Contact [OWC] is found at 3500m AH (2945m TVD)
- The Gas Oil Contact [GOC] is found at 3359m AH (2845m TVD)
- Formation pressure at OWC is measured to be 14.05 kPa/m
- Oil gradient is 7.80 kPa/m
- and gas gradient is 2.30 kPa/m

What would be the **minimum Mud Density** to drill this well? [6 pts]

3.2 The 12-1/4" hole is being drilled with 8-1/4" Drill Collars and 5" HWDP. All joints are 10m long. The 8-1/2" Drill Collars weigh 239 kg/m and the HWDP weigh 74 kg/m. The mud gradient is 12.0 kPa/m with a buoyancy factor of 0.844. We only have 10 joints of Drill Collars on location. If we would like to use a minimum of 27 Mton Weight-on-Bit [WOB], **how many HWDP joints** would you use (as a minimum)? Note: only 90% of the Drill Collars and HWDP may be placed in compression. [2 pts]

3.3 The kick-off in a 16" hole of a deviated well is at 1000m. The first 100m (to 1100m AH) have been drilled with bent on a motor and we have achieved 10 deg inclination and 90 deg True North azimuth. The remainder of the build section will be drilled with a conventional rotary assembly and MWD (no mudmotor !) What would the **BHA** look like to ensure we can drill the build-up section to 60 deg with a build-up rate of approx. 3 deg/30m? What is the name of such a **rotary build-up assembly**? [2 pts]

4. Short General Knowledge Questions [20]

4.1 We have just closed in the well after experiencing a gas kick. It takes up to 20 minutes before the drill pipe and annulus pressures stabilize. What is the most likely cause for this long(er) duration? [2 pts]

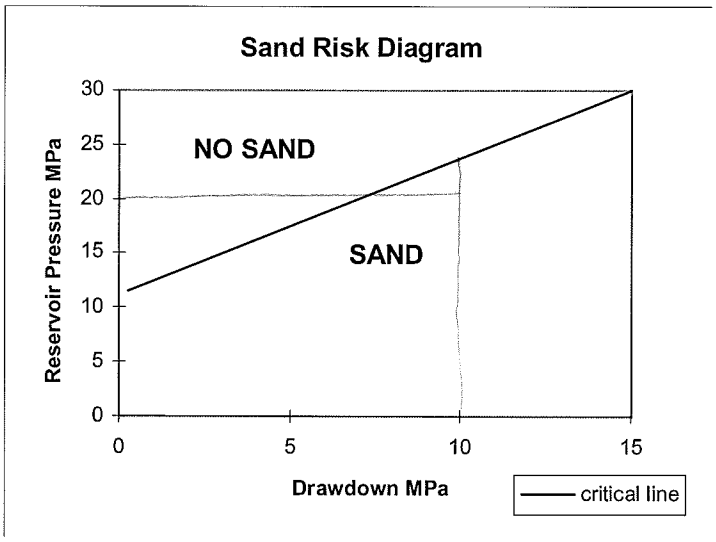
4.2 What do we mean with the term 'differential sticking' and mention 3 causes. [2 pts]

4.3 Mention at least 2 differences between a PDC and a TSP drilling bit [2 pts]

4.4 The Driller is running in the hole and experiences hole problems. The bit and string are unable to go down and we are not able to circulate or rotate the string either. What action should the Driller take? Briefly describe this operation and its limitation. [2 pts]

4.5 Mention the two pieces of devices used during the drilling phase to monitor the well for influxes and losses. Explain briefly the operating principle of each monitoring device [2 pts]

4.6 The initial pressure in a reservoir is 20 MPa. The initial production rate from a well is planned at 2000 m^3/day, and the PI is 200 m^3/day/Mpa. The sand risk diagram is given below. Do you anticipate sand production? [2 pts]



4.7 Describe the difference between over-balanced and under-balanced perforating. What are the advantages of each method? [2 pts]

4.8 Name three types of deposition that can occur in a well as a result of phase changes. Describe how to prevent one of these types of deposition. [2 pts]

4.9 A well completion is designed for safe operations. Name 3 other aims that are important in designing the well completion. [2 pts]

4.10 A hydraulic fracture is created in a vertical well. The minimum horizontal principal stress is oriented North-South. In which direction do you expect the fracture to propagate? [2 pts]

5. Casing Design [25 pts]

The API data for 9 5/8" casing is given on the next page.

5.1. What are the usual "**collapse" design criteria** for a casing? [5 pts]

5.2. A vertical gas production well is producing from a reservoir interval at a depth of 7300 - 7500 ft. The well has a 9 5/8" intermediate casing string set at depth 7000 ft and a 7" liner landed at 7500 ft and hung-off with a packer in the 9 5/8" casing at 6900 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. [6 pts]

5.3 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. [8 pts]

5.4 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 [6 pts]

DIMENSIONS					
Total cross-section area (sq.in)	**Weight per foot (lbs)**	**Inside diameter (in)**	**Inside cross-section area (sq.in)**	**Wall thickness (in)**	**Metal cross section area (sq.in)**
72.760	36.00 40.00 43.50 47.00 53.50	8.921 8.835 8.755 8.681 8.535	62.502 61.308 60.201 59.188 57.216	0.352 0.395 0.435 0.472 0.545	10.258 11.452 12.559 13.572 15.544
	Nominal weight lbs/ft	**K55**	**C-75**	**N-80**	**P-110**
Minimum collapse pressure	36.00	2020			
psi	40.00	2570	2980	3090	
	43.50		3750	3810	4430
	47.00		4630	4750	5310
	53.50		6380	6620	7930
Maximum burst pressure	36.00	3520			
psi	40.00	3950	5390	5750	
	43.50		5930	6330	8700
	47.00		6440	6870	9440
	53.50		7430	7930	10900
Maximum allowable tensile load	36.00				
1000 lbs	40.00	975	975	1027	
	43.50		975	1027	1283
	47.00		1032	1086	1358
	53.50		1173	1235	1544

6. Stimulation [15 pts]

6.1 Explain the roles of **the pre-flush**, the **main flush** and the **post-flush** in matrix acidizing of sandstone formations. [2 pts]

6.2 In a sandstone acidizing treatment. The **mud-acid** is an HF/HCl acid blend, formed of 1.5%

by wt HF and 13.5% HCl. One of the minerals present is kaolinite $Al_4Si_4O_{10}(OH)_8$. Calculate the **Volumetric Dissolving Power** for HF for the primary reaction given by

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

The molecular mass of kaolinite is 516.4 and of HF 20. The density of the acid blend is 1070 kg/m^3 and of kaolonite 2800 kg/m^3. [5 pts]

6.3 The wellbore has diameter of 20 cm. The interval to be treated is 50m in height. The mud-acid must react with all kaolinite to a depth of 30 cm from the wellbore (over the whole of the 50m interval). The sandstone has porosity 0.25 and it contains 2% of kaolonite. What is the minimum **mud-acid volume** in m^3? [5 pts]

6.4 What are the potential problems in pumping acid into such a long **open-hole interval**. How can you try to avoid these? [3 pts]