EXAMINATION: AES1330 Drilling & Production Engineering

30th March 2009

- Write your name and personal student number ***clearly*** at the top of ***each*** page.

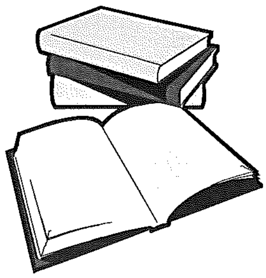
- Decimal points and comma's in this examination paper are used in the *English* manner,
- thus, for example 100,000 is hundred thousand, <u>not</u> 100 with three decimals !

- 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)

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

Total : *100 points*

1. Casing Cementation [20 pts]

17-1/2" hole has been drilled to section TD or 1405m. The 13-3/8" casing is run without problems. We are now ready to execute the cementation.

The following data is available:-

Depth of 17-1/2" Hole:	1405 m
Data on 13-3/8" Casing	
- Depth of 13-3/8" Casing:	1400 m
- Shoetrack Length:	24 m
- Weight of 13-3/8" casing:	101.2 kg/m
- Capacity of 13-3/8" Casing:	78.1 litres/m
Data on 18-5/8" Casing	
- Depth of 18-5/8" Casing:	850 m
- Weight of 18-5/8" Casing:	130.21 kg/m
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'	690 m
- Excess cement slurry over '**open hole**'	30%
Drilling Fluid and Spacers	
- Gradient of Drilling Fluid:	12.2 kPa/m
- Gradient of Water Spacer:	10.0 kPa/m
- Water Spacer **Ahead** of Slurry:	8 m^3
- Water Spacer **Behind** Slurry:	1 m^3

1.1 Calculate the required volume of **Cement Slurry**. The annular capacity between 17-1/2" hole and 13-3/8" casing is 64.6 litres/m. Find or calculate the capacity between 18-5/8" casing and 13-3/8" casing from the tables provided. Do not forget excess cement slurry over open hole. [6 pts]

1.2 Calculate the total amount [in metric tons] of **Dry Cement** we will use. Note that one sack of cement weighs 42.6 kg. [4 pts]

1.3 Calculate the total amount [in m^3 or litres] of **Mix Water** we will use, including the spacers ahead and behind. [2 pts]

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

1.5 Calculate the **Pressure Differential** between the casing string contents and annulus contents, when the cement slurries have been pumped in place. Ensure to incorporate the effect of the water spacers. [6 pts]

2. Well Control [20 pts]

We are now drilling the long 12-1/4" hole section at **2720m** MD/TVD. The well kicks unexpectedly, because reservoir sections of any kind at this depth have not been prognosed. But the crew was alert and succeeded in closing in the well timely.
The following information has been pre-recorded:-

Drill String	
- 9 pcs 8-1/4" by 2-1/4" Drill Collar (each Drill Collar is 9.2 m)	Capacity: 2.57 litres/m
- 18 pcs 5" HWDP (each HWDP is 9.2 m)	Capacity: 4.61 litres/m
- 5" Drill Pipe to Surface (each Drill Pipe is 9.2 m)	Capacity: 8.97 litres/m
Annulus	
- Annular Capacity between Drill Collar and Open Hole	Capacity: 41.5 litres/m
- Annular Capacity between 5" HWDP and Open Hole	Capacity: 62.7 litres/m
- Annular Capacity between 5" Drill Pipe and Open Hole	Capacity: 62.7 litres/m
Casing	
- Last set casing: 13-3/8", 107.15 kg/m	Set at 1510m
- Leak-Off Pressure	4375 kPa
- Drilling Fluid Gradient during Leak-Off	12.8 kPa/m
Drilling Fluid and Pump	
- Current Drilling Fluid Gradient	15.2 kPa/m
- Slow Circulation Pressure at 40 Strokes/min	3200 kPa
- Mud Pump Output (at 97% efficiency)	16 litres/stroke

Closed in well information:
- Stabilised SIDPP [P_{DP}]: 815 kPa
- Stabilised SICP [P_{ANN}]: 1545 kPa
- Influx volume: 4515 litres

2.1 Calculate the **Maximum Allowable Annular Surface Pressure** when the well was closed after the kick. [2 pts]

2.2 Calculate the **Reservoir Pressure at 2720m.** [2 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 Casing Shoe.** [5 pts]

2.5 Accurately construct the **Kill Graph for a 'Wait and Weight' Kill Method'.** Clearly show SIDPP [P_{DP}], ~~PL~~ (P_{C1} at 40 SPM), ~~ICP~~ [P_{ST}], ~~FCP~~ [P_{C2}], Strokes for Phase 1 and Strokes from Bit to Casing Shoe. [5 pts]

2.6 Calculate the **Influx Gradient.** What type of influx have we encountered (gas, oil or water) [4 pts]

3. Short calculation questions. General knowledge [10 pts]

3.1 A well is filled with 12.5 kPa/m drilling fluid. The Driller accidentally pumps 5m3 water into the drill string. He discovers his error before the water has left the bit. He stops the pump and raises alarm. He concludes that the well is underbalanced and closes the BOP. What happened to the Bottom Hole Pressure before closing the BOP and what should we do ? [2 pts]

3.2 How is a **leak-proof seal** achieved in drill pipe tool joints and drill collar connections ? What are non-magnetic drill collars and what are they used for ? [2 pts]

3.3 Over the next interval that we have drill, we will encounter 4 different type of formations. These are (a) a clay formation, (b) a tight sand stone formation, (c) a fractured limestone formation and (d) a salt/anhydrite formation. If we have considerable overbalance with the mud weight in use, over which formation is **differential sticking** likely to occur and why ? [2 pts]

3.4 We commonly recognize 2 types of bits, (a) tri-cone bits (either steel mill tooth or tungsten carbide insert) and (b) fixed cutter bits (either PDC, TSP or Diamond). Describe the **mechanism of cutting rock** for steel mill tooth bits, for tungsten carbide insert bits and for PDC bits. [2 pts]

3.5 You plan to run a 9-5/8" casing with 12 lines strung in the block instead of the 10 lines strung for drilling. Will the derrick load be the same if we would have left the block with 10 lines strung or will it change (up or down) ? Explain your answer ! [2 pts]

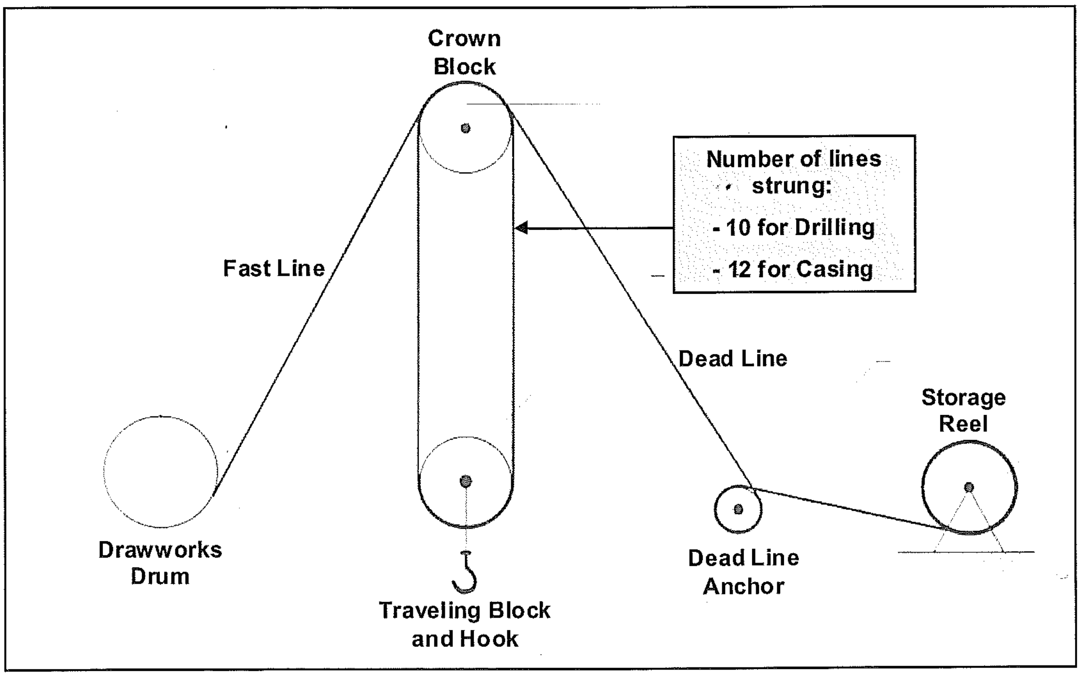


Fig. 1

3.6 What is the design collapse pressure for a casing at depth 7000 ft if the mud has specific gravity 1.25 (the pressure gradient for water is 0.43 psi/ft)? [3 pts]

3.7 In a new field, shortly to be developed, it is planned to drill 10 production wells. The average PI of the wells is estimated to be 100 m^3/day/MPa. The initial reservoir pressure is 27.5 MPa. The Sand Risk diagram for the field is shown in Fig. 1. The initial production rate from each well is planned as 1000 m^3/day. Will sand be produced initially? [2 pts]

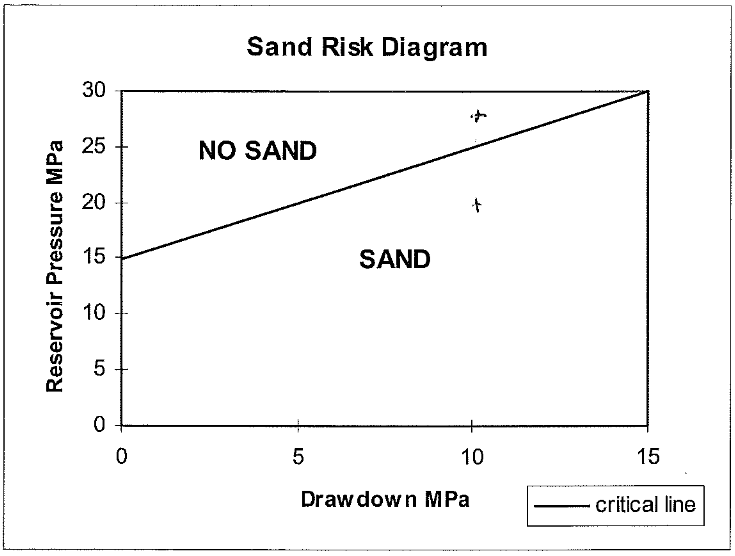


Fig. 2

3.8 Size a horizontal separator to handle the following volume flow rates (measured at the pressure and temperature at which the separator operates):

gas flow rate	169 000 m^3 /day
oil flow rate	400 m3 /day

Typical droplet sizes are 100 micron (10-4 m), and for these droplets and the given composition and operating conditions the empirical value of K in the terminal velocity formula is 100. [3 pts]

3.9 List three key properties of hydraulic fracturing fluids. Indicate four fluids that are often used for hydraulic fracturing fluids. [1 pts]

3.10 Name three types of pumps used in the oil industry and explain briefly the main characteristics of each type of pump. [1 pts]

4. Well Inflow Performance [20 pts]

A well is completed in an oil reservoir as shown schematically in Fig. 3. The following properties of the reservoirs and the well are given:

Type of formation	Sandstone
Reservoir depth, TVD	2000 m
Height of pay zone, h	10 m
Porosity, ϕ	0.20
Permeability, k_o	150 mD

Production Tubing Radius, r_p	0.10 m
Production Casing Radius, r_w	0.20 m
Reservoir Radius, r_e	100 m
Oil Density, ρ_o	890 kg/m^3
Oil Viscosity, ηo	5 mP.s
Oil Formation Volume Factor, B_o	1.15 m^3/m^3

In a first attempt to put the reservoir in production the well is opened at the surface. No production is observed. Examination of the fluid level in the production tubing shows that the oil column stabilized at depth of 260 m.

4.1 Sketch the well diagram and carefully draw the corresponding pressure-depth (P-D) diagram. [3 pts]

4.2 Determine the reservoir pressure assuming the gas gradient to be negligible. [2 pts]

A methanol-water mixture (hereafter referred to simply as methanol) with a density 750 kg/m^3 is injected above the oil column in order to verify the Productivity index of the well. It is assumed that the Productivity and Injectivity Indexes are equal. It is further assumed that the methanol and oil are totally immiscible and that methanol is not transferred into the oil during this operation. A critical operational requirement is that the methanol mixture should not penetrate the reservoir! The methanol is injected at a constant well-head pressure of 0.2 MPa, while monitoring the flow rate as a function of time.

4.3 Calculate the maximum depth reached by the methanol column. What can you conclude? [5 pts]

4.4 The initial flow rate during methanol injection is found to be 165 m^3/day. Determine the flowing bottom-hole pressure, neglecting frictions losses. Determine the PI of the well. Discuss qualitatively how would this result change if friction losses were taken into account? [5 pts]

4.5 Determine the PI of the well from the data given above assuming that the formation is undamaged. What can you conclude? Compute the skin of the formation. [5 pts]

5. Well Stimulation [20 pts]

It has been decided to stimulate the well in the above question using acid before production is continued. Combining porosity log data with permeability-porosity correlations it is found that the permeability around the wellbore is 80 mD.

Mineralogical analyses indicate that the formation damage has resulted from the precipitation of dolomite $CaMg(CO3)_2$ and that dolomite forms 12% of the rock.

The density of dolomite is 2650 kg/m^3 and the density of the acid blend is 1050 kg/m^3. The molecular mass of Dolomite is 184.4 g/mole and of HCl 36.5 g/mole.

5.1 Using the skin factor obtained in the previous question determine to which depth the formation is damaged. If you did not find the answer in the previous questions use the fictitious value S = 2.5. [5 pts]

5.2 It was decided to use acid blend containing 15% HCl to remove the damage around the wellbore. Write down the equation for the reaction of dolomite with acid and then determined the dissolving power of the acid. [5 pts]

5.3 Compute the minimum amount of acid that is needed to remove completely the formation damage. [5 pts]

5.4 Propose a possible injection sequence for the acidizing treatment and give a short explanation of the function of each step. [5 pts]

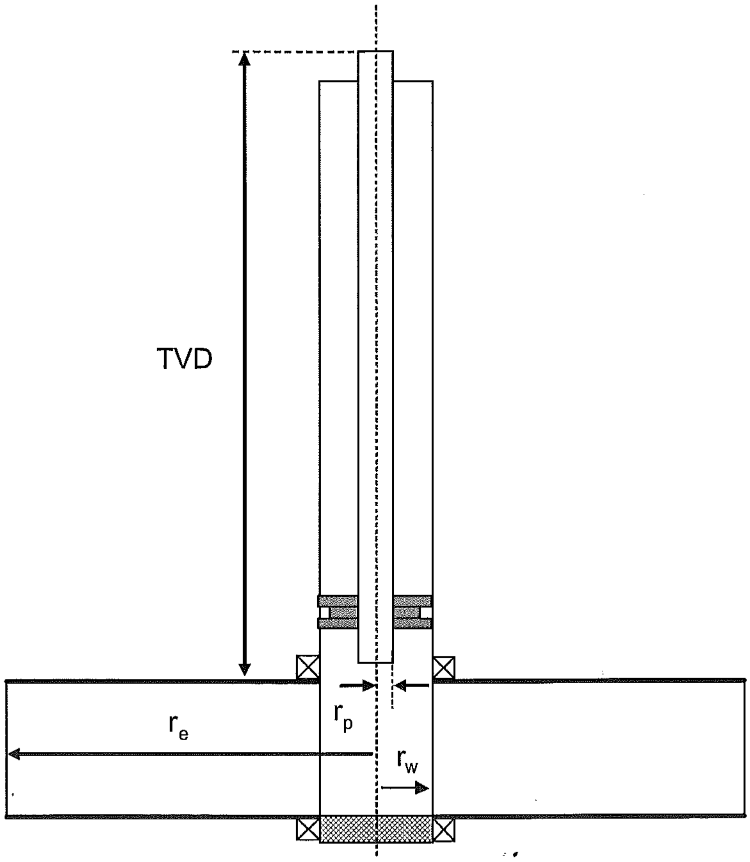


Fig. 3

TABLES YOU NEED FOR THE DRILLING RELATED EXERCISES

DERRICK LOAD CALCULATIONS

(neglecting the weight of the derrick itself and the crown block)

> Note:
> In all calculations involving hook load, this is by convention taken to include the weight of the hook itself , including also the travelling block.
> Thus :
> Hook load as shown on weight indicator (Martin-Decker)
> = weight of string **in drilling fluid** + weight of travelling block and hook

Static loads

Under static conditions:

load in each line = fast line load = dead line load = $\frac{\text{hook load}}{N}$

where N = number of lines strung

Static derrick load = hook load + fast line load + dead line load

$$= \frac{N+2}{N} \times \text{hook load}$$

Dynamic loads

Under dynamic conditions, due to both friction in the sheave bearing and internal friction in the block line, the tension on the fastline side of a given sheave is higher than the tension on the deadline side by a factor "k". This factor is normally taken to be 1.04 for roller bearing sheaves (API RP9B).

The result, for a constant hook load (i.e. no drag) travelling at a constant speed, is that the dynamic fast line tension is higher than the static fast line tension by a certain factor. The factor depends on the number of lines strung and its value for different 'N's are tabulated below. In fact, for these ideal conditions, the dead line load would actually decrease with respect to the static load, and these factors are also shown in the table.

N	2	4	6	8	10	12
dynamic fast line factor	1.060	1.102	1.145	1.188	1.233	1.279
dynamic dead line factor	0.980	0.942	0.905	0.868	0.833	0.799

Also Dynamic derrick load = Hook load + dynamic fast line tension + dynamic dead line tension

Notes :

1. Previous practice was to divide the static load by an "efficiency" factor to give the dynamic fast line tension. The efficiency factor was the reciprocal of the factor tabulated above.
2. The reduction in dead line tension is generally neglected (see note 3 below).
3. In theory, the decrease in dead line tension would cause the hook load indicated on the weight indicator to be too low. In practice the effects of drag, acceleration and shock loads, and the fact that critical hook loads are generally applied in small increments, make this error unimportant.

CAPACITY OF CASING (2)

Size O.D.		Weight with couplings		Inside diameter		Drift diameter		Bbls per foot	m^3/m	Feet per bbl	m/m^3
inch	mm	lbs/ft	kg/m	inch	mm	inch	mm				
7.625	193.68	20.00*	29.76*	7.125	180.98	7.000	177.80	0.0493	0.0257	20.28	38.66
		24.00	35.72	7.025	178.44	6.900	175.26	0.0479	0.0250	20.86	39.97
		26.40	39.29	6.969	177.01	6.844	173.84	0.0472	0.0246	21.20	40.62
		29.70	44.20	6.875	174.63	6.750	171.45	0.0459	0.0240	21.78	41.74
		33.70	50.15	6.765	171.83	6.640	168.66	0.0445	0.0232	22.49	43.11
		39.00	58.04	6.625	168.28	6.500	165.10	0.0426	0.0222	23.45	44.95
		45.30*	67.41*	6.435	163.45	6.310	160.27	0.0402	0.0210	24.86	47.64
7.750*	196.85*	46.10	68.60	6.560	166.62	6.500	165.10	0.0418	0.0218	23.92	45.84
8.000*	203.20*	26.00	38.69	7.386	187.60	7.261	184.43	0.0530	0.0277	18.87	36.16
8.125*	206.38*	28.00	41.67	7.485	190.12	7.360	186.94	0.0544	0.0284	18.37	35.21
		32.00	47.62	7.385	187.58	7.260	184.40	0.0530	0.0276	18.88	36.17
		35.50	52.83	7.285	185.04	7.160	181.86	0.0516	0.0269	19.40	37.17
		39.50	58.78	7.185	182.50	7.060	179.32	0.0501	0.0262	19.94	38.21
8.625	219.08	20.00*	29.76*	8.191	208.05	8.066	204.88	0.0652	0.0340	15.34	29.40
		24.00	35.72	8.097	205.66	7.972	202.49	0.0637	0.0332	15.70	30.09
		28.00	41.67	8.017	203.63	7.892	200.46	0.0624	0.0326	16.02	30.69
		32.00	47.62	7.921	201.19	7.796	198.00	0.0609	0.0318	16.41	31.44
		36.00	53.57	7.825	198.76	7.700	195.58	0.0595	0.0310	16.81	32.22
		38.00*	56.55*	7.775	197.49	7.650	194.31	0.0587	0.0306	17.03	32.63
		40.00	59.53	7.725	196.22	7.600	193.04	0.0580	0.0302	17.25	33.06
		43.00*	63.99*	7.651	194.34	7.526	191.16	0.0569	0.0297	17.59	33.70
		44.00	65.48	7.625	193.68	7.500	190.50	0.0565	0.0295	17.71	33.93
		49.00	72.92	7.511	190.78	7.386	187.60	0.0548	0.0286	18.25	34.97
8.750*	222.25*	49.70	73.96	7.636	193.95	7.500	190.50	0.0566	0.0296	17.65	33.83
9.000*	228.60*	34.00	50.60	8.290	210.57	8.134	206.60	0.0668	0.0348	14.98	28.71
		38.00	56.55	8.196	208.18	8.040	204.22	0.0653	0.0341	15.32	29.37
		40.00	59.53	8.150	207.01	7.994	203.05	0.0645	0.0337	15.50	29.70
		45.00	66.97	8.032	204.01	7.876	200.05	0.0627	0.0327	15.96	30.58
		55.00	81.85	7.812	198.43	7.656	194.46	0.0593	0.0309	16.87	32.33
9.625	244.48	29.30*	43.60*	9.063	230.20	8.907	226.24	0.0798	0.0416	12.53	24.02
		32.30	48.07	9.001	228.63	8.845	224.66	0.0787	0.0411	12.71	24.35
		36.00	53.57	8.921	226.59	8.765	222.63	0.0773	0.0403	12.93	24.79
		38.00*	56.55*	8.885	225.68	8.760	222.50	0.0767	0.0400	13.04	24.99
		40.00	59.53	8.835	224.41	8.679	220.45	0.0758	0.0396	13.19	25.27
		43.50	64.74	8.755	222.38	8.599	218.42	0.0745	0.0389	13.43	25.74
		47.00	69.64	8.681	220.50	8.525	216.54	0.0732	0.0382	13.66	26.18
		53.50	79.62	8.535	216.79	8.379	212.83	0.0708	0.0369	14.13	27.08
		58.40*	86.91	8.435	214.25	8.279	210.29	0.0691	0.0361	14.47	27.73
		61.10*	90.93	8.375	212.73	8.219	208.76	0.0681	0.0356	14.68	28.13
		71.80*	106.85*	8.125	206.38	7.969	202.41	0.0641	0.0335	15.59	29.88
9.750*	247.65*	59.20	88.10	8.560	217.42	8.500	215.90	0.0712	0.0371	14.05	26.92
9.875*	250.83*	62.80	93.46	8.625	219.08	8.500	115.90	0.0723	0.0377	13.84	26.52
10.000*	254.00*	33.00	49.11	9.384	238.35	9.228	234.39	0.0855	0.0446	11.69	22.40
10.750	273.05	32.75	48.74	10.192	258.88	10.036	254.91	0.1009	0.0527	9.91	18.99
		35.75*	53.20*	10.136	257.45	9.980	253.49	0.0998	0.0521	10.02	19.20
		40.50	60.27	10.050	255.27	9.894	251.31	0.0981	0.0512	10.19	19.53
		45.50	67.71	9.950	252.73	9.794	248.77	0.0862	0.0502	10.40	19.93
		51.00	75.90	9.850	250.19	9.694	246.23	0.0943	0.0492	10.61	20.33
		54.00*	80.36*	9.784	248.51	9.628	244.55	0.0930	0.0485	10.75	20.61
		55.50	82.59	9.760	247.90	9.604	243.94	0.0925	0.0483	10.81	20.71
		60.70*	90.33*	9.660	245.36	9.504	241.40	0.0906	0.0473	11.03	21.14
		65.70	97.77*	9.560	242.82	9.404	238.86	0.0888	0.0463	11.26	21.59
		71.10*	105.81*	9.450	240.03	9.294	236.07	0.0868	0.0453	11.53	22.09

* Not API standard. Shown for information only

CAPACITY OF CASING (3)

Size O.D.		Weight with couplings		Inside diameter		Drift diameter		Bbls per foot	m^3/m	Feet per bbl	m/m^3
inch	mm	lbs/ft	kg/m	inch	mm	inch	mm				
11.750	298.45	38.00*	56.55*	11.150	283.21	10.994	279.25	0.1208	0.0630	8.28	15.87
		42.00	62.50	11.084	281.53	10.928	277.57	0.1193	0.0623	8.38	16.06
		47.00	69.94	11.000	279.40	10.844	275.44	0.1175	0.0613	8.51	16.30
		54.00	80.36	10.880	276.35	10.724	272.39	0.1150	0.0600	8.70	16.67
		60.00	89.29	10.772	273.61	10.616	269.65	0.1127	0.0588	8.87	17.00
		65.00*	96.73*	10.682	271.32	10.526	267.36	0.1108	0.0578	9.02	17.29
		71.00*	105.66*	10.586	268.88	10.430	264.92	0.1089	0.0568	9.19	17.60
11.875	301.63	71.80	106.85	10.711	272.06	10.625	269.88	0.1114	0.0582	8.97	17.20
12.000*	304.80*	40.00	59.53	11.384	289.15	11.228	285.19	0.1259	0.0657	7.94	15.22
13.000*	330.20*	40.00	50.53	12.438	315.93	12.282	311.96	0.1503	0.0784	6.65	12.75
		45.00	66.97	12.360	313.94	12.204	309.98	0.1484	0.0774	6.74	12.91
		50.00	74.41	12.282	311.96	12.126	308.00	0.1465	0.0765	6.82	13.08
		54.00	80.36	12.220	310.39	12.064	306.43	0.1451	0.0757	6.89	13.21
13.375	339.73	48.00	71.43	12.715	322.96	12.559	319.00	0.1571	0.0820	6.37	12.20
		54.50	81.10	12.615	320.42	12.459	316.46	0.1546	0.0807	6.47	12.40
		61.00	90.78	12.515	317.88	12.359	313.92	0.1521	0.0794	6.57	12.60
		68.00	101.20	12.415	315.34	12.259	311.38	0.1497	0.0781	6.68	12.80
		72.00	107.15	12.347	313.61	12.191	309.65	0.1481	0.0773	6.75	12.94
		77.00*	114.59*	12.275	311.79	12.119	307.82	0.4464	0.0764	6.83	13.09
		80.70*	120.09*	12.215	310.26	12.059	306.30	0.1449	0.0756	6.90	13.22
		83.00*	123.52*	12.175	309.25	12.019	305.28	0.1440	0.0751	6.94	13.31
		85.00*	126.49*	12.159	308.84	12.003	304.88	0.1436	0.0749	6.96	13.34
		86.00*	127.98*	12.125	307.98	11.969	304.01	0.1428	0.0745	7.00	13.42
		92.00*	136.91*	12.031	305.59	11.875	301.63	0.1406	0.0734	7.11	13.63
		98.00*	145.84*	11.937	303.20	11.781	299.24	0.1384	0.0722	7.22	13.84
13.500*	342.90*	81.40	121.14	12.340	313.44	12.250	311.15	0.1479	0.0772	6.76	12.96
13.625*	346.08*	88.20	131.26	12.375	314.33	12.250	311.15	0.1488	0.0776	6.72	12.88
14.000*	355.60*	50.00	74.41	13.344	338.94	13.156	334.16	0.1730	0.0903	5.78	11.08
16.000	406.40	55.00*	81.85*	15.375	390.53	15.187	385.75	0.2296	0.1198	4.35	8.35
		65.00	96.73	15.250	387.35	15.062	382.58	0.2259	0.1179	4.43	8.48
		70.00*	104.17*	15.198	386.03	15.010	381.25	0.2244	0.1171	4.46	8.54
		75.00	111.61	15.124	384.15	14.936	379.38	0.2222	0.1159	4.50	8.62
		84.00	125.01	15.010	381.25	14.822	376.48	0.2189	0.1142	4.57	8.76
		109.00*	162.21*	14.688	373.08	14.500	368.30	0.2096	0.1094	4.77	9.14
18.625	473.08	78.00*	116.08*	17.855	453.52	17.667	448.74	0.3097	0.1616	3.23	6.19
		87.50	130.21	17.755	450.98	17.567	446.20	0.3062	0.1598	3.27	6.26
		96.50*	143.61*	17.655	448.44	17.467	443.66	0.3028	0.1580	3.30	6.33
20.000	508.00	94.00	139.89	19.124	485.75	18.936	480.98	0.3553	0.1854	2.81	5.39
		106.50	158.49	19.000	482.60	18.812	477.83	0.3507	0.1830	2.85	5.46
		133.00	197.93	18.730	475.74	18.542	470.97	0.3408	0.1778	2.93	5.62
21.500*	546.10*	92.50	137.66	20.710	526.04	20.522	521.26	0.4166	0.2174	2.40	4.60
		103.00	153.28	20.610	523.50	20.422	518.72	0.4126	0.2153	2.42	4.64
		114.00	169.65	20.510	520.96	20.322	516.18	0.4086	0.2132	2.45	4.69
24.000*	609.60*	94.62	140.81	23.250	590.55	--.---	---.--	0.5251	0.2740	1.90	3.65
		125.49	186.75	23.000	584.20	--.---	---.--	0.5139	0.2682	1.95	3.73
		156.03	232.20	22.750	577.85	--.---	---.--	0.5028	0.2624	1.99	3.81
		186.23	277.14	22.500	571.50	--.---	---.--	0.4918	0.2566	2.03	3.90
24.500*	622.30*	100.50	149.56	23.750	603.25	23.562	598.48	0.5479	0.2859	1.83	3.50
		113.00	168.16	23.650	600.71	23.462	595.94	0.5433	0.2835	1.84	3.53
30.000*	762.00*	118.65	176.57	29.250	742.95	--.---	---.--	0.8311	0.4337	1.20	2.31
		157.53	234.43	29.000	736.60	--.---	---.--	0.8170	0.4263	1.22	2.35
		196.08	291.80	28.750	730.25	--.---	---.--	0.8029	0.4190	1.25	2.39
		234.29	348.66	28.500	723.90	--.---	---.--	0.7890	0.4117	1.27	2.43

* Not API standard. Shown for information only

THE VOLUME OF A CYLINDER

I.D. or O.D. inches	mm	Bbls per lin. foot	m^3/m	Lin. feet per bbl.	m/m^3	I.D. or O.D. inches	mm	Bbls per lin. foot	m^3/m	Lin. feet per bbl.	m/m^3
2.000	50.80	0.00389	0.00203	257.4	493.4	10.000	254.0	0.097	0.0507	10.29	19.74
2.125	53.98	0.00439	0.00229	228.0	437.0	10.125	257.2	0.100	0.0519	10.04	19.25
2.250	57.15	0.00492	0.00257	203.3	389.8	10.250	260.4	0.102	0.0532	9.80	18.78
2.375	60.33	0.00548	0.00286	182.5	349.9	10.375	263.5	0.105	0.0545	9.56	18.33
2.500	63.50	0.00607	0.00317	164.7	315.8	10.500	266.7	0.107	0.0559	9.34	17.90
2.625	66.68	0.00669	0.00349	149.4	286.4	10.625	269.9	0.110	0.0572	9.12	17.48
2.750	69.85	0.00735	0.00383	136.1	261.0	10.750	273.1	0.112	0.0586	8.91	17.08
2.875	73.03	0.00803	0.00419	124.5	238.8	10.875	276.2	0.115	0.0599	8.70	16.69
3.000	76.20	0.00874	0.00456	114.4	219.3	11.000	279.4	0.118	0.0613	8.51	16.31
3.125	79.38	0.00949	0.00495	105.4	202.1	11.125	282.6	0.120	0.0627	8.32	15.95
3.250	82.55	0.0103	0.00535	97.5	186.8	11.250	285.8	0.123	0.0641	8.13	15.59
3.375	85.73	0.0111	0.00577	90.4	173.3	11.375	288.9	0.126	0.0656	7.96	15.25
3.500	88.90	0.0119	0.00621	84.0	161.1	11.500	292.1	0.128	0.0670	7.78	14.92
3.625	92.08	0.0128	0.00666	78.3	150.2	11.625	295.3	0.131	0.0685	7.62	14.60
3.750	95.25	0.0137	0.00713	73.2	140.3	11.750	298.5	0.134	0.0700	7.46	14.29
3.875	98.43	0.0146	0.00761	68.6	131.4	11.875	301.6	0.137	0.0715	7.30	14.00
4.000	101.6	0.0155	0.00811	64.3	123.3	12.000	304.8	0.140	0.0730	7.15	13.71
4.125	104.8	0.0165	0.00862	60.5	116.0	12.125	308.0	0.143	0.0745	7.00	13.42
4.250	108.0	0.0175	0.00915	57.0	109.3	12.250	311.2	0.146	0.0760	6.86	13.15
4.375	111.1	0.0186	0.00970	53.8	103.1	12.375	314.3	0.149	0.0776	6.72	12.89
4.500	114.3	0.0197	0.0103	50.8	97.5	12.500	317.5	0.152	0.0792	6.59	12.63
4.625	117.5	0.0208	0.0108	48.1	92.3	12.625	320.7	0.155	0.0808	6.46	12.38
4.750	120.7	0.0219	0.0114	45.6	87.5	12.750	323.9	0.158	0.0824	6.33	12.14
4.875	123.8	0.0231	0.0120	43.3	83.0	12.875	327.0	0.161	0.0840	6.21	11.91
5.000	127.0	0.0243	0.0127	41.2	78.9	13.000	330.2	0.164	0.0856	6.09	11.68
5.125	130.2	0.0255	0.0133	39.2	75.1	13.125	333.4	0.167	0.0873	5.98	11.46
5.250	133.4	0.0268	0.0140	37.3	71.6	13.250	336.6	0.171	0.0890	5.86	11.24
5.375	136.5	0.0281	0.0146	35.6	68.3	13.375	339.7	0.174	0.0906	5.75	11.03
5.500	139.7	0.0294	0.0153	34.0	65.2	13.500	342.9	0.177	0.0923	5.65	10.83
5.625	142.9	0.0307	0.0160	32.5	62.4	13.625	346.1	0.180	0.0941	5.55	10.63
5.750	146.1	0.0321	0.0168	31.1	59.7	13.750	349.3	0.184	0.0958	5.44	10.44
5.875	149.2	0.0335	0.0175	29.8	57.2	13.875	352.4	0.187	0.0975	5.35	10.25
6.000	152.4	0.0350	0.0182	28.6	54.8	14.000	355.6	0.190	0.0993	5.25	10.07
6.125	155.6	0.0364	0.0190	27.4	52.6	14.125	358.8	0.194	0.1011	5.16	9.89
6.250	158.8	0.0379	0.0198	26.4	50.5	14.250	362.0	0.197	0.1029	5.07	9.72
6.375	161.9	0.0395	0.0206	25.3	48.6	14.375	365.1	0.201	0.1047	4.98	9.55
6.500	165.1	0.0410	0.0214	24.4	46.7	14.500	368.3	0.204	0.1065	4.90	9.39
6.625	168.3	0.0426	0.0222	23.5	45.0	14.625	371.5	0.208	0.1084	4.81	9.23
6.750	171.5	0.0443	0.0231	22.6	43.3	14.750	374.7	0.211	0.1102	4.73	9.07
6.875	174.6	0.0459	0.0239	21.8	41.8	14.875	377.8	0.215	0.1121	4.65	8.92
7.000	177.8	0.0476	0.0248	21.0	40.3	15.000	381.0	0.219	0.1140	4.58	8.77
7.125	181.0	0.0493	0.0257	20.3	38.9	15.125	384.2	0.222	0.1159	4.50	8.63
7.250	184.2	0.0511	0.0266	19.6	37.5	15.250	387.4	0.226	0.1178	4.43	8.49
7.375	187.3	0.0528	0.0276	18.9	36.3	15.375	390.5	0.230	0.1198	4.35	8.35
7.500	190.5	0.0546	0.0285	18.3	35.1	15.500	393.7	0.233	0.1217	4.28	8.21
7.625	193.7	0.0565	0.0295	17.7	33.9	15.625	396.9	0.237	0.1237	4.22	8.08
7.750	196.9	0.0583	0.0304	17.1	32.9	15.750	400.1	0.241	0.1257	4.15	7.96
7.875	200.0	0.0602	0.0314	16.6	31.8	15.875	403.2	0.245	0.1277	4.08	7.83
8.000	203.2	0.0622	0.0324	16.1	30.8	16.000	406.4	0.249	0.1297	4.02	7.71
8.125	206.4	0.0641	0.0335	15.6	29.9	16.125	409.6	0.253	0.1318	3.96	7.59
8.250	209.6	0.0661	0.0345	15.1	29.0	16.250	412.8	0.257	0.1338	3.90	7.47
8.375	212.7	0.0681	0.0355	14.7	28.1	16.375	415.9	0.260	0.1359	3.84	7.36
8.500	215.9	0.0702	0.0366	14.2	27.3	16.500	419.1	0.264	0.1380	3.78	7.25
8.625	219.1	0.0723	0.0377	13.8	26.5	16.625	422.3	0.268	0.1400	3.72	7.14
8.750	222.3	0.0744	0.0388	13.4	25.8	16.750	425.5	0.273	0.1422	3.67	7.03
8.875	225.4	0.0765	0.0399	13.1	25.1	16.875	428.6	0.277	0.1443	3.61	6.93
9.000	228.6	0.0787	0.0410	12.7	24.4	17.000	431.8	0.281	0.1464	3.56	6.83
9.125	231.8	0.0809	0.0422	12.4	23.7	17.125	435.0	0.285	0.1486	3.51	6.73
9.250	235.0	0.0831	0.0434	12.0	23.1	17.250	438.2	0.289	0.1508	3.46	6.63
9.375	238.1	0.0854	0.0445	11.7	22.5	17.375	441.3	0.293	0.1530	3.41	6.54
9.500	241.3	0.0877	0.0457	11.4	21.9	17.500	444.5	0.298	0.1552	3.36	6.44
9.625	244.5	0.0900	0.0469	11.1	21.3	17.625	447.7	0.302	0.1574	3.31	6.35
9.750	247.7	0.0923	0.0482	10.8	20.8	17.750	450.9	0.306	0.1596	3.27	6.26
9.875	250.8	0.0947	0.0494	10.6	20.2	17.875	454.0	0.310	0.1619	3.22	6.18