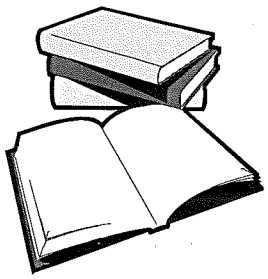
EXAMINATION: AES1330 Drilling & Production Engineering

21 August 2009

- 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.
- 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	4	3	4	2	2					**20**
Question 2	6	4	2	2	6						**20**
Question 3	2	1	3	1	3	2	2	3	2	1	**20**
Question 4	2	3	5	5	5						**20**
Question 5	5	5	5	5	5						**20**
TOTAL											**100**

Total : *100 points*

1. Drill String [20 pts]

A driller is running a drill string with drill collars [DC] and heavy weight drill pipe [HWDP]. The supervisor has instructed him to use no more than 200 kN 'Weight-on-Bit' [WOB], which means that he must run enough drill collars and heavy weight drill pipe in the mud to reach this WOB. On the pipe rack he find 10 joints of DCs and 30 joints of HWDP. Each joint is 9.5m long.

Further information:

Item	Outside Diameter (OD)		Inside Diameter (ID)		Weight / m
	mm	inches	mm	inches	kg/m
Drill Collars	165.1	6 1/2	71.4	2 13/16	135.4
HWDP	127	5	76.2	3	73.4

We also know:-
-Mud gradient is12.2 kPa/m with a Buoyancy Factor of 0.841
-The "neutral point" in the BHA has to be at **90%** of the total BHA buoyant weight.

1.1. Calculate the **minimum** number of HWDP that the driller must run in order to achieve the criteria of 200 kN weight on bit. Ensure to use **all** available drill collars below the HWDP.

1.2. Whilst drilling ahead, a sudden weight loss of 33 kN is observed, accompanied by a large pressure loss at the pump. It is concluded that the drill string has broken. Calculate the number of drill collars (and HWDPs?) that have been lost down hole.

1.3. Recalculate the **number of HWDPs** to achieve 200 kN weight on bottom in the event that the hole is deviated by 35 degrees inclination. The entire BHA is in the inclined section.

1.4. We now have to insert and place **stabilisers** to drop the well deviation from 35 degrees to vertical. We do not have a mud-motor, so the directional control will need to be accomplished by placing the stabilisers in the right place. Where would you place the stabiliser in the drill collars? and what do we call such a Bottom Hole Assembly?

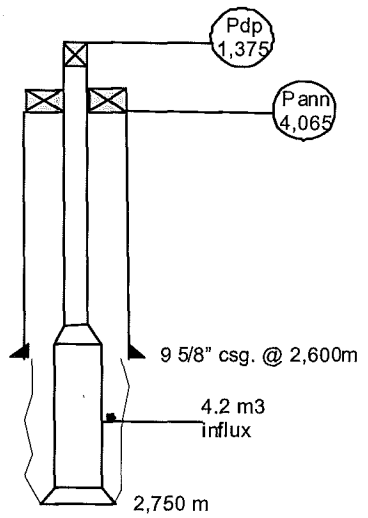
1.5. What is the significance of the **'neutral point'** in a Bottom Hole Assembly?

1.6. Describe how we achieve **sealing** between the **tool joints** of drill collars, HWDP and drill pipe?

2. Well Control [20 pts]

Prior drilling out the 9 5/8" casing shoe at 2600m, a well was displaced to a new mud with a density of 13.2 kPa/m. A leak off test was performed which resulted in a leak off at an EMG (Equivalent Mud Gradient) of 15.02 kPa/m. Whilst drilling ahead at a depth of 2750 meter a ***'kick'*** is experienced. The Driller closes in the well. He observes an influx volume of **4.2 m³**. The driller collects and records all the data associated with the kick as follows:

Drill string pressure P_{dp}	**1,375 kPa**
Annulus pressure P_{ann}	**4,065 kPa**
Drilling Fluid Gradient	13.2 kPa/m
Slow circulating pressure @ 30 strokes/min	4,900 kPa
Capacity between drill collars & hole	13.5 l/m
Capacity between drill collar & casing	15.8 l/m
Capacity between drill pipe & casing	25.8 l/m
Length of drill collars in the hole	158 m
Pump output	13.88 l/stroke



2.1 What is the **height of the influx** in the annulus, and the influx gradient (in kPa/m).

2.2 Was the MAASP value exceeded when the well was closed in? - Show calculations to validate your answer. *Hint: Determine top of influx, is in open hole or casing?*

2.3 What mud weight should be used to kill the well?

2.4 The well kill is started and an initial standpipe pressure of 6,275 kPa is recorded. What will the standpipe pressure be whilst circulating during Phase 1, during Phase 2, during Phase 3, and during Phase 4 of the well kill?

2.5 How many strokes are required to circulate the **entire influx** out of the well?

3. General knowledge and short calculation questions. [10 pts]

3.1 In a well the casing shoe has been set at 2455 meters; the shoe track drilled out, and new hole drilled to 2480 meters. A formation *leak-off test* (formation strength test) was performed and the maximum stable pressure at surface during this test was 6,850 kPa. The drilling fluid in the hole has a density of 12.6 kPa/m.

If we lower the drilling fluid density from 12.6 to 11.9 kPa/m (during the drilling phase hereafter), what will then be the new MAASP (*Maximum Allowable Annular Surface Pressure)* value ?

3.2 What are PDC cutters? What makes PDC bits drill so fast in most claystone formations.

3.3 A vertical well is completed with 3-1/2" production tubing with a circulating tool (we call it 'Sliding Side Door) set at 4,210 m. The annulus is filled with a completion fluid having a gradient of 13.8 kPa/m whereas the tubing is filled with oil having a API gravity of 52 deg.

What would be the static differential pressure across the circulation tool?

Note: The Specific Gravity [in kg/l] of API oil is 141.5 / (131.5 + °API)

3.4 What is a "bent sub" or "bent housing" and for what purpose is it used?

3.5 Calculations define that a cement slurry volume of 57.8 m^3 are required to cement a casing in place. The following recipe has been provided from town:-

Gradient of the cement slurry to be used	15.4 kPa/m
Yield value of the dry cement	33.2 litre/sack
Mix water for the cement slurry	25.9 litre/sack
Specific density of the drilling fluid	1.22 kg/dm^3

Calculate the number of sacks of dry cement and the amount of mix water required to perform this cementation.

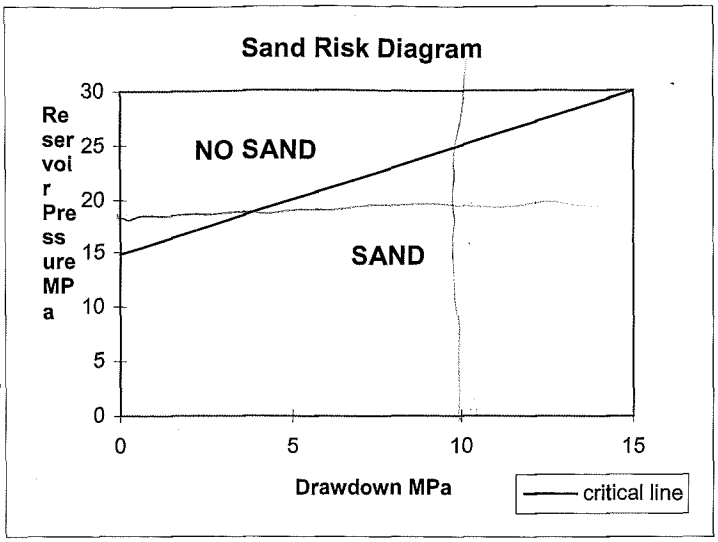
3.6 A well completion is designed to achieve various aims. Name 4 possible aims of well completion.

3.7 A well is producing at a production rate 400 bbl/day and bottom hole pressure 2800 psi. Assuming a PI of 4 bbl/day/psi, calculate the reservoir pressure.

3.8 Why is a shaped-charge used in perforating? Under what circumstances would you choose for a deep perforation, as opposed to a wide perforation.

3.9 Name three methods for preventing scale formation, and three methods of scale removal.

3.10 The initial pressure in a reservoir is 18 MPa. The initial production rate from a well is planned at 1000 m^3/day, and the PI is 100 m^3/day/MPa. The sand risk diagram is given below. Do you anticipate sand production?



4. Stimulation [20 pts]

4.1 Explain the functions of HCl and HF acids in matrix acidising of sandstone formations.

4.2 What are thought to be the reasons for the failures in the past when using mud acid with high HF concentrations?

4.3 An HF/HCl acid blend is formed of 2% by wt HF and 13% HCl. Calculate the volumetric dissolving power for the primary reaction of HF with sodium feldspar $NaAlSi_3O_8$, given by

$$NaAlSi_3O_8 + 14\ HF + 2H^+ \leftrightarrow Na^+ + AlF_2^+ + 3SiF_4 + 8H_2O$$

The molecular mass of sodium feldspar is 262.3 and of HF 20. The density of the acid blend is 1070 kg/m^3 and of sodium feldspar 2700 kg/m^3.

4.4 In a sandstone acidizing treatment, the above acid blend is used to remove sodium feldspar. The porosity of the sandstone is 0.28 and it contains 3% [by volume] sodium feldspar. The aim is to remove all sodium feldspar to a depth of 15 cm. The borehole radius is 10 cm. What is the minimum required volume of acid blend in m^3/metre of perforated interval?

4.5 During the actual treatment, more acid is pumped than is required and is not displaced deeper into the formation. Non-reacted acid is left in the formation at the end of the treatment. What problems might arise from this, once the well is put on production?

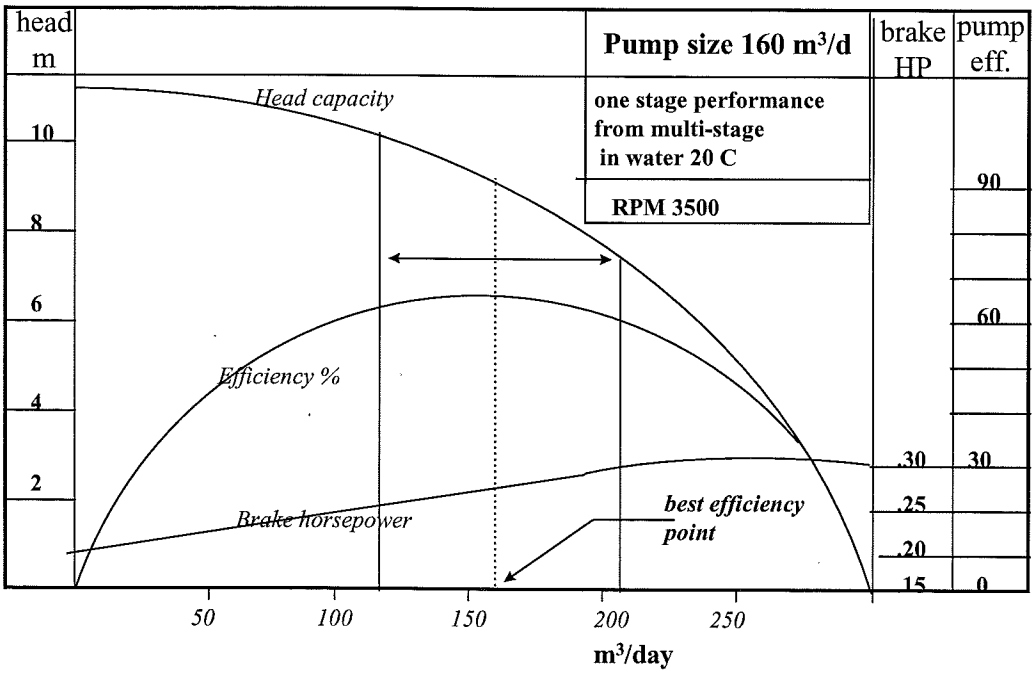
5. Artificial Lift [20 pts]

5.1 It is planned to produce the following well at a production rate of 1000 bbl/day.

Depth	10000 ft
Watercut	0%
Reservoir pressure	2500 psi
Productivity Index PI	4 bbl/day/psi

An ESP is installed at the bottom of the well. The required pressure at the outlet of the ESP is 2500 psi, in order to achieve the required tubing head pressure. Calculate the pressure difference that must be supplied by the pump at the planned production rate (1000 bbl/day).

5.2 How many stages should the ESP have, based on the following performance curve (1 psi = 6.89 kPa, 1 bbl = 0.159 m^3)



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?

5.4 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.