DRILLING FORMULAE

WARNING SIGNS OF REDUCING OVERBALANCE

1. Increasing Drill Rate.
2. Increasing Torque and Drag.
3. Increased Cuttings Size.
4. Increased Background/Trip Gas.
5. Presence of Connection Gas
6. Improper Hole Fill during Trip.
7. Increased Chlorides and Mud Temperature.
8. Decreasing Shale Density.

WARNING SIGNS/INDICATORS OF A KICK

1. Increase in FLOW RATE.
2. Increase in PIT LEVEL.
3. DRILLING BREAK.
4. FLOW with PUMPS OFF.
5. Increase in SPM/Decrease in Pump Pressure.

GLOBALSANTAFE

PROPERTY OF:

DRILLING FORMULAE

NINTH PRINTED EDITION
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GUIDE TO THE USE OF DRILLING FORMULAE

1. All formulae titles are listed in bold type as a main entry.

2. A statement identifying the purpose of the formula usually follows the entry.

3. A sample problem is given in each formula. These numbers are given for an example only. In the actual application of each formula, the real numbers are to be provided by you.

4. The title of the formula is listed again followed by the formula in bold type.

5. This section shows how the elements of the formula are applied and worked through. You must provide the correct numbers that apply to the problem you are solving.

6. Solution to the formula, based on the sample information given in (3)

---

1. BOYLES LAW

2. This formula expresses relationship between gas volume and gas pressure.

3. Original Pressure (P_1) = 6000 psi
   Original Volume (V_1) = 20 bbl
   Current Pressure (P_2) = 1000 psi

4. BOYLES LAW

5. **P_1 x V_1 x = P_2 x V_2**

Find V_2

$$V_2 = \frac{P_1 \text{ x } V_1}{P_2}$$

$$= \frac{6000 \text{ x } 20}{1000}$$

$$= \frac{120000}{1000}$$

= 120 barrels

NOTES

N O T E S

PART 1: VOLUMES

SQUARE SIDED TANK VOLUME, bbls

$$= \frac{\textbf{Length, ft x Width, ft x Depth, ft}}{\boldsymbol{5.6146}}$$

CYLINDRICAL TANK VOLUME, bbls

$$= \frac{\boldsymbol{.7854} \text{ x (Diameter, ft)}^2 \text{ x Depth, ft}}{\boldsymbol{5.6146}}$$

PIPE VOLUME

$$= \frac{\text{ID}^2\text{, inches}}{1029}\text{, bbl ft or } \frac{\text{ID}^2\text{, millimetres}}{1{,}273{,}000}\text{, m}^3/\text{m}$$

ANNULAR VOLUME, bbl/ft

$$= \frac{(Dh^2 - dp^2)}{1029}$$

Dh = Hole wall diameter, inches
dp = Tubular OD, inches

STROKES TO PUMP

= Volume ÷ Pump Output/Stroke

TIME, minutes

= Strokes ÷ SPM

or

= Volume ÷ Pump Output/Stroke ÷ SPM

ANNULAR VOLUME, bbls/ft (2 Tubings)

$$= \frac{(D_1^2 - D_2^2 - D_3^2)}{1029}$$

D_1 = Outer Casing
D_2 = OD of Inner Tubing
D_3= OD of Inner Tubing

DRILL PIPE SIZES AND CAPACITIES

OD (in)	Nominal Weight (lbs/ft)			ID (in)	Barrels per foot
	IU	EU	IEU		
3.5	8.5			3.063	.0091
	9.5	9.5		2.992	.0087
	11.2			2.900	.0082
	13.3	13.3	13.3	2.764	.0074
	15.5	15.5	15.5	2.602	.0066
4.0	11.85	11.85		3.476	.01174
	14.00	14.00	14.00	3.340	.01084
	15.70		15.30	3.240	.01020
4.5	12.75			4.000	.01554
	13.75	13.75		3.958	.01522
	16.60	16.60	16.60	3.826	.01422
		18.15	18.15	3.754	.01369
	20.00	20.00	20.00	3.640	.01287
5.0	16.25		16.25	4.408	.01887
	19.50		19.50	4.276	.01776
	20.50	20.50		4.214	.01725
6.625			25.2	5.965	.0346

5" HWDP, 49.3 lbs/ft, 3" ID Bore, NC50
Capacity = .0087 bbls/ft
Displacement = .01795 bbls/ft

4½" HWDP, 41.0 lbs/ft, 2¾" ID Bore, NC46 (4" IF)
Capacity = .0073 bbls/ft
Displacement = .0149 bbls/ft

4" HWDP, 29.7 lbs/ft, $2^9/_{16}$" ID Bore, NC40 (4" FH)
Capacity = .0064 bbls/ft
Displacement = .0108 bbls/ft

3½" HWDP, 25.3 lbs/ft, $2^1/_{16}$" ID Bore, NC38 ($3^1/_2$" IF)
Capacity = .0041 bbls/ft
Displacement = .0092 bbls/ft

CAPACITY OF CASING

OD (in)	Wt/Ft (lbs)	ID (in)	Drift Diameter (ins)	Barrels per foot	Annular Capacity bbls/ft
					3.5"
	17.0	6.538	6.413	.04152	.0296
	20.0	6.456	6.331	.0405	.0286
	23.0	6.366	6.241	.0394	.0275
	26.0	6.276	6.151	.0383	.0264
7	29.0	6.184	6.059	.0371	.0253
	32.0	6.094	5.969	.0361	.0242
	35.0	6.004	5.879	.0350	.0231
	38.0	5.920	5.795	.0340	.0222
					5"
	32.30	9.001	8.845	.0787	.0544
	36.00	8.921	8.765	.0773	.053
$9^5/_8$	40.00	8.835	8.679	.0758	.0516
	43.50	8.755	8.599	.0745	.0502
	47.00	8.681	8.525	.0732	.0489
	53.50	8.535	8.379	.0708	.0465
					5"
	48.0	12.715	12.559	.1571	.1328
	54.5	12.615	12.459	.1546	.1304
$13^3/_8$	61.0	12.515	12.359	.1521	.1279
	68.0	12.415	12.259	.1497	.1255
	72.0	12.347	12.191	.1481	.1239
					5"
$18^5/_8$	87.50	17.755	17.567	.3062	.2821
					5"
	94.0	19.124	18.936	.3553	.3311
20	106.5	19.00	18.812	.3507	.3265
	133.0	18.73	18.542	.3408	.3166

COMMON ANNULAR VOLUMES

Bit Diameter		Tubular OD		bbls/ft
26”	to	5”	=	.6324
17.5”	to	5”	=	.2733
17.5”	to	9.5”	=	.2098
17.5”	to	8”	=	.2353
12.25”	to	5”	=	.1215
12.25”	to	6.625”	=	.1032
12.25”	to	8”	=	.0836
8.5”	to	5”	=	.0459
8.5”	to	6.25”	=	.0322
8.5”	to	6.5”	=	.0292

DRILL COLLAR WEIGHTS, lb/ft

	ID, inches							
OD, ins	**1.5"**	**1.75"**	**2"**	**2.25"**	**2.5"**	**2.8125"**	**3"**	**3.25"**
4.5	48	46	43	41				
4.75	54	52	50	47	44			
5.0	61	59	56	53	50			
5.25	68	65	63	60	57	53		
5.5	75	73	70	67	64	60	57	
5.75	83	80	78	75	72	67	64	
6.0	90	88	85	83	79	75	72	68
6.25	98	96	94	91	88	83	80	76
6.5	107	105	102	99	96	92	88	85
6.75	116	114	111	108	105	101	98	94
7.0	125	123	120	117	114	110	107	103
7.25	134	132	130	127	124	119	116	112
7.5	144	142	140	137	134	129	126	122
7.75	154	152	150	147	144	139	136	132
8.0	165	163	160	157	154	150	147	143
8.25	176	174	171	168	165	161	158	154
8.5	187	185	182	179	176	172	169	165
8.75	198	196	194	191	188	183	180	176
9.0		208	206	203	200	195	192	188
9.25		220	218	215	212	207	204	200
9.5		233	230	228	224	220	217	213
9.75		246	243	240	237	233	230	226
10.0			256	254	250	246	243	239
10.25			270	267	264	259	257	252
10.5			284	281	278	273	270	266
10.75			298	295	292	287	285	280
11.0					306	302	299	295
11.25					321	317	314	310
11.5					336	332	329	325
11.75					352	348	345	340
12.0					368	363	361	356
CAPACITIES								
bbls/ft	**.0022**	**.003**	**.0039**	**.0049**	**.0061**	**.0077**	**.0087**	**.0103**

2747 lbs of steel will displace 1 bbl
1000 lbs of steel will displace .364 bbl

N O T E S

BUOYANCY FACTOR

Used to calculate weight of a STEEL tubular in mud.

Dry Weight/Foot	=	90 lbs
Mud Weight	=	11.2 ppg

BUOYANCY FACTOR

$$= \frac{\mathbf{(\mathit{65.44} - Mud\ Wt,\ ppg)}}{\mathbf{\mathit{65.44}}}$$

$$= \frac{\left(\mathit{65.44} - 11.2\right)}{\mathit{65.44}}$$

$$= \frac{54.24}{\mathit{65.44}}$$

$= \underline{.829}$

BUOYED WEIGHT, lbs/ft

= **Dry Weight, lbs/ft x Buoyancy Factor**

= 90 x .829

= <u>74.61 lbs/ft</u>

If SG mud weight is used, replace 65.44 with 7.856.
For PCF use 490.

See page 4.2 for list of Buoyancy Factors.

TON MILES

For complete round trip

W	=	Buoyed Weight of Drill Pipe	=	17.52 lbs/ft
D	=	Total Length of Drill String	=	10,000 ft
L	=	Average Stand Length	=	93 ft
M	=	Total Weight of Blocks, Hook and Drill String Compensator (if any)	=	40,000 lbs
C	=	Buoyed Weight of BHA minus the Buoyed Weight of equal length of Drill Pipe	=	27,240 lbs

TON MILES

$$= \frac{\mathbf{W \times D \times (D + L)}}{\mathbf{\mathit{10{,}560{,}000}}} + \frac{\mathbf{D \times (M + .5C)}}{\mathbf{\mathit{2{,}640{,}000}}}$$

$$= \frac{17.52 \times 10{,}000 \times (10{,}000 + 93)}{10{,}560{,}000} + \frac{10{,}000 \times (40{,}000 + 13{,}620)}{2{,}640{,}000}$$

$$= \frac{1{,}768{,}293{,}600}{10{,}560{,}000} + \frac{536{,}200{,}000}{2{,}640{,}000}$$

$$= 167.4 + 203.1$$

$$= \underline{370.5 \text{ Ton Miles}}$$

DRILLING TON MILES

No Reaming at Connections = **(RTTM after Drilling - RTTM before Drilling) x 2***

Ream Once at Connections = **(RTTM after Drilling - RTTM before Drilling) x 3****

Ream Twice at Connections = **(RTTM after Drilling - RTTM before Drilling) x 4****

RTTM = Round Trip Ton Miles ** Remove for Top Drive* *** Gives extra safety margin for Top Drives*

CORING TON MILES

= **(RTTM after Coring - RTTM before Coring) x 2**

CASING TON MILES

$$= \left[\frac{\textbf{Block Wt, lbs}}{\mathbf{\mathit{1000}}} + \frac{\textbf{Total Buoyed Wt. of Casing, lbs}}{\mathbf{\mathit{4000}}}\right] \times \frac{\textbf{Shoe Depth, ft}}{\mathbf{\mathit{5280}}}$$

WIPER TRIP TON MILES

$$= \left[\frac{\textbf{String Wt after } {}^{1}/_{2} \textbf{ the Stands pulled x Wiper Trip Stands Pulled}}{\textbf{\textit{56774}}}\right] + \left[\frac{\textbf{Block Wt x Wiper Trip Stands Pulled}}{\textbf{\textit{28387}}}\right]$$

TON MILES FOR MIXED STRING

Use same formula for TON MILES but replace W with W_{AVG}

W_{AVG}	=	Average Buoyed lbs/ft of Drill Pipe
C	=	Average Buoyed Weight of Equal Length of Drill Pipe

eg.	3½" DP =	2187 ft x 15.5 lbs/ft	= 33,898 lbs
	5" DP =	6766 ft x 19.5 lbs/ft	= 131,937 lbs
	Total =	8953 ft	= 165,835 lbs
	Avg. Wt =	165835 ÷ 8953	= 18.52 lbs/ft

If 10 ppg then W_{AVG}

= 18.52 x .847*

= 15.69 lbs/ft

*Buoyancy Factor

STEEL DISPLACEMENT

For volume taken up by steel tubular.

Dry weight of Pipe = 21.9 lbs/ft (see next page)

DISPLACEMENT, bbls/ft

$$= \frac{\textbf{Dry Weight, lbs/ft}}{\textbf{\textit{2747}}}$$

$$= \frac{21.9}{2747}$$

$= \underline{.00797 \text{ bbls / ft}}$

2747 = weight, lbs of 1 bbl of steel

CLOSED END DISPLACEMENT, bbls/ft

= Steel Displacement, bbls/ft + Pipe Capacity, bbls/ft

WEIGHTS PER FOOT

Figures taken from API RP 7G

5" Drill Pipe, IEU, Nom. Wt 19.5, XH

Grade E = 20.9 lbs/ft
Grade X = 21.4 lbs/ft
Grade G = 21.9 lbs/ft
Grade S = 22.5 lbs/ft

3½" Drill Pipe, EU, Nom. Wt 15.5, NC 38

Grade E = 16.39 lbs/ft
Grade X = 16.69 lbs/ft
Grade G = 16.88 lbs/ft
Grade S = 17.56 lbs/ft (NC 40)

6$^{5}/_{8}$" Drill Pipe, IEU, Nom. Wt 25.2, FH

Grade E = 27.3 lbs/ft
Grade X = 27.15 lbs/ft
Grade G = 28.2 lbs/ft
Grade S = 29.63 lbs/ft

6$^{5}/_{8}$" Drill Pipe, IEU, Nom. Wt 27.7, FH

Grade E = 29.06 lbs/ft
Grade X = 30.11 lbs/ft
Grade G = 30.11 lbs/ft
Grade S = 31.54 lbs/ft

5" Heavy Wall Drill Pipe = 49.3 lbs/ft

Drill Collars and Casing

Use tables on page 1.5 to get actual wt/ft
for specific ODs and IDs.

SLUG VOLUME/WEIGHT/LENGTH

How big should your slug be or how heavy?

Mud Weight = 10 ppg
Pipe Capacity = .01776 bbls/ft
Required Level drop in mud below Rotary
Table (L.dry) = 200 ft
Slug Weight = 11.5 ppg

VOLUME OF SLUG, bbls

$$= \frac{\textbf{M.Wt, ppg x L.dry, ft x Pipe Cap, bbls/ft}}{\textbf{(Slug Wt, ppg - Mud Wt, ppg)}}$$

$$= \frac{10 \text{ x } 200 \text{ x } .01776}{(11.5 - 10)}$$

$$= \frac{35.52}{1.5}$$

$$= \underline{23.68 \text{ bbl}}$$

SLUG WEIGHT, ppg

$$= \left[\frac{\textbf{M.Wt, ppg x L.dry x Pipe Cap, bbls/ft}}{\textbf{Slug Vol, bbls}}\right] + \textbf{M.Wt, ppg}$$

(using a Slug Volume of 25 bbls)

$$= \left[\frac{10 \text{ x } 200 \text{ x } .01776}{25}\right] + 10$$

$$= \left[\frac{35.52}{25}\right] + 10$$

$$= 1.42 + 10 = \underline{11.42 \text{ ppg}}$$

LENGTH OF DRY PIPE, ft

$$\textbf{L. dry} = \left(\textbf{Slug Length x} \frac{\textbf{Slug Weight}}{\textbf{Mud Weight}}\right) \textbf{- Slug Length}$$

Note: Slug Length = Slug Volume ÷ Pipe Capacity

LEVEL/PRESSURE DROP WHEN TRIPPING (DRY PIPE)

Due to pulling out of the hole

Mud Weight	=	10.5 ppg
Metal Disp.	=	.00797 bbls/ft (see page 2.3)
Casing Capacity without any pipe in hole	=	.1522 bbls/ft
Stand Length	=	93 ft

LEVEL DROP/STAND

$$= \frac{\textbf{Metal Disp, bbls/ft x Stand Length, ft}}{\textbf{(Casing Cap, bls/ft - Metal Disp, bls/ft)}}$$

$$= \frac{.00797 \text{ x } 93}{(.1522 - .00797)}$$

$$= \frac{.74121}{.14423}$$

= <u>5.14 ft</u>

PRESSURE DROP, psi

= Level Drop, ft x M. Wt, ppg x .052

= 5.14 x 10.5 x .052

= <u>2.8 psi</u>

LEVEL DROP FOR DRILL COLLARS

LEVEL DROP, ft

$$= \frac{\textbf{Metal Displacement, bbls/ft}}{\textbf{Casing Capacity, bbls/ft}} \textbf{ x Collar Length, ft}$$

PRESSURE DROP WET PIPE

If returns are not routed back to Trip Tank
via Mud Bucket, then use

PRESSURE DROP/STAND

$$\left[\frac{\textbf{Mud Gradient x (Metal Disp. + DP Cap.)}}{\textbf{Annular Capacity}}\right] \textbf{ x Stand Length, ft}$$

Gradient in psi/ft
Capacity/Disp. in bbls/ft

NOTE: Annular Capacity = Casing Capacity – (Metal Displacement + Pipe Capacity)

LENGTH OF COLLARS TO PULL

Amount of collars to pull to achieve a required level drop.

Level drop required	=	25 ft
Casing capacity	=	.1552 bbls/ft
Metal displacement	=	.0546 bbls/ft

LENGTH OF COLLARS TO PULL, ft

$$= \textbf{Level Drop required, ft x } \frac{\textbf{Casing Capacity, bbls/ft}}{\textbf{Metal Disp. bbls/ft}}$$

$$= 25 \text{ ft x } \frac{.1522}{.0546}$$

$$= 25 \text{ x } 2.787$$

= <u>70 ft</u>

NOTES

PART 3: STUCK PIPE

Formulae for STEEL Pipe Only!

FREE LENGTH OF STUCK PIPE

e = Differential Stretch of Pipe = 24 inches

Differential Pull to obtain ‘e’ = 30,000 lbs

Wdp = Drill Pipe PLAIN END* Weight = 17.93 lbs/ft

*Excludes Tool Joints - see Table 1, p.4 in RP7G,
Jan 1, 1995. Plain end weight for 5” (19.5 lbs/ft) Drill Pipe = 17.93 lbs/ft

FREE LENGTH OF STUCK PIPE, ft

$$= \frac{\textbf{\textit{735,294}} \textbf{ x e x Wdp}}{\textbf{Differential Pull, lbs}}$$

$$= \frac{735{,}294 \text{ x } 24 \text{ x } 17.93}{30{,}000}$$

$$= \frac{316{,}411{,}714}{30{,}000}$$

$$= \underline{10{,}547 \text{ ft}}$$

STRETCH OF SUSPENDED STRING

Stretch due to its own weight.

Length of String (L) = 10,520 ft

Mud Wt = 11 ppg

STRETCH, inches

$$= \frac{\mathbf{L^2, ft}}{\boldsymbol{96{,}250{,}000}} \ \mathbf{x} \left[\boldsymbol{65.44} \ \mathbf{- (}\boldsymbol{1.44} \ \mathbf{x\ Mud\ Wt, ppg)} \right]$$

$$= \frac{10{,}520^2}{96{,}250{,}000} \ \text{x} \left[65.44 - (1.44 \text{ x } 11) \right]$$

$$= 1.1498 \ \text{x} \ [65.44 - (15.84)]$$

$$= 1.1498 \ \text{x} \ 49.6$$

= <u>57 inches</u>

GENERAL STRETCH FORMULA

Stretch due to weight on end of steel pipe.

Length of Pipe	= 800 ft
Casing Weight attached to end of Pipe	= 350,000 pounds
Pipe OD	= 5”
Pipe ID	= 4.276”

Example shows stretch of pipe when running casing to seafloor wellhead.

STRETCH, inches

$$= \frac{\textbf{Stretching Force, pounds x Pipe Length, ft}}{\boldsymbol{1{,}963{,}500} \ \mathbf{x\ (Pipe\ OD^2 - Pipe\ ID^2)}}$$

$$= \frac{350{,}000 \text{ x } 800}{1{,}963{,}500 \text{ x } (5^2 - 4.276^2)}$$

$$= \frac{280{,}000{,}000}{1{,}963{,}500 \text{ x } 6.7158}$$

$$= \frac{280{,}000{,}000}{13{,}186{,}473}$$

= <u>21.2 inches</u>

PLAIN END WEIGHT, lbs/ft

Weight of steel pipe (excluding tool joints).

$= \boldsymbol{2.67}$ **x (Pipe OD^2 – Pipe ID^2)**

OD	=	inches
ID	=	inches

MAXIMUM OVERPULL (MOP)

Overpull in pounds, allowed on stuck pipe.

MOP (Single Grade Only e.g. S)

= **(Pa (S) x .*9*) - B.st**

Pa = max. allowable design load in tension,
e.g. 560760 lbs for 5”, Grade S

B.st = Buoyed String Weight (Hook Load less Hook Weight),
e.g. = 229,500 lbs

= (560,760 x .9) - 229,500

= 504,684 – 229,500

= <u>275,184 pounds</u>

NOTES

PART 4: WELL CONTROL

HYDROSTATIC PRESSURE (all depths TVD)

CONSTANTS:

PPG	x FT	x	***.052***	= PSI,	SG	x	MT	x	***.1***	= kg/cm^2,
SG	x FTx		***.433***	= PSI,	SG	x	MT	x	***9.8***	= kPa,
SG	x MT	x	***1.42***	= PSI,	Kg/m^3	x	MT	÷	***102***	= kPa,
PPG	x MT	x	***.171***	= PSI,	PPG	x	MT	x	***1.176***	= kPa,
SG	x MT	x	***.098***	= BARS,	PPG	x	FT	x	***.358***	= kPa,
PCF	x FTx		***.0069***	= PSI,						

MT = metres, FT = feet

PRESSURE, psi

= **Mud Weight x Constant x Depth, (TVD)**

PRESSURE GRADIENT, psi/ft

= **Mud Weight x Constant**

OR

= **Pressure, psi ÷ TVD, ft**

MUD WEIGHT

= **Pressure, psi ÷ TVD, ft ÷ Constant**

OR

= **Pressure Gradient, psi/ft ÷ Constant**

FORCE

= **Pressure x Area**

LENGTH TO CREATE A PRESSURE, ft

= **Pressure, psi ÷ Gradient psi/ft**

OR

= **Pressure, psi ÷ Mud Weight ppg ÷ *.052***

FORMATION PRESSURE, psi

= **(Mud Wt, ppg x *.052* x Bit TVD, ft) + SIDPP, psi**

BUOYANCY FACTORS AND MUD WEIGHT EQUIVALENTS

PPG	BUOYANCY FACTOR	PSI/FT	SG	Kg/M^3	PCF
8.34	.873	.433	1.0	1000	62.4
8.4	.872	.436	1.01	1008	62.8
8.6	.868	.447	1.03	1032	64.3
8.8	.865	.457	1.06	1056	65.8
9.0	.862	.468	1.08	1080	67.3
9.2	.860	.478	1.10	1104	68.8
9.4	.856	.488	1.13	1128	70.3
9.6	.853	.499	1.15	1152	71.3
9.8	.850	.509	1.18	1176	73.3
10.0	.847	.519	1.20	1200	74.8
10.2	.844	.530	1.22	1224	76.3
10.4	.841	.540	1.25	1248	77.8
10.6	.839	.551	1.27	1272	79.3
10.8	.836	.561	1.29	1296	80.8
11.0	.833	.571	1.32	1320	82.3
11.2	.829	.582	1.34	1344	83.8
11.4	.826	.594	1.37	1368	85.3
11.6	.823	.603	1.39	1392	86.8
11.8	.820	.613	1.41	1416	88.3
12.0	.817	.623	1.44	1440	89.8
12.2	.814	.634	1.46	1464	91.3
12.4	.810	.644	1.49	1488	92.8
12.6	.808	.655	1.51	1512	94.3
12.8	.804	.665	1.53	1536	95.8
13.0	.801	.675	1.56	1560	97.3
13.2	.798	.686	1.58	1584	98.7
13.4	.795	.696	1.61	1608	100.3
13.6	.792	.706	1.63	1632	101.8
13.8	.789	.717	1.65	1656	103.3
14.0	.786	.727	1.68	1680	104.8
14.2	.783	.738	1.70	1704	106.3
14.4	.780	.748	1.73	1728	107.8
14.6	.777	.758	1.75	1752	109.3
14.8	.774	.769	1.77	1776	110.8
15.0	.771	.779	1.80	1800	112.3
15.2	.768	.790	1.82	1824	113.8
15.4	.765	.800	1.85	1848	115.3
15.6	.763	.810	1.87	1872	116.8
15.8	.759	.821	1.89	1896	118.3
16.0	.755	.831	1.92	1920	119.8
16.3	.751	.848	1.96	1956	122
16.6	.746	.862	1.99	1992	124
17.0	.740	.883	2.04	2040	127
17.3	.735	.900	2.08	2076	130
17.6	.731	.914	2.11	2112	132
18.0	.725	.935	2.16	2160	135
18.3	.720	.952	2.20	2196	137
18.6	.716	.966	2.23	2232	139
19.0	.710	.987	2.28	2280	142

KILL MUD WEIGHT/ICP/FCP

Bit TVD	=	10,000 ft
Mud Weight	=	10.6 ppg
SIDPP	=	800 psi

Slow Circulating Rate Pressure @ 40 SPM = 900 psi

KILL MUD WEIGHT, ppg

= **(SIDPP, psi ÷ *.052* ÷ TVD, ft) + Mud Wt, ppg**

= (800 ÷ *.052* ÷ 10,000) + 10.6

= 1.54 + 10.6

= <u>12.14 ppg</u>

ICP (Initial Circulating Pressure)

= **Slow Circulating Rate Pressure, psi + SIDPP, psi**

= 900 + 800

= <u>1,700 psi</u>

FCP (Final Circulating Pressure)

$$= \textbf{Slow Circulating Rate Pressure, psi} \times \frac{\textbf{Kill Mud Wt}}{\textbf{Old Mud Wt}}$$

$$= 900 \times \frac{12.14}{10.6}$$

= 900 x 1.1453

= <u>1,031 psi</u>

Note: <u>After a correct Start-Up the actual SCR pressure = Actual ICP - SIDPP</u>

If using units other than PPG, Feet and PSI then refer to page 4.1 for constants.

STEP DOWN CHART*

Used to calculate pressure drop versus strokes as KILL MUD is pumped to the BIT. There are 2 ways this can be done:-

FIXED STROKE INTERVAL OR FIXED PRESSURE INTERVAL

FIXED STROKE INTERVAL

$$\textbf{PSI Drop/100 Strokes} = \frac{\textbf{ICP - FCP}}{\textbf{Surface to Bit Strokes}} \times 100\,*$$

*(This number should be replaced if you use a different stroke interval e.g. 50, 200, 300 etc)

FIXED PRESSURE INTERVAL

$$\textbf{Strokes/50 PSI Drop} = \frac{\textbf{Surface to Bit Strokes x 50 psi}\ **}{\textbf{(ICP - FCP)}}$$

**(This number should be replaced if you use a different pressure interval e.g. 40, 60, etc)

EXAMPLE: ICP = 1600, FCP = 900
Surface to Bit Strokes = 1084

Fixed Strokes

$$= \frac{(1600 - 900)}{1084} \times 100$$

= 65 psi approx.

Fixed Pressure

$$= \frac{1084 \times 50}{(1600 - 900)}$$

= 77 strokes approx.

STROKES	PSI		STROKES	PSI	
0	1600	(ICP)	0	1600	(ICP)
100	1535		77	1550	
200	1470		154	1500	
300	1405		231	1450	
400	1340		308	1400	
500	1275		385	1350	
600	1210		462	1300	
700	1145		539	1250	
800	1080		616	1200	
900	1015		693	1150	
1000	950		770	1100	
1084	900	(FCP)	847	1050	
			924	1000	
			1001	950	
			1084	900	(FCP)

With Kill Mud at the Bit the pressure is then held constant for remainder of Kill.
Used for WAIT and WEIGHT Method.

Note: See page 4.20 for Deviated Step Down

INFLUX HEIGHT/GRADIENT

SIDPP	=	800 psi
SICP	=	900 psi
Collar Length	=	538 ft
Annular Volume around Collars	=	.0836 bbls/ft
Annular Volume around Pipe	=	.1215 bbls/ft
Mud Weight	=	10.6 ppg

Total Annular Volume around Collars

= **Collar Length, ft x Collar Annular Volume, bbls/ft**

= 538 ft x .0836 bbls/ft

= <u>45 barrels</u>

If INFLUX is LESS THAN volume around collars e.g. 20 barrels

INFLUX HEIGHT, ft

= **Influx Volume, bbls ÷ Annular Volume around Collar bbls/ft**

= 20 ÷ .0836

= <u>239 ft</u>

If INFLUX is GREATER THAN volume around collars e.g. 75 bbls

INFLUX HEIGHT, ft

$$= \left[\frac{\textbf{(Influx Vol., bbls - Collar Ann. Vol, bbls)}}{\textbf{Annular Volume around Pipe, bbls/ft}}\right] + \textbf{Collar Length, ft}$$

$$= \frac{(75-45)}{.1215} + 538$$

$$= \frac{30}{.1215} + 538$$

$$= 247 + 538$$

$$= \underline{785 \text{ feet}}$$

INFLUX HEIGHT/GRADIENT (continued)

Using example on previous page where:

Influx Volume	=	20 bbls
Influx Height	=	239 ft

INFLUX GRADIENT, psi/ft

$$= \mathbf{(Mud\ Wt, ppg\ x\ .052) - \left[\frac{SICP, psi - SIDPP, psi}{Influx\ Height, ft}\right]}$$

$$= (10.6 \text{ x } .052) - \left[\frac{900 - 800}{239}\right]$$

$$= .5512 - \left[\frac{100}{239}\right]$$

$$= .5512 - .4184$$

$$= \underline{.1328 \text{ psi/ft}}$$

Gradient of .2 or less	=	Gas
Gradient of .4 or more	=	Water

In between could be oil or mixture of oil, water and gas.

FRACTURE MUD WEIGHT/GRADIENT/PRESSURE

Fracture can be calculated using a Leak Off Pressure Test.

Shoe TVD = 8000 ft

Leak Off Test (LOT) was 2000 psi with 10.0 ppg mud in hole.

FRACTURE MUD WEIGHT (MAX. EQUIV. MUD WT), ppg

= **(LOT, psi ÷ Shoe TVD, ft ÷ *.052*) + Mud Wt, ppg**

= (2000 ÷ 8000 ÷ .052) + 10.0

= 4.81 + 10.0

= 14.81 ppg

FRACTURE GRADIENT, psi/ft

= **Fracture Mud Wt, ppg x *.052***

= 14.81 x .052

= .77 psi/ft

FRACTURE PRESSURE, psi

= **Fracture Mud Wt, ppg x *.052* x Shoe TVD, ft**

= 14.81 x .052 x 8000 ft

= 6161 psi

MAASP

Maximum pressure allowed on casing pressure gauge during operations.

Fracture Mud Wt, ppg	=	14.81	(See example on previous page)
Current Mud Wt, ppg	=	10.6 ppg	
Shoe TVD, ft	=	8000 ft	

MAASP, psi

$$= (\textbf{Frac. M. Wt, ppg - Current M.Wt, ppg}) \textbf{ x } \boldsymbol{.052} \textbf{ x Shoe TVD, ft}$$

$$= (14.81 - 10.6) \text{ x } .052 \text{ x } 8000$$

$$= 4.21 \text{ x } .052 \text{ x } 8000$$

$$= \underline{1751 \text{ psi}}$$

MAXIMUM SURFACE CASING PRESSURE

Approximate max. pressure at Casing Pressure gauge during a well kill operation. (Occurs when influx of gas is almost at surface). Using Wait and Weight.

Formation Pressure (Fp)	=	6000 psi (See page 4.1 for formula)
Pit Gain	=	20 bbls
Kill Mud Weight	=	11.5 ppg
Surface Annular Volume	=	.1279 bbls/ft

MAXIMUM CASING PRESSURE, psi

$$= \textbf{200 x} \sqrt{\frac{\textbf{Fp, psi x Pit Gain, bbls x Kill Mud Wt, ppg}}{\textbf{Surface Ann. Vol, bbls/ft x } \boldsymbol{1,000,000}}}$$

$$= 200 \text{ x} \sqrt{\frac{6000 \text{ x } 20 \text{ x } 11.5}{.1279 \text{ x } \mathit{1,000,000}}}$$

$$= 200 \text{ x} \sqrt{\frac{1,380,000}{127,900}}$$

$$= 200 \text{ x} \sqrt{10.7897}$$

$$= 200 \text{ x } 3.2848$$

$$= \underline{657 \text{ psi}}$$

VOLUME INCREASE

Approximate volume gain at surface due to gas expansion when circulating out a kick.

Formation Pressure (Fp)	=	6000 psi (see page 4.1 for formula).
Pit Gain	=	20 bbls
Surface Annular Volume	=	.1279 bbls/ft
Kill Mud Wt	=	11.5 ppg

VOLUME INCREASE, bbls

$$= \boldsymbol{4} \times \sqrt{\frac{\textbf{Fp, psi x Pit Gain, bbls x Ann. Vol, bbl/ft}}{\textbf{Kill Mud Wt, ppg}}}$$

$$= \mathbf{4} \times \sqrt{\frac{6000 \times 20 \times .1279}{11.5}}$$

$$= \mathbf{4} \times \sqrt{\frac{15348}{11.5}}$$

$$= \mathbf{4} \times \sqrt{1334.6}$$

$$= \mathbf{4} \times 36.5$$

$$= \underline{146 \text{ bbls}}$$

TRIP MARGIN

Approximate Mud Wt. value to be added after killing a kick.

Yield Point of Mud	=	14
Hole Diameter (Dh)	=	12¼"
Pipe Outside Diameter (dp)	=	5"

TRIP MARGIN, ppg

$$= \frac{\textbf{Yield Point x } \boldsymbol{.085}}{\textbf{(Dh - dp)}}$$

$$= \frac{14 \times .085}{(12.25 - 5)}$$

$$= \frac{1.19}{7.25}$$

$$= \underline{0.164 \text{ ppg}}$$

BOYLES LAW

This formula expresses relationship between gas volume and gas pressure.

Original Pressure (P_1) = 6000 psi
Original Volume (V_1) = 20 bbls
Current Pressure (P_2) = 1000 psi

BOYLES LAW

$$\mathbf{P_1 \times V_1 = P_2 \times V_2}$$

Find V_2

$$V_2 = \frac{P_1 \times V_1}{P_2}$$

$$= \frac{6000 \times 20}{1000}$$

$$= \frac{120{,}000}{1000}$$

= <u>120 barrels</u>

GAS EXPANSION FOR T° AND 'Z'

This formula is based on Boyles Law and Charles Law, incorporating temperature and compressibility effects.

$$\mathbf{V_2 = \frac{V_1 \times P_1 \times T_2 \times Z_2}{P_2 \times T_1 \times Z_1}}$$

T^o	=	$F^o + 460$
Z	=	Variable (get from client)
P	=	psi + 14.7

GAS PERCOLATION RATE, ft/hr

How fast is gas percolating (migrating) up the hole.

SIDPP at time Zero	=	700 psi
SIDPP after 15 mins	=	725 psi
Mud Weight	=	10.5 ppg

GAS PERCOLATION RATE, ft/hr

$$= \frac{\textbf{SIDPP increase, psi/hour}}{\textbf{(Mud Wt, ppg x }\boldsymbol{.052}\textbf{)}}$$

Increase per 15 minute interval	=	25 psi
Increase per hour = 4 x 25 psi	=	100 psi

$$= \frac{100}{(10.5 \text{ x } .052)}$$

$$= \frac{100}{.546}$$

= <u>183 ft/hr</u>

(SIDPP can be replaced with SICP)

PSI/BARREL

A factor representing the pressure exerted by 1 barrel of mud in the annulus.

Mud Weight	=	11 ppg
Annular Volume	=	.1215 bbls/ft

PSI/BARREL

$$= \frac{\textbf{Mud Weight, ppg x } \textbf{\textit{.052}}}{\textbf{Annular Volume, bbls/ft}}$$

$$= \frac{11 \text{ x } .052}{.1215}$$

$$= \frac{.572}{.1215}$$

$$= \underline{4.7 \text{ psi/barrel}}$$

(Can be used for inside Pipe by using Pipe Capacity instead of Annular Volume).

MUD TO BLEED DUE TO BUBBLE RISE (VOLUMETRIC)

Method of bringing gas to surface without SIDPP reading and unable to circulate.

Pressure rise allowed while well is shut in = 100 psi
Current psi/barrel factor = 14 psi (see above formula)

VOLUME TO BLEED, bbls

$$= \frac{\textbf{Pressure Rise on Casing Pressure Gauge, psi}}{\textbf{Current psi/bbl factor}}$$

$$= \frac{100}{14}$$

$$= \underline{7 \text{ barrels}}$$

e.g
If SICP = 800 psi,
Allow 50 to 100 psi for Safety.
Let SICP rise with well shut in due to gas migration to 800 + Safety, e.g. 875 psi.
Allow SICP to continue to rise to 875 + 100 = 975 psi.
At 975 psi carefully manipulate choke to maintain 975 psi while bleeding-off 7 barrels of mud (see above answer).
Once 7 bbls has been bled, shut in and allow SICP to rise to 975 + 100 = 1075.
Again continue to hold at 1075 psi while bleeding 7 bbls.
Process is repeated until gas arrives at choke.
Shut in and remove gas by Lubricating Method.

SOFT SHUT IN PROCEDURE (Drilling)
Choke open while Drilling

1. Pick up off bottom to clear first tooljoint.
2. Check flow - (if Positive go on).
3. Open H.C.R. or Failsafe.
4. Close Annular or Ram (if space out known).
5. Close Remote Adjustable Choke.
6. Close Gate Valve at Choke in case it leaks.
7. Complete Shut In e.g. monitor for leaks, contact toolpusher, hang off, install Kick Joint etc.

HARD SHUT IN PROCEDURE (Drilling)
Choke closed while Drilling

1. Pick up off bottom to clear first tooljoint.
2. Check flow - (if Positive go on)
3. Open H.C.R. or Failsafe.
4. Close Annular or Ram (if space out known).
5. Close Gate Valve at Choke in case it leaks.
6. Complete Shut In e.g. monitor for leaks, contact toolpusher, hang off, install Kick Joint etc.

SOFT SHUT IN PROCEDURE (Tripping)
Choke open while Drilling

1. Install Safety Valve.
2. Close Safety Valve.
3. Open H.C.R. or Failsafe.
4. Close Annular or Ram (if space out is known).
5. Close Remote Adjustable Choke.
6. Close Gate Valve at Choke in case it leaks.
7. Complete Shut In e.g. monitor for leaks, contact toolpushert etc.
8. Prepare course of action e.g. strip to bottom, kill at current depth, etc.

HARD SHUT IN PROCEDURE (Tripping)
Choke closed while Drilling

1. Install Safety Valve
2. Close Safety valve
3. Open H.C.R. or Failsafe.
4. Close Annular or Ram (if space out known).
5. Close Gate Valve at Choke in case it leaks.
6. Complete Shut In e.g. monitor for leaks, contact toolpusher. etc.

6\. Prepare course of action e.g. strip to bottom, kill at current depth, etc.

START UP PROCEDURE

Bring Pumps up to Kill Speed holding CASING PRESSURE constant.

For deep water ‘floater’ application, Casing pressure may require to be lowered during start up by an amount equal to Choke Line Friction Loss. One way to do this is to monitor kill line pressure during start up i.e. bring pumps up to kill speed holding kill line pressure constant by manipulating the choke on the choke line. Once up to speed the Casing Pressure would have reduced by choke line friction loss.

DRILLERS METHOD

1st Circulation.

Start Up - bring pumps up to speed holding casing pressure constant.

Once up to speed look at drill pipe pressure and hold this constant for one complete circulation.

2nd Circulation.

Start Up - bring pumps up to speed holding casing pressure constant.

Once up to speed, continue to hold casing pressure constant until kill mud is at the bit. At this point, switch over to drill pipe pressure and hold constant until kill mud reaches surface.

Note : As the Annulus may not be clean after 1st Circulation, it is recommended that the procedure for Wait and Weight be used in place of 2nd Circulation.

WAIT AND WEIGHT METHOD

Start Up - bring pumps up to speed holding casing pressure constant.

Once up to speed look at drill pipe. This should read approximately ICP*.

Allow drill pipe pressure to fall to FCP in accordance with step down chart or graph.

With kill mud at bit hold drill pipe pressure at FCP until kill mud reaches surface.

*If drill pipe pressure is greater than or less than ICP then (without shutting down) redo step down chart based on new ICP and FCP. If you feel that difference is too great or have any doubts then shut down and discuss possible cause of pressure difference.

Recalculate slow circulating rate pressure.

New SCR = New ICP - SIDPP

then recalculate FCP

$$= \textbf{New SCR, psi} \times \frac{\textbf{Kill Mud Wt}}{\textbf{Old Mud Wt}}$$

BARITE REQUIRED

Amount added to mud to obtain kill weight.

Original Mud Wt (W_1)	=	10 ppg
Kill Mud Wt (W_2)	=	11.5 ppg
Pit Volume	=	840 barrels

BARITE REQUIRED, pounds/barrel

$$= \frac{\mathbf{\mathit{1470}\,(W_2 - W_1)}}{\mathbf{(\mathit{35} - W2)}}$$

$$= \frac{\mathit{1470}\,(11.5 - 10)}{(\mathit{35} - 11.5)}$$

$$= \frac{\mathit{1470} \times 1.5}{23.5}$$

$$= \frac{2205}{23.5}$$

= <u>94 pounds/barrel</u>

TOTAL BARITE, pounds

= **Mud Volume in Pits, bbls x Barite Required, lbs/bbl**

= 840 x 94

= <u>78,960 pounds</u>

VOLUME INCREASE/100 BARRELS OF MUD

(due to adding barite)

$$= \frac{\textbf{Barite Required, pounds/barrel}}{\textbf{\textit{15}}}$$

$$= \frac{94}{15}$$

= <u>6.3 barrels/100 barrels of Mud</u>

(each 15 sacks of Barite added increases volume by approx 1 barrel).

TOTAL VOLUME after weight up

$$= \frac{\textbf{Barrels/ 100 barrels of Mud x Pit Volume}}{\textbf{\textit{100}}} + \textbf{Pit Volume}$$

$$= \frac{6.3 \text{ x } 840}{100} + 840$$

$$= \frac{5292}{100} + 840$$

= 53 + 840

= <u>893 barrels</u>

USABLE FLUID VOLUME

Gallons of usable fluid in a *single* Accumulator Bottle.
Multiply by number of bottles to get total.

USABLE FLUID VOLUME, gals/bottle

$$= \textbf{Bottle Vol. x} \left(\frac{\textbf{Precharge Press.}}{\textbf{Min. Operating Press.}} - \frac{\textbf{Precharge Press.}}{\textbf{Acc. Operating Press.}} \right)$$

API RP53 gives recommended pressures for various units:-

Precharge Pressure is normally 1000 psi
Minimum Operating is normally 1200 psi
Accumulator Operating Pressure is 3000 psi for most current units

Check API RP 53 for 500 psi units

Minimum Operating Pressure is the pressure required to operate a Ram against full rated Wellbore Pressure.

MINIMUM OPERATING PRESSURE

$$= \frac{\textbf{BOP Ram Maximum Rated Working Pressure}}{\textbf{Ram Closing Ratio}}$$

Note:- This calculated value of minimum operating pressure is normally applied in the Usable Fluid equation **only** when the result is greater than the API recommendation of 1200 psi

ACCUMULATOR VOLUME REQUIRED

GALLONS OF FLUID REQUIRED,

$$= \mathbf{V_R} \div \left(\frac{\textbf{Precharge Pressure}}{\textbf{Min. Operating Press.}} - \frac{\textbf{Precharge Pressure}}{\textbf{Acc. Operating Press.}} \right)$$

V_R = Volume required to perform chosen functions, (either from API specs, client requirements or local regulations).

ACCUMULATOR PRECHARGE PRESSURE

A method of measuring average Accumulator Precharge Pressure by operating the unit with charge pumps switched off.

Accumulator Starting Pressure (Ps)	=	3000 psi
Accumulator Final Pressure (Pf)	=	2200 psi
Total Accumulator Volume	=	180 gallons
Volume of Fluid Removed	=	20 gallons

AVERAGE PRECHARGE PRESSURE, psi

$$= \frac{\textbf{Volume of Fluid Removed, bbls}}{\textbf{Total Accumulator Volume, bbls}} \times \left[\frac{\textbf{Pf x Ps}}{\textbf{Ps - Pf}}\right]$$

$$= \frac{20}{180} \times \left[\frac{2200 \times 3000}{3000 - 2200}\right]$$

$$= .1111 \times \left[\frac{6{,}600{,}000}{800}\right]$$

$$= .1111 \times 8250$$

$$= \underline{917 \text{ psi}}$$

COMBINED STRIPPING AND VOLUMETRIC FORMULAE

The following calculations are used for stripping pipe in the hole when influx migration is a potential problem.

V_k	=	Kick Volume, bbls
A_1	=	Open Hole Capacity, bbls/ft
A_2	=	Drill Collar to Open Hole Capacity, bbls/ft
V_1	=	Closed End Displacement of 1 stand of drill pipe, bbls
V_2	=	Volume to Bleed, bbls
Mg	=	Mud Gradient, psi/ft
Ig	=	Influx Gradient, psi/ft
SICP	=	Shut in Casing Pressure, psi
Pw	=	Chosen Working Pressure, psi
Ps	=	Safety Pressure for Hydrostatic Pressure lost when BHA penetrates kick, psi
Pchoke	=	Choke Pressure Reading, psi

Step 1 Calculate Ps, psi

$$\mathbf{Ps} = \left(\frac{V_k}{A_2} - \frac{V_k}{A_1}\right) \mathbf{x}\ (\mathbf{Mg - Ig})$$

Step 2 Choose Pw
Between 50 and 200 psi

Step 3 Calculate V_2 bbls

$$\mathbf{V_2 = Pw\ x}\ \frac{A_2}{Mg}$$

Step 4 Strip into hole without bleeding mud, until SICP increases to **$Pchoke_1$**.

$Pchoke_1$ = SICP + Ps + Pw

Step 5 Continue stripping in the hole holding casing pressure constant at **$Pchoke_1$**. This will require mud to be bled from the well. Fill pipe regularly.

Step 6 The amount of mud gained in the Trip Tank over and above the drill pipe closed end displacement (V_1) will be the effect of gas expansion. (Some rigs have a Stripping Tank to allow for bleed-off of V_1 every stand).

Step 7 When gain in Trip Tank due to gas expansion equals V_2, continue to strip with choke closed to build casing pressure up to **$Pchoke_2$**.

$Pchoke_2$ = $Pchoke_1$ + Pw

Step 8 Continue stripping in hole holding casing pressure constant at **$Pchoke_2$.**

Step 9 Repeat Steps 6, 7 and 8 (increasing **Pchoke** by Pw each time V_2 is measured in Trip Tank) until back to bottom.

Step 10 Kill well as per standard well control techniques.

DEVIATED STEP DOWN CALCULATION

The following can be used to calculate step down pressure on a deviated well.

SIDP = 300 psi
ICP = 800 psi
FCP = 550 psi
SCR = 500 psi

MD	0	1000’	2000’	3000’	4000’	5000’
TVD	0	1000’	2000’	2500’	3000’	3400’

P circ (x) = Pressure to circulate at depth of interest

P circ (x)

$$= \left[\mathbf{SCR} + \left(\left(\mathbf{FCP - SCR}\right)\mathbf{x}\,\frac{\mathbf{MD(x)}}{\mathbf{MD\ total}}\right)\right] + \left[\mathbf{SIDPP} - \left(\mathbf{SIDPP\ x}\,\frac{\mathbf{TVD(x)}}{\mathbf{TVD\ total}}\right)\right]$$

For x = 3000 ft TVD (4000 ft MD)

$$= \left[500 + \left((550 - 500)\,\text{x}\,\frac{4000}{5000}\right)\right] + \left[300 - \left(300\ \text{x}\ \frac{3000}{3400}\right)\right]$$

$$= [500 + (50\ \text{x}\ .8)] + [300 - (300\ \text{x}\ .8823)]$$

$$= (500 + 40\ \ ) + (300 - 265\ \ )$$

$$= 540 + 35$$

$$= 575\ \text{psi}$$

Equivalent using Vertical Step Down calculation

= 600 psi

NOTES

N O T E S

BUOYANT FORCE ON CASING

Effect of cementing operation on a String of Casing. Most dangerous with Shallow strings of large diameter. Heavy cement may want to float the casing out of the hole.

C_1	=	Casing Length	=	1500ft
Cwt	=	Casing Wt/Ft	=	106.5 lbs/ft
Ccap	=	Casing Cap	=	.3507 bbls/ft
Wcmt	=	Cement Weight	=	15.4 ppg
B.F. cmt	=	Cement Buoyancy Factor	=	.765
M.Wt	=	Mud Weight	=	9.0 ppg

BUOYANCY FORCE

$$= \mathbf{C_1 \text{ x } \left[\left(C_{wt} \text{ x } B.F._{cmt} \right) - \left(42 \text{ x } C_{cap} \text{ x } \left(W_{cmt} - M.Wt \right) \right) \right]}$$

$$= 1500 \left[(106.5 \text{ x } .765) - \left(42 \text{ x } .3507 \text{ x } (15.4 - 9.0) \right) \right]$$

$$= 1500 \left[81.47 - (14.73 \text{ x } 6.4) \right]$$

$$= 1500 \left[(81.47 - 94.27) \right]$$

$$= 1500 \text{ x } (-12.8)$$

= **<u>-19200 lbs</u> (this is a MINUS number)**

A minus number means a force upward: a positive number means a force downward.

N O T E S

BALANCE MUD WEIGHT

Weight of Mud to displace cement if Buoyant force is upward.

Wcmt	=	Cement Weight	=	15.4 ppg
Cwt	=	Casing Wt/ft	=	106.4 lbs/ft
B.F.cmt	=	Cement Buoyancy Factor	=	.765
Ccap	=	Casing Capacity	=	.3507 bbls/ft

BALANCE MUD WEIGHT

$$= \mathbf{Wcmt} - \left[\frac{\mathbf{Cwt \times B.F.cmt}}{\mathit{42} \times \mathbf{Ccap}}\right]$$

$$= 15.4 - \left[\frac{106.4 \times .765}{42 \times .3507}\right]$$

$$= 15.4 - \left[\frac{81.396}{14.729}\right]$$

$$= 15.4 - 5.5$$

$= \underline{9.9 \text{ ppg}}$

SACKS OF CEMENT

Volume of Cement required	=	500 bbls
Yield/sack of cement	=	1.15 cu. ft/sack

SACKS

$$= \frac{\mathbf{Volume\ of\ Cement,\ bbls \times \mathit{5.6146}}}{\mathbf{Yield/Sack,\ cu.\ ft}}$$

$$= \frac{500 \times 5.6146}{1.15}$$

$$= \frac{2807.3}{1.15}$$

$= \underline{2441 \text{ sacks}}$

BALANCED PLUGS

CEMENT VOLUME REQUIRED, bbls

$$= \left(\frac{\textbf{Dia. of Hole}^2}{\textbf{\textit{1029}}} \right) \textbf{x Required Plug Length, ft}$$

WATER SPACER AHEAD, bbls

Choose a volume but be careful that loss of hydrostatic does not cause kick.

LENGTH OF SPACER IN ANNULUS, ft (V1)

$$= \frac{\textbf{Spacer Volume, bbls}}{\textbf{Ann. Volume, bbls/ft}}$$

VOLUME OF SPACER BEHIND CEMENT, bbls (V2)

$$= \textbf{V1 x Pipe Cap, bbls/ft}$$

LENGTH OF BALANCED CEMENT COLUMN, ft

$$= \frac{\textbf{Cement Volume, bbls}}{\textbf{(Ann, Vol, bbls/ft + Pipe Cap, bbls/ft)}}$$

MUD TO DISPLACE PLUG INTO POSITION, bbls

$$= \left[\left(\textbf{C.base - L. plug} \right) \textbf{x Pipe Cap, bbls/ft} \right] \textbf{- V2}$$

STROKES TO DISPLACE

$$= \frac{\textbf{Mud to Displace, bbls}}{\textbf{Pump Output/Stroke}}$$

C.base	=	Base of Plug, ft
L.Plug	=	Length of Cement Plug, ft
V2	=	Spacer volume behind cement, bbls

EXAMPLE

Plug Length required	=	400 ft
Water Spacer ahead	=	20 bbls
Annular Volume	=	.1215 bbls/ft
Pipe Capacity	=	.01776 bbls/ft
Hole Capacity	=	.1458 bbls/ft
Depth of Plug base	=	10,000 ft
Pump Output	=	.109 bbls/stroke

Cement Volume Required, bbls

= .1458 x 400 ft

= <u>58.32 bbls</u>

Length of Spacer in Annulus, ft

$$= \frac{20}{.1215} = \underline{164.6 \text{ ft}}$$

Volume of Spacer behind Cement, bbls

= 164.6 x .01776 = <u>2.92 bbls</u>

Length of Balanced Cement Column

$$= \frac{58.32}{.1215 + .01776} = \frac{58.32}{.13926} = \underline{418.8 \text{ ft}}$$

Mud to Displace into Position, bbls

$$= (10{,}000 \text{ ft} - 418.8) \times .01776$$

$$= 170.16 \text{ bbls} - 2.92 \text{ bbls}$$

$$= \underline{167.24}$$

Strokes to Displace

$$= \frac{167.24}{.109} = \underline{1534 \text{ strokes}}$$

N O T E S

PART 6: HYDRAULICS

ANNULAR VELOCITY ft/min

Flow Rate	=	450 gallons per minute (GPM)		
Dh	=	Hole Diameter	=	12¼"
dp	=	Pipe OD	=	5"

ANNULAR VELOCITY, ft/min

$$= \frac{\boldsymbol{24.51 \text{ x GPM}}}{\left(\mathbf{Dh^2 - dp^2}\right)}$$

$$= \frac{24.51 \text{ x } 450}{\left(12.25^2 - 5^2\right)}$$

$$= \frac{11029.5}{125.0625}$$

= 88.2 ft/min

EQUIVALENT CIRCULATING DENSITY (ECD)*

For low mud weight.

Mud Wt	=	11 ppg		
Yield Point	=	13		
Dh	=	Hole Diameter	=	12¼"
dp	=	Pipe OD	=	5"

ECD, ppg

$$\mathbf{= Mud\ Wt, ppg} + \left[\frac{\mathbf{Yield\ Point\ x\ .1}}{\mathbf{(Dh - dp)}}\right]$$

$$= 11 + \left[\frac{13 \text{ x } .1}{(12.25 - 5)}\right]$$

$$= 11 + \left[\frac{1.3}{7.25}\right]$$

$$= 11 + .18$$

$$= \underline{11.18 \text{ ppg}}$$

*Field Approximation

EQUIVALENT CIRCULATING DENSITY*

For Mud Weights greater than 13 ppg.

Mud Weight	=	15 ppg		
Yield Point	=	18		
Plastic Viscosity	=	30		
Dh	=	Hole Diameter	=	12¼”
dp	=	Pipe OD	=	5”
V	=	Annular Velocity	=	90 ft/min

ECD, ppg

$$= \mathbf{M.\ Wt} + \left[\frac{\boldsymbol{0.1}}{(\mathbf{Dh - dp})} \ \mathbf{x} \ \left(\mathbf{YP} \ + \left(\frac{(\mathbf{PV} \ + \ \mathbf{V})}{\boldsymbol{300} \ \mathbf{x} \ (\mathbf{Dh - dp})} \right) \right) \right]$$

$$= 15 + \left[\frac{0.1}{(12.25 - 5)} \ \text{x} \ \left(18 \ + \left(\frac{30 \ \text{x} \ 90}{300 \ \text{x} \ (12.25 - 5)} \right) \right) \right]$$

$$= 15 + \left[\frac{0.1}{7.25} \ \text{x} \ \left(18 \ + \left(\frac{2700}{(300 \ \text{x} \ 7.25)} \right) \right) \right]$$

$$= 15 + \left[.0138 \ \text{x} \ \left(18 \ + \left(\frac{2700}{2175} \right) \right) \right]$$

$$= 15 + (.0138 \ \text{x} \ (18 \ + \ 1.2414))$$

$$= 15 + (.0138 \ \text{x} \ 19.2414)$$

$$= 15 + .2655$$

$$= \underline{15.26 \text{ ppg}}$$

*Field Approximation

ECD USING ANNULAR PRESSURE LOSS

ECD ppg = **(Annular Pressure Loss ÷ *.052* ÷ TVD, ft.) + Mud Wt., ppg**

GALLONS PER MINUTE FOR OPTIMIZATION: Roller Cone Bits

= Bbls/Stroke x SPM x 42

Recommended range is between 30 and 70 GPM/inch of Bit Diameter.

E.g. 30 GPM x 12¼" = <u>367.5 GPM</u>

70 GPM x 12¼" = <u>857.5 GPM</u>

HHP REQUIRED AT SURFACE (INPUT)

This is the 10 D rule.

HHP required at surface.

= *10* (Bit Size)^2

CRITICAL VELOCITY, ft/min

Mud Velocity above which flow changes from Laminar to Turbulent.

Mud Wt	=	11 ppg		
Plastic Viscosity	=	30		
Yield Point	=	15		
Dh	=	Hole Diameter	=	12¼”
dp	=	Pipe OD	=	5”

CRITICAL VELOCITY, ft/min

$$= 60 \text{ x} \left[\frac{\mathbf{1.08\,PV + 1.08\sqrt{PV^2 + \left(9.26\,(Dh - dp)^2 \text{ x } YP \text{ x } M.Wt\right)}}}{\mathbf{M.Wt \text{ x } (Dh - dp)}} \right]$$

$$= 60 \text{ x} \left[\frac{(1.08 \text{ x } 30) + 1.08\sqrt{30^2 + \left(9.26\,(12.25 - 5)^2 \text{ x } 15 \text{ x } 11\right)}}{11 \text{ x } (12.25 - 5)} \right]$$

$$= 60 \text{ x} \left[\frac{32.4 + 1.08\sqrt{900 + \left(9.26\,(52.5625) \text{ x } 165\right)}}{79.75} \right]$$

$$= 60 \text{ x} \left[\frac{32.4 + 1.08\sqrt{900 + 80310}}{79.75} \right]$$

$$= 60 \text{ x} \left[\frac{32.4 + 1.08\sqrt{81210}}{79.75} \right]$$

$$= 60 \text{ x} \left[\frac{32.4 + (1.08 \text{ x } 284.974)}{79.75} \right]$$

$$= 60 \text{ x} \left[\frac{32.4 + 307.77}{79.75} \right]$$

$$= 60 \text{ x} \left(\frac{340.17}{79.75} \right)$$

$$= 60 \text{ x } 4.265$$

$$= \underline{256 \text{ ft/min}}$$

GPM TO OBTAIN CRITICAL VELOCITY

Critical Velocity = 256 ft/min
Dh = Hole Diameter = 12¼"
dp = Pipe OD = 5"

GPM

$$= \frac{\textbf{Critical Velocity x } (\mathbf{Dh^2 - dp^2})}{\mathbf{24.51}}$$

$$= \frac{256 \text{ x } (12.25^2 - 5^2)}{24.51}$$

$$= \frac{256 \text{ x } 125.0625}{24.51}$$

$$= \frac{32016}{24.51}$$

= <u>1306 GPM</u>

TOTAL FLUID AREA (TFA) FOR PDC AND ROCK BITS

As a RULE OF THUMB and a possible starting point for designing hydraulics

D = Bit Diameter = 12¼"

AVERAGE TFA, square inches

$$= \mathbf{{}^{1}/_{10}(D)}$$

= 0.1 (12.25)

=<u>1.225 sq ins</u>

PRESSURE DROP ACROSS THE BIT

Two formulae : one for Total Area of the Nozzles, sq. ins.
: the other for nozzle size in 32nds.

GPM = 450
M. Wt. = 12 ppg
Nozzles = 3 x 12/32nds
or = .3313 sq. ins.

PRESSURE DROP, psi

$$= \frac{\mathbf{GPM^2\ x\ M\ Wt, ppg}}{\boldsymbol{10863.1}\ \mathbf{x\ Nozzle\ Area^2}} \qquad \textbf{OR} \qquad = \frac{\boldsymbol{156.482}\ \mathbf{x\ GPM^2\ x\ M.\ Wt}}{\left(\mathbf{J_1}^2 + \mathbf{J_2}^2 + \mathbf{J_3}^2\right)^2}$$

$$= \frac{450^2 \text{ x } 12}{10863.1 \text{ x } .3313^2} \qquad \text{OR} \qquad = \frac{156.482 \text{ x } 450^2 \text{ x } 12}{\left(12^2 + 12^2 + 12^2\right)^2}$$

$$= \frac{202500 \text{ x } 12}{10863.1 \text{ x } .10976} \qquad \text{OR} \qquad = \frac{156.482 \text{ x } 202500 \text{ x } 12}{\left(144 + 144 + 144\right)^2}$$

$$= \frac{2430000}{1192.33} \qquad \text{OR} \qquad = \frac{380251260}{(432)^2}$$

$$= \underline{2038 \text{ psi}} \qquad \text{OR} \qquad = \frac{380251260}{186624}$$

$$= \underline{2038 \text{ psi}}$$

NOZZLE AREA

NOZZLE AREA, square inches

$$= \sqrt{\frac{\mathbf{GPM^2\ x\ Mud\ Wt.}}{\boldsymbol{10863.1}\ \mathbf{x}\ \mathbf{P_{Bit}}}}$$

(See page 6.8 for table of Nozzle Size/TFA comparison)

NOZZLE SIZES

For bits with 2, 3 or more nozzles.

M. Wt	=	12 ppg
Pressure Drop at Bit	=	2038 psi
GPM	=	450
No. of Jets	=	3

NOZZLE SIZE

$$= \boldsymbol{3.536}\sqrt{\frac{\textbf{GPM}}{\textbf{No. of Jets}}\sqrt{\frac{\textbf{M. Wt, ppg}}{\textbf{Pressure Drop at Bit}}}}$$

$$= 3.536\sqrt{\frac{450}{3}\sqrt{\frac{12}{2038}}}$$

$$= 3.536\sqrt{150\sqrt{.00589}}$$

$$= 3.536\sqrt{150 \text{ x } .0767}$$

$$= 3.536\sqrt{11.51}$$

$$= 3.536 \text{ x } 3.3926$$

$$= \underline{11.99}$$

Interpretation of answers.

Example:If answer is between 11.8 and 12.2,
choose 3 x 12/32nds.

Example:If answer is between 11.5 and 11.8,
choose 1 x 11/32nds and 2 x 12/32nds.

Example:If answer is between 11.2 and 11.5,
choose 2 x 11/32nds and 1 x 12/32nds.

T.F.A. COMPARISON CHART

T.F.A Comparison Chart (Total Flow Area)									
Jet Size	**T.F.A of 1 Jet**	**T.F.A of 2 Jets**	**T.F.A of 3 Jets**	**T.F.A of 4 Jets**	**T.F.A of 5 Jets**	**T.F.A of 6 Jets**	**T.F.A of 7 Jets**	**T.F.A of 8 Jets**	**T.F.A of 9 Jets**
7/32”	.038	.076	.114	.152	.190	.228	.266	.305	.342
8/32”	.049	.098	.147	.196	.245	.295	.344	.393	.442
9/32”	.062	.124	.186	.249	.311	.373	.435	.497	.559
10/32”	.077	.153	.230	.307	.383	.460	.537	.614	.690
11/32”	.093	.186	.278	.371	.464	.557	.650	.742	.835
12/32”	.110	.221	.331	.442	.552	.663	.773	.884	.994
13/32”	.130	.259	.389	.518	.648	.778	.907	1.037	1.167
14/32”	.150	.300	.450	.600	.750	.900	1.050	1.200	1.350
15/32”	.172	.344	.516	.688	.860	1.032	1.204	1.376	1.548
16/32”	.196	.392	.588	.784	.980	1.176	1.372	1.568	1.764
18/32”	.249	.498	.747	.996	1.245	1.494	1.743	1.992	1.241
20/32”	.307	.613	.921	1.228	1.535	1.842	2.148	2.455	2.762
22/32”	.371	.742	1.113	1.484	1.855	2.226	2.597	2.969	3.339
24/32”	.441	.883	1.325	1.767	2.209	2.650	3.092	3.534	3.976

AVERAGE NOZZLE SIZE IN 32nds

TFA = Total Fluid Area in square inches = 0.6
0.7854 = Constant
3 = for 3 Nozzles (use 4 if 4 nozzle bit)

$$= \left(\sqrt{\frac{\mathbf{TFA}}{\boldsymbol{0.7854}\ \mathbf{x}\ \mathbf{3}}}\right) \mathbf{x}\ \boldsymbol{32}$$

$$= \left(\sqrt{\frac{0.6}{0.7854 \text{ x } 3}}\right) \text{x } 32$$

$$= \left(\sqrt{0.2547}\right) \text{x } 32$$

$$= 0.5046 \text{ x } 32$$

$$= 16.148$$

for 3 nozzle bit = 16 : 16 : 16 approx

NOZZLE (JET) VELOCITY, ft/sec

Speed at which mud travels through each nozzle.
Often called Jet Velocity.

GPM	=	450
Nozzle Size	=	3 x 12/32nds
or	=	.3313 square inches

NOZZLE VELOCITY, ft/sec

$$= \frac{\boldsymbol{\mathit{418.3}}\ \mathbf{x\ GPM}}{\mathbf{J_1^2 + J_2^2 + J_3^2}} \qquad \text{———} \qquad = \frac{\mathbf{GPM}}{\boldsymbol{\mathit{3.12}}\ \mathbf{(Nozzle\ Area)}}$$

$$= \frac{418.3 \text{ x } 450}{12^2 + 12^2 + 12^2} \qquad \text{———} \qquad = \frac{450}{3.12 \text{ x } .3313}$$

$$= \frac{188235}{144 + 144 + 144} \qquad \text{———} \qquad = \frac{450}{1.0336}$$

$$= \frac{188235}{432} \qquad \text{———} \qquad = \underline{435 \text{ ft/sec}}$$

$$= \underline{436 \text{ ft/sec}}$$

HYDRAULIC HORSEPOWER AT BIT (HHP)

GPM	=	450
Pressure Loss at Bit	=	2038 psi
Total Pump Pressure	=	3000 psi
Bit Diameter	=	12¼"

HHP AT BIT

$$= \frac{\textbf{GPM x Pressure Loss at Bit, psi}}{\textbf{\textit{1714}}}$$

$$= \frac{450 \times 2038}{1714}$$

$$= \frac{917100}{1714}$$

$$= \underline{535 \text{ HHP}}$$

TOTAL HHP

$$= \frac{\textbf{GPM x Total Pump Pressure, psi}}{\textbf{\textit{1714}}}$$

$$= \frac{450 \times 3000}{1714}$$

$$= \underline{787.6 \text{ HHP}}$$

HSI OF BIT DIAMETER

$$= \frac{\textbf{HHP at Bit}}{\textbf{\textit{.7854} x Bit Dia}^2} \quad \textbf{OR} \quad \frac{\textbf{GPM x P}_{\textbf{Bit}}}{\textbf{\textit{1346} (Bit OD)}^2}$$

$$= \frac{535}{.7854 \times 12.25^2}$$

$$= \frac{535}{117.86}$$

$$= \underline{4.5 \text{ HSI}}$$

P_{Bit} = Pressure Loss across the Bit
HSI = Horsepower per Square Inch of Bit Diameter.

% HHP AT BIT

Percentage of total HHP. Optimum hydraulics range is 50 to 65%.
(Generally 50% for Roller Cone and 65% for Fixed Cutter Bits)

There are two formulae: one using HHP, the other using Pressure.

HHP Total =	787.6;	Total Pressure	=	3000
HHP at Bit =	535;	Pressure Loss at Bit	=	2038

% HHP

$$= \frac{\textbf{HHP at Bit x } \textbf{\textit{100}}}{\textbf{Total HHP}} \qquad \text{———} \qquad = \frac{\textbf{Pressure Loss at Bit x } \textbf{\textit{100}}}{\textbf{Total Pump Pressure}}$$

$$= \frac{535 \times 100}{787.6} \qquad \text{———} \qquad = \frac{2038 \times 100}{3000}$$

$$= \underline{67.9\%} \qquad \text{———} \qquad = \underline{67.9\%}$$

IMPACT FORCE, lbs

GPM	=	450
M.Wt	=	12 ppg
Jet Velocity	=	435 ft/sec

IMPACT FORCE, lbs

$$= \frac{\textbf{GPM x M.Wt, ppg x Jet Velocity, ft/sec}}{\textbf{\textit{1932}}}$$

$$= \frac{450 \times 12 \times 435}{1932}$$

$$= \underline{1216 \text{ lbs}}$$

PRESSURE/STROKE/MUD WEIGHT RELATIONSHIP

Effect on pump pressure due to changes in SPM or Mud Weight.

Current Pressure	=	3000 psi
Current SPM	=	80
Current Mud Wt	=	11
New SPM	=	90
New Mud Wt	=	12

NEW PRESSURE, psi
(for SPM change)

$$= \textbf{Current Pressure, psi} \times \left(\frac{\textbf{New SPM}}{\textbf{Old SPM}}\right)^{2^*}$$

$$= 3000 \times \left(\frac{90}{80}\right)^2$$

$$= 3000 \times (1.125)^2$$

$$= 3000 \times 1.2656$$

$$= \underline{3797 \text{ psi}}$$

NEW PRESSURE, psi
(for Mud Weight change)

$$= \textbf{Current Pressure, psi} \times \frac{\textbf{New M. Wt.}}{\textbf{Old M. Wt.}}$$

$$= 3000 \times \frac{12}{11}$$

$$= 3000 \times 1.0909$$

$$= \underline{3273 \text{ psi}}$$

* A more accurate answer can be obtained by using the power 1.86 instead of 'squaring'.
This needs a special function key on your calculator.

PLASTIC VISCOSITY/YIELD POINT

PV = **Fann 600 Reading - Fann 300 Reading**
(General Rule: keep as low as possible)

YP = **Fann 300 Reading - PV**
(General Rule: no less than Mud Weight.ppg)

Fann 600 reading = 2PV + YP

Fann 300 reading = YP + PV

APPARENT VISCOSITY

$$= \frac{\textbf{Fann 600 Reading}}{\textbf{2}}$$

HYDRAULIC RULES OF THUMB

General rules of optimization of hydraulics (remember that technology is extending values given below).

Flow Rate: 30 - 70 gpm/inch of Bit diameter

(values higher than 70 are not uncommon, values lower than 70 may not provide adequate hole cleaning, especially in high angle wells)

HSI: 2.5 to 7

(values up to 12 are not uncommon)

%Pressure Loss at Bit: 50 - 65%

(May be different depending on requirement for Hole Cleaning; Generally 50% for Roller Cone and 65% for Fixed Cutter Bits)

Jet Velocity: 350 - 450 feet/second

(may vary with changes to above)

NOTES

N O T E S

PART 7: MISCELLANEOUS

CRITICAL RPM (accurate to + or - 15%)

RPM to avoid due to excessive vibration.

L	=	Length of one joint of pipe	=	31ft
OD	=	Pipe OD	=	5”
ID	=	Pipe ID	=	4.276”

CRITICAL RPM

$$= \frac{\boldsymbol{33055}}{\mathbf{L^2}} \mathbf{x} \sqrt{\mathbf{(OD^2 + ID^2)}}$$

$$= \frac{33055}{31^2} \text{ x } \sqrt{(5^2 + 4.276^2)}$$

$$= \frac{33055}{961} \text{ x } \sqrt{43.284}$$

= 34.3964 x 6.579

= <u>226 RPM</u>

Rule of thumb: for 5” drill pipe, do not exceed 200 RPM for any depth.

TEST VOLUME

Approximate volume of Mud to pump to achieve a desired test pressure.

Test pressure required = 7500 psi

V_m = Mud volume between testing pump and other end of system (e.g. closed ram), = 15 bbls.

TEST VOLUME, bbls

= V_m x .000003 x Test Pressure, psi

= 15 x .000003 x 7500

= <u>.34 bbls</u>

MUD BUILDING FORMULAS

V_C	=	Volume of clay based mud, bbls.
V_F	=	Final volume of mud required, bbls.
MW_F	=	Final mud wt.
MW_C	=	Clay based Mud wt.
V_W	=	Volume of starting water.
MW_W	=	Weight of water, ppg.

1. $$V_C = V_F \left[\frac{(35 - MW_F)}{(35 - MW_C)} \right]$$

2. $$V_W = V_C \left[\frac{(21.66 - MW_C)}{(21.66 - MW_W)} \right]$$

3. $$\text{Clay Req.} = V_W \left[\frac{910\,(MW_C - MW_W)}{(21.66 - MW_C)} \right]$$

4. $$\text{Barite Req.} = V_C \left[\frac{1470\,(MW_F - MW_C)}{(35 - MW_F)} \right]$$

5. $$\text{Volume Check} = V_W + \frac{\text{Clay Req.}}{910} + \frac{\text{Barite Req.}}{1470}$$

Note: Bentonite increases pit volume by approx. 1 bbl every 9 sxs.
Barite increases pit volume by approx. 1 bbl every 15 sxs.

EXAMPLE FOR MUD BUILDING

500 bbls., of clay based mud weighing 9.5 ppg is required.
Weight of water = 8.4 ppg, weight of clay based mud = 8.8 ppg.

1. $V_C = 500\left[\dfrac{35 - 9.5}{35 - 8.8}\right] = 486.6$ bbls

2. $V_W = 486.6\left[\dfrac{21.66 - 8.8}{21.66 - 8.4}\right] = 472$ bbls

3. Clay Req. $= 472\left[\dfrac{910\,(8.8 - 8.4)}{21.66 - 8.8}\right] = 13{,}360$ pounds

4. Barite Req. $= 486.6\left[\dfrac{1470\,(9.5 - 8.8)}{35 - 9.5}\right] = 19{,}636$ pounds

5. Vol. Check $= 472 + \dfrac{13360}{910} + \dfrac{19636}{1470}$

$$= 472 + 14.7 + 13.3$$

$$= \underline{500 \text{ bbls}}$$

MASS BALANCE EQUATION:

States that Density x Volume of the individual components = sum of Volumes x Final Density.

$$\mathbf{D_1\, V_1 + D_2\, V_2 + D_3\, V_3 = V_{sum}\, D_F}$$

Pits 1, 2 and 3 contain the following:

Pit 1	=	80 bbls. of 11.2 ppg mud
Pit 2	=	240 bbls. of 10.0 ppg mud
Pit 3	=	100 bbls. of 8.4 ppg drillwater

What will be the weight of mud if all three pits are mixed together?

$$(11.2 \text{ x } 80) + (10 \text{ x } 240) + (8.4 \text{ x } 100) = (80 + 240 + 100)\, D_F$$

$$896 + 2400 + 840 = 420\, D_F$$

$$\frac{4136}{420} = D_F$$

$$9.85 \text{ ppg} = D_F$$

MICRON SIZES

Clay and Bentonite	-	less than	1
Barite	-		2 - 60
Silt	-		2 - 74
API Sand	-	greater than	74
Talcum Powder	-		5 - 50
Kitchen Flour	-		1 - 80

MICRON CUT POINTS

Centrifuge	-	3 - 5 Micron
Desilter	3" - 4" Cones	12 - 60 Micron
Desander	5" - 12" Cones	30 - 60 Micron

PRESSURE AT CONE MANIFOLD

A rule of thumb for required pump pressure at cone manifold on Desilters or Desanders.

= 4 x M. Wt (ppg)

CONE CAPACITIES

4"	50 GPM/cone
6"	100 GPM/cone
8"	155 GPM/cone
10"	500 GPM/cone
12"	600 GPM/cone

pH

Measure of effective acidity or alkalinity of mud.

Range is 0 - 14. pH 7 is neutral.

Greater than 7 is ALKALINE.

Less than 7 is ACID.

MARSH FUNNEL

Time for fresh water to drain

= 26 secs ± 1/2 second per quart.

NORMAL FORMATION PRESSURE

.465 psi/ft or 8.94 ppg.

FRESH WATER GRADIENT

.433 psi/ft. or 8.33 ppg

OVERBURDEN GRADIENT

1.0 psi/ft. or 19.3 ppg

VOLUME OF A CONE

$= {}^{1}/_{3}\,\pi\,r^2\,h$

AREA OF A CONE

$= \pi\,r\,s$

h = vertical height   r = radius   s= length along cone from base to point

---

VOLUME OF A SPHERE

$= {}^{4}/_{3}\,\pi\,r^3$

AREA OF A SPHERE

$= 4\,\pi\,r^3$

r = radius

VOLUME OF A PYRAMID

= $^{1}/_{3}$ Base Area x Vertical Height

N O T E S

PART 8: CONVERSION FACTORS

All Gallons are **U.S.** unless otherwise stated

MULTIPLY	BY	TO OBTAIN
Acres	.4047	hectares
Acres	43560.	square feet
Acres	.00156	square miles
Atmospheres	76.	Cms of mercury
Atmospheres	760.	Millimetres of mercury
Atmospheres	29.92	Inches of mercury
Atmospheres	33.90	Feet of water
Atmospheres	1.0333	Kgs/sq cm
Atmospheres	14.70	psi
Atmospheres	1.058	Tons/sq ft
Atmospheres	101325.	Newtons/m^2
Barrel	5.6146	Cubic ft
Barrel	.15897	Cubic metres
Barrels-oil	42.	Gallons-oil
Barrel of water	.1588	Metric tons
Barrel (36 A.P.I.)	.1342	Metric tons
Barrel/hour	.0936	Cubic ft per minute
Barrel/hour	.7	Gallons per minute
Barrel/hour	2.695	Cubic ins/sec
Barrel/day	.02917	Gallons per minute
Bbls/ft	.52161	Cubic metres/metre
Bars	100000.	Newtons/m^2
Bars	.9869	Atmospheres
Bars	2089.	Lbs/sq ft
Bars	14.50	psi
Bars	100	Kilopascals
Bars/mt	4.421	psi/ft
Btu	.2520	Kilogram - calories
Btu	.2928	Watt hour
Btu	777.5	Foot-lbs
Btu	.0003927	Horsepower - hours
Btu	107.5	Kilogram - metres
Btu	.0002928	Kilowatt - hours
Btu/min	12.96	Foot - lbs/sec
Btu/min	.02356	Horsepower
Btu/min	.01757	Kilowatts
Btu/min	17.57	Watts
Centigrams	.01	Grams
Centilitres	.01	Litres

Centimetres	.3937	Inches
Centimetres	.01	Metres
Centimetres	10.	Millimetres
Centimetres of mercury	.01316	Atmospheres
Centimetres of mercury	.4461	Feet of water
Centimetres of mercury	136.0	Kgs/sq metre
Centimetres of mercury	27.85	Lbs/sq ft
Centimetres of mercury	.1934	psi
Centimetres/second	1.969	Feet/min
Centimetres/second	.03281	Feet/sec
Centimetres/second	.036	Kilometres/hr
Centimetres/second	.6	Metres/min
Centimetres/second	.02237	Miles/hr
Centimetres/second	.0003728	Miles/min
Centimetres/second/second	.03281	Feet/sec/sec
Centipoise	1.0	Millipascal seconds
Cubic centimetres	.00003531	Cubic feet
Cubic centimetres	.06102	Cubic inches
Cubic centimetres	.000001	Cubic metres
Cubic centimetres	.0002642	Gallons
Cubic centimetres	.001	Litres
Cubic centimetres	.002113	Pints (liq)
Cubic feet	.1781	Barrels
Cubic feet	28320.	Cubic cms
Cubic feet	1728.	Cubic inches
Cubic feet	.02832	Cubic metres
Cubic feet	7.48052	Gallons
Cubic feet	28.32	Litres
Cubic feet	59.84	Pints (liq)
Cubic feet/minute	472.0	Cubic cm/sec
Cubic feet/minute	.1247	Gallons/sec
Cubic feet/minute	.472	Litres/sec
Cubic feet/minute	62.43	Lbs of water/min
Cubic feet/minute	10.686	Barrels per hour
Cubic feet/minute	28.8	Cubic in/sec
Cubic feet/second	.646317	Million gals/day
Cubic feet/second	448.831	Gallons/min
Cubic feet/second	1699.	Litres/min
Cubic inches	16.39	Cubic centimetres
Cubic inches	.0005787	Cubic feet
Cubic inches	.00001639	Cubic metres
Cubic inches	.004329	Gallons
Cubic inches	.01639	Litres
Cubic inches	.03463	Pints (liq)

Cubic metres	6.2905	Barrels
Cubic metres	1000000.	Cubic centimetres
Cubic metres	35.31	Cubic feet
Cubic metres	61023.	Cubic inches
Cubic metres	1.308	Cubic yards
Cubic metres	264.2	Gallons
Cubic metres	1000.	Litres
Cubic metres	2113.	Pints (liq)
Decigrams	.1	Grams
Decilitres	.1	Litres
Decimetres	.1	Metres
Degrees (angle)	60.	Minutes
Degrees (angle)	.01745	Radians
Degrees (angle)	3600.	Seconds
Degrees/sec	.01745	Radians/sec
Degrees/sec	.1667	Revolutions/min
Degrees/sec	.002778	Revolutions/sec
Dekagrams	10.	Gram
Dekalitres	10.	Litres
Dekametres	10.	Metres
Fathoms	6.	Feet
Feet	30.48	Centimetres
Feet	12.	Inches
Feet	.3048	Metres
Feet	.3600	Varas (Texas)
Feet	.3333	Yards
Feet of water	.02950	Atmospheres
Feet of water	.8826	Inches of mercury
Feet of water	.03048	Kgs/sq cm
Feet of water	62.43	Lbs/sq ft
Feet of water	.4335	psi
Feet/min	.508	Centimetres/sec
Feet/min	.01667	Feet/sec
Feet/min	.01829	Kilometres/hr
Feet/min	.3048	Metres/min
Feet/min	.01136	Miles/hr
Feet/sec	.68182	Miles per hour
Feet/sec/sec	30.48	Cms/sec/sec
Feet/sec/sec	.3048	Metres/sec/sec

Foot-pounds	.002186	Btu
Foot-pounds	.000000505	Horsepower-hrs
Foot-pounds	.0003241	Kilogram-calories
Foot-pounds	.1383	Kilogram - metres
Foot-pounds	.0000003766	Kilowatt-hrs
Foot-pounds	1.3558	Newton-metres
Foot-pounds/min	.001286	Btu/min
Foot-pounds/min	.01667	Foot-pounds/sec
Foot-pounds/min	.0000303	Horsepower
Foot-pounds/min	.0003241	Kg-calories/min
Foot-pounds/min	.0000226	Kilowatts
Foot-pounds/sec	.07717	Btu/min
Foot-pounds/sec	.001818	Horsepower
Foot-pounds/sec	.01945	Kg-calories/min
Foot-pounds/sec	.001356	Kilowatts
Gallons	.02381	Barrel
Gallons	.83267	Gallons (Imperial)
Gallons	.00378	Cubic metres
Gallons	3785.	Cubic centimetres
Gallons	.1337	Cubic feet
Gallons	231.	Cubic inches
Gallons	.003785	Cubic metres
Gallons	3.785	Litres
Gallons	8.	Pints (liq)
Gallons	4.	Quarts (liq)
Gallons (Imperial)	1.20095	Gallons
Gallons (Imperial)	277.419	Cubic inches
Gallons (Imperial)	4.546	Litres
Gallons of water	8.3453	Pounds of water
Gallons/min	1.429	Barrels per hour
Gallons/min	.1337	Cubic ft/min
Gallons/min	34.286	Barrels/day
Gallons/min	.06308	Litres/sec
Gallons/min	8.0208	Cubic ft/hr
Gallons/min	.002228	Cubic ft/sec
Gallons of water/min	6.0086	Tons water/24 hrs
Grains/U.S. gallons	17.118	Parts/million
Grains/U.S. gallons	142.86	Lbs/million gal
Grains/Imperial gallons	14.286	Parts/million
Grams	980.7	Dynes
Grams	15.43	Grains
Grams	.001	Kilograms
Grams	1000.	Milligrams
Grams	.03527	Ounces (Avoir.)
Grams	.002205	Pounds

Grams/cm	.0056	Pounds/inch
Grams/cubic cm	62.43	Pounds/cubic foot
Grams/cubic cm	.03613	Pounds/cubic inch
Grams/litre	8.345	Pounds/1000 gals
Grams/litre	.062427	Pounds/cubic foot
Grams/litre	1000.	Parts/million
Hectare	2.47105	Acres
Hectograms	100.	Grams
Hectolitres	100.	Litres
Hectowatts	100.	Watts
Horsepower	42.44	Btu/min
Horsepower	33000.	Foot-lbs/min
Horsepower	550.	Foot-lbs/sec
Horsepower	1.014	Horsepower (metric)
Horsepower	10.70	Kg-calories/min
Horsepower	.7457	Kilowatts
Horsepower	745.7	Watts
Horsepower (boiler)	33479.	Btu/hr
Horsepower (boiler)	9.803	Kilowatts
Horsepower-hours	2547.	Btu
Horsepower-hours	1980000.	Foot-lbs
Horsepower-hours	641.7	Kilogram-calories
Horsepower-hours	273700.	Kilogram - metres
Horsepower-hours	.7457	Kilowatt-hours
Inches	2.540	Centimetres
Inches of Mercury	.03342	Atmospheres
Inches of Mercury	1.133	Feet of water
Inches of Mercury	.03453	Kgs/sq cm
Inches of Mercury	70.73	Lbs/sq ft
Inches of Mercury	.4912	psi
Inches of Water	.002458	Atmospheres
Inches of Water	.07355	Inches of Mercury
Inches of Water	.002540	Kgs/sq cm
Inches of Water	.5781	Ounces/sq in
Inches of Water	5.202	Lbs/sq ft
Inches of Water	.03613	psi
Kilograms	980665.	Dynes
Kilograms	2.205	Lbs
Kilograms	.001102	Tons (short)
Kilograms	1000.	Grams
Kilograms	9.81	Newtons
Kilograms	.981	decaNewtons

Kilograms/metre	.6720	Lbs/ft
Kilograms/metre	.98067	decaNewtons/metre
Kilogram - metres	7.233	Ft-lbs
Kilogram - metres	.98	Newton-metre
Kilograms/cm^2	.9678	Atmospheres
Kilograms/cm^2	32.81	Feet of water
Kilograms/cm^2	28.96	Inches of mercury
Kilograms/cm^2	2048.	Lbs/sq ft
Kilograms/cm^2	14.22	psi
Kilograms/cm^2	.981	Bars
Kilograms/cm^2	98.1	Kilopascals
Kilograms/m^3	.001	SG
Kilograms/m^3	.00833	pounds/gallon
Kgs/sq millimetre	1000000.	Kgs/sq metre
Kilolitres	1000.	Litres
Kilometres	100000.	Centimetres
Kilometres	3281.	Feet
Kilometres	1000.	Metres
Kilometres	.6214	Miles
Kilometres	.5396	Miles (nautical)
Kilometres/hr	27.78	Centimetres/sec
Kilometres/hr	54.68	Feet/min
Kilometres/hr	.9113	Feet/sec
Kilometres/hr	.5396	Knots
Kilometres/hr	16.67	Metres/min
Kilometres/hr	.6214	Miles/hr
Kms/hr/sec	27.78	cms/sec/sec
Kms/hr/sec	.9113	Ft/sec/sec
Kms/hr/sec	.2778	Metres/sec/sec
Kilopascal	.1	Newton/cm^2
Kilopascal	1000.	Newtons/m^2
Kilopascal	.0102	Kg/cm^2
Kilopascal	.145	psi
Kilowatts	56.92	Btu/min
Kilowatts	44250.	Foot-lbs/min
Kilowatts	737.6	Foot-lbs/sec
Kilowatts	1.341	Horsepower
Kilowatts	14.34	Kg-calories/min
Kilowatts	1000.	Watts
Kilowatt-hours	3415.	Btu
Kilowatt-hours	2655000.	Foot-lbs
Kilowatt-hours	1.341	Horsepower-hrs
Kilowatt-hours	860.5	Kilogram-calories
Kilowatt-hours	367100.	Kilogram - metres

Knot	1.	Nautical miles/hr
Knot	1.151	Statute miles/hr
Litres	1000.	Cubic centimetres
Litres	.03531	Cubic feet
Litres	61.02	Cubic inches
Litres	.001	Cubic metres
Litres	.001308	Cubic yards
Litres	.2642	Gallons
Litres	.0063	Bbls
Litres/min	.0005886	Cubic ft/sec
Litres/min	.004403	Gals/sec
Metres	100.	Centimetres
Metres	3.281	Feet
Metres	39.37	Inches
Metres	.001	Kilometres
Metres	1000.	Millimetres
Metres/min	1.667	Centimetres/sec
Metres/min	3.281	Feet/min
Metres/min	.05468	Feet/sec
Metres/min	.06	Kilometres/hr
Metres/min	.03728	Miles/hr
Metres/sec	196.8	Feet/min
Metres/sec	3.281	Feet/sec
Metres/sec	3.6	Kilometres/hr
Metres/sec	.06	Kilometres/min
Metres/sec	2.237	Miles/hr
Metres/sec	.03728	Miles/min
Microns	.000001	Metres
Miles	160900.	Centimetres
Miles	5280.	Feet
Miles	1.609	Kilometres
Mile (Nautical)	6080.27	Feet
Mile (Nautical)	1.15	Mile (statute)
Miles/hr	44.70	Centimetres/sec
Miles/hr	88.	Feet/min
Miles/hr	1.467	Feet/sec
Miles/hr	1.609	Kilometres/hrs
Miles/hr	.8684	Knots
Miles/hr	26.82	Metres/min

Miles/min	2682.	Centimetres/sec
Miles/min	88.	Feet/sec
Miles/min	1.609	Kilometres/min
Miles/min	60.	Miles/hr
Milliers	1000.	Kilograms
Milligrams	.0010	Grams
Millilitres	.0010	Litres
Millimetres	.1	Centimetres
Millimetres	.03937	Inches
Milligrams/litre	1.	Parts/million
Million gals/day	1.54723	Cubic feet/sec
Minutes (angle)	.0002909	Radians
Newton	.22481	Pounds
Newton/cm^2	10	kilopascal
Newton/cm^2	10000	Newton/m^2
Newton/m^2	.0001	Newton/cm^2
Newton/m^2	.001	kilopascal
Newton/m^2	.000145	psi
Newton-metre	.7376	Ft-lbs
Newton-metre	1.02	Kilogram - metres
Ounces	437.5	Grains
Ounces	.0625	Pounds
Ounces	28.349527	Grams
Ounces (fluid)	1.805	Cubic inches
Ounces (fluid)	.02957	Litres
Ounces/sq inch	.0625	psi
Parts/million	.0584	Grains/U.S. gal
Parts/million	.07016	Grains/Imperial gal
Parts/million	8.345	Lbs/million gal
Pascal	1.0	Newton/m^2
Pounds	16.	Ounces
Pounds	7000.	Grains
Pounds	.0005	Tons (short)
Pounds	453.5924	Grams
Pounds	.4536	Kilograms
Pounds	.445	Decanewton
Pounds	4.45	Newton
Pounds of Water	.01602	Cubic feet
Pounds of Water	27.68	Cubic inches
Pounds of Water	.1198	Gallons
Pounds/ft	1.4881	kilograms/metre

Pounds/100 ft^2	.4788	Pascals
Pounds/cubic foot	.01602	Grams/cubic cm
Pounds/cubic foot	16.02	Kgs/cubic metre
Pounds/cubic foot	.0005787	Lbs/cubic inch
Pounds/cubic foot	.1337	pounds/gallon
Pounds/cubic inch	27.68	Grams/cubic cm
Pounds/cubic inch	27680.	Kgs/cubic metre
Pounds/cubic inch	1728.	Lbs/cubic foot
Pounds of water/min	.000267	Cubic ft/sec
Pounds/foot	1.488	Kgs/metre
Pounds/gallon	.12	Grams/cubic cm
Pounds/gallon	120.	Kgs/$metre^3$
Pounds/gallon	.01175	Bars/metre
Pounds/gallon	.1198	SG
Pounds/gallon	.052	psi/ft
Pounds/gallon	7.48	lbs/cu. ft. (pcf)
Pounds/inch	178.6	Grams/cm
Pounds/sq foot	.01602	Feet of water
Pounds/sq foot	.0004883	Kgs/sq cm
Pounds/sq foot	.006945	psi
Psi	.06804	Atmospheres
Psi	2.307	Feet of water
Psi	2.036	Inches of mercury
Psi	.07031	Kgs/sq cm
Psi	6.895	Kilopascals
Psi	6894.76	Newtons/m^2
Psi/ft	22.624	Kilopascals/metre
Psi/ft	.2262	bars/metre
Psi/ft	19.23	pounds/gallon
Pounds-force	4.448	Newtons
Pounds-force	0.4448	Decanewtons
Secs/quart	1.057	Secs/litre
Square centimetre	.1550	Square inchs
Square foot	.0929	Square metres
Square foot	.1296	Square vara (Texas)
Square inch	6.452	Square centimetres
Square inch	645.2	Square millimetres
Square kilometre	.3861	Square mile

Square metre	10.76	Square feet
Square mile	2.590	Square kilometres
Square mile	640.	Acre
Specific Gravity (SG)	.0981	Bars/metre
Temp (C.) + 17.78	1.8	Temp (F.)
Temp (F.) - 32	.5555	Temp (C.)
Tons (long)	1016.	Kilograms
Tons (long)	2240.	Pounds
Tons (long)	1.12	Tons (short)
Tonne (metric)	1000.	Kilograms
Tonne (metric)	2205.	Pounds
Tonne (metric)	981.	Decanewtons

1000000	=	10^6	=	mega	=	M
1000	=	10^3	=	kilo	=	k
100	=	10^2	=	hecto	=	h
10	=	10^1	=	deca	=	da
1	=	Base Unit				
0.1	=	10^{-1}	=	deci	=	d
.01	=	10^{-2}	=	centi	=	c
.001	=	10^{-3}	=	milli	=	m
.000001	=	10^{-6}	=	micro	=	µ

1/32 inch x .7937 = millimetre.