DRILLING ENGINEERING

Drilling String Design

1.6 Rotary System

Main Parts:

1. Swivel
2. Kelly
3. Rotary Drive
4. Rotary Table
5. Drill Pipe
6. Drill Collar

1. Swivel:

Supports the weight of the drillstring and permits rotation i.e. Bail and Gooseneck.

2. Kelly:

Square or Hexagonal to be gripped easily. Torque is transmitting through kelly bushings. Kelly saver sub is used to prevent wear on the kelly threads.

3. Slips:

During making up a joint slips are used to prevent drillstring from falling in hole.

4. Rotary Drive:

Provides the power to turn the rotary table.

* Power Sub: can be used to connect casing.

5. Drill Pipe:

Specified by (a) Outer Diameter
(b) Weight per foot
(c) Steel grade
(d) Range Length

Range	Length (ft)
1	18 to 22
2	27 to 30
3	38 to 45

* ***Tool Joint***: Female is called Box. Male is called Pin.

* ***Upset :*** Thicker portion of the pipe.
* ***Internal upset***: Extra thick.
* ***Thread Type:*** Round, tungsten carbide hard facing.

6. *Drill Collar:*

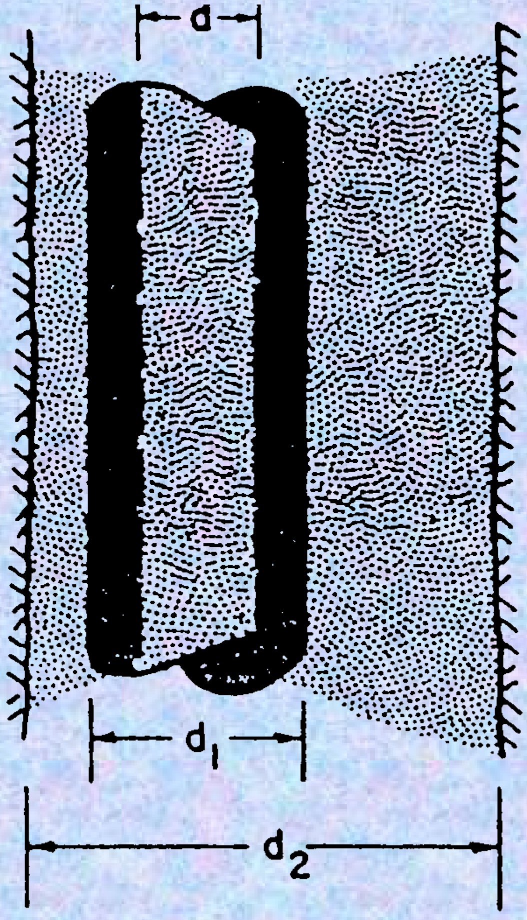
Thick walled heavy steel pipe used to apply weight to the bit.

* ***Stabilizer Subs*** : Keep drill collars centralized.
* ***Capacity :*** Volume per unit Length.

$$A_p = \frac{\pi}{4} d^2$$ = Capacity of pipe (1.13)

$$A_a = \frac{\pi}{4} (d_2^2 - d_1^2)$$ = Capacity of annulus (1.14)

$$A_s = \frac{\pi}{4} (d_1^2 - d^2)$$ = Displacement (1.15)



CAPACITY OF PIPE

$$A_p = \frac{\pi}{4} d^2$$

CAPACITY OF ANNULUS

$$A_a = \frac{\pi}{4} (d_2^2 - d_1^2)$$

DISPLACEMENT OF PIPE

$$A_s = \frac{\pi}{4} (d_1^2 - d^2)$$

Capacity and displacement nomenclature

TABLE 1.5 – DIMENSIONS AND STRENGTH OF API SEAMLESS INTERNAL UPSET DRILLPIPE

Size of Outer Diameter (in.)	Weight per Foot With Coupling (lbf)	Internal Diameter (in.)	Internal Diameter At Full Upset (in.)	Collapse Pressure*				Internal Yield Pressure*				Tensile Strength*			
				D (psi)	E (psi)	G** (psi)	S-135** (psi)	D (psi)	E (psi)	G** (psi)	S-135 (psi)	D 1,000 (lbf)	E 1,000 (lbf)	G** 1,000 (lbf)	S-135** 1,000 (lbf)
2⅜	4.85	1.995	1.437	6,850**	11,040	13,250	16,560	7,110**	10,500	14,700	18,900	70	98	137	176
2⅜	6.65	1.815	1.125	11,440	15,600	18,720	23,400	11,350	15,470	21,660	27,850	101	138	194	249
2⅞	6.85	2.441	1.875	–	10,470	12,560	15,700	–	9,910	13,870	17,830	–	136	190	245
2⅞	10.40	2.151	1.187	12,110	16,510	19,810	24,760	12,120	16,530	23,140	29,750	157	214	300	386
3½	9.50	2.992	2.250	–	10,040	12,110	15,140	–	9,520	13,340	17,140	–	194	272	350
3½	13.30	2.764	1.875	10,350	14,110	16,940	21,170	10,120	13,800	19,320	24,840	199	272	380	489
3½	15.50	2.602	1.750	12,300	16,770	20,130	25,160	12,350	16,840	23,570	30,310	237	323	452	581
4	11.85	3.476	2.937	–	8,410	10,310	12,820	–	8,600	12,040	15,470	–	231	323	415
4	14.00	3.340	2.375	8,330	11,350	14,630	17,030	7,940	10,830	15,160	19,500	209	285	400	514
4½	13.75	3.958	3.156	–	7,200	8,920	10,910	–	7,900	11,070	14,230	–	270	378	486
4½	16.60	3.826	2.812	7,620	10,390	12,470	15,590	7,210	9,830	13,760	17,690	242	331	463	595
4½	20.00	3.640	2.812	9,510	12,960	15,560	19,450	9,200	12,540	17,560	22,580	302	412	577	742
5	16.25	4.408	3.750	–	6,970	8,640	10,550	–	7,770	10,880	13,980	–	328	459	591
5	19.50	4.276	3.687	7,390	10,000	12,090	15,110	6,970	9,500	13,300	17,100	290	396	554	712
5½	21.90	4.778	3.812	6,610	8,440	10,350	12,870	6,320	8,610	12,060	15,500	321	437	612	787
5½	24.70	4.670	3.500	7,670	10,460	12,560	15,700	7,260	9,900	13,860	17,820	365	497	696	895
5 9/16	19.00**	4.975	4.125	4,580	5,640	–	–	5,090	6,950	–	–	267	365	–	–
5 9/16	22.20**	4.859	3.812	5,480	6,740	–	–	6,090	8,300	–	–	317	432	–	–
5 9/16	25.25**	4.733	3.500	6,730	8,290	–	–	7,180	9,790	–	–	369	503		
6⅝	22.20**	6.065	5.187	3,260	4,020	–	–	4,160	5,530	–	–	307	418	–	–
6⅝	25.20	5.965	5.000	4,010	4,810	6,160	6,430	4,790	6,540	9,150	11,770	359	489	685	881
6⅝	31.90**	5.761	4.625	5,020	6,170	–	–	6,275	8,540	–	–	463	631	–	–

*Collapse, internal yield, and tensile strengths are minimum values with no safety factor. D, E, G, S-135 are standard steel grades used in drillpipe.[5]

**Not API standard; shown for information only.

TABLE 1.6 – AVERAGE DISPLACEMENTS FOR RANGE 2 DRILL PIPE

Size of Outer Diameter (in.)	Nominal Weight (lbm/ft)	Tool-Joint Type	Actual Weight in Air (lbm/ft)	Displacement (ft/bbl)	Displacement (bbl/ft)	Displacement bbl/90 ft Stand
2⅜	6.65	internal flush	6.90	398.4	0.00251	0.23
2⅞	10.40	internal flush	10.90	251.9	0.00397	0.36
		slim hole	10.40	263.0	0.00379	0.34
3½	13.30	full hole	13.90	197.6	0.00506	0.46
		slim hole	13.40	204.9	0.00488	0.44
		internal flush	13.80	199.2	0.00502	0.45
	15.50	internal flush	16.02	171.5	0.00583	0.52
4	14.00	full hole	15.10	181.8	0.00550	0.50
		internal flush	15.10	176.1	0.00568	0.51
4½	16.60	full hole	17.80	154.3	0.00648	0.58
		xtrahole	18.00	152.7	0.00655	0.59
		slim hole	17.00	161.6	0.00619	0.56
		internal flush	17.70	155.3	0.00644	0.58
	20.00	xtrahole	21.40	128.5	0.00778	0.70
		full hole	21.30	129.0	0.00775	0.70
		slim hole	20.50	134.0	0.00746	0.67
		internal flush	21.20	129.5	0.00772	0.69
	22.82	xtrahole	24.10	114.0	0.00877	0.79
	32.94	xtrahole	36.28	75.7	0.01320	1.19
5	19.50	xtrahole	20.60	133.3	0.00750	0.68
	25.60	xtrahole	26.18	107.4	0.00932	0.84
	42.00	xtrahole	45.2 ±	60.8 ±	0.0165 ±	1.48 ±

Example 1.4: ***A drillstring is composed of 7,000 ft of 5-in., 19.5-lbm/ft drillpipe and 500 ft of 8-in. OD by 2.75-in ID drill collars when drilling a 9.875-in. borehole. Assuming that the borehole remains in gauge, compute the number of pump cycles required to circulate mud from the surface to the bit and from the bottom of the hole to the surface if the pump factor is 0.178 bbl/cycle.***

Solution:

For field units of feet and barrels, Eq. 1.13 becomes

$$A_p = \left(\frac{\pi}{4} d^2\right) in.^2 \left(\frac{gal}{231 in.^3}\right)\left(\frac{bbl}{42 gal}\right)\left(\frac{12 in}{ft}\right) = \left(\frac{d^2}{1{,}029.4}\right) bbl/ft$$

Using Table 1.5, the inner diameter of 5-in., 19.5 lbm/ft drillpipe is 4.276 in.; thus, the capacity of the drillpipe is

$$= \frac{4.276^2}{1{,}029.4} = 0.01766\, bbl/ft$$

And the capacity of the drill collars is

$$= \frac{2.75^2}{1{,}029.4} = 0.00735\, bbl/ft$$

The number of pump cycles required to circulate new mud bit is given by

$$= \frac{[0.01776(7{,}000) + 0.00735(500)]\, bbl}{0.1781\, bbl/cycle} = 719 cycles.$$

Similarly, the annular capacity outside the drillpipe is given by

$$= \frac{9.875^2 - 5^2}{1{,}029.4} = 0.0704\, bbl/ft$$

And the annulus capacity outside the drill collars is

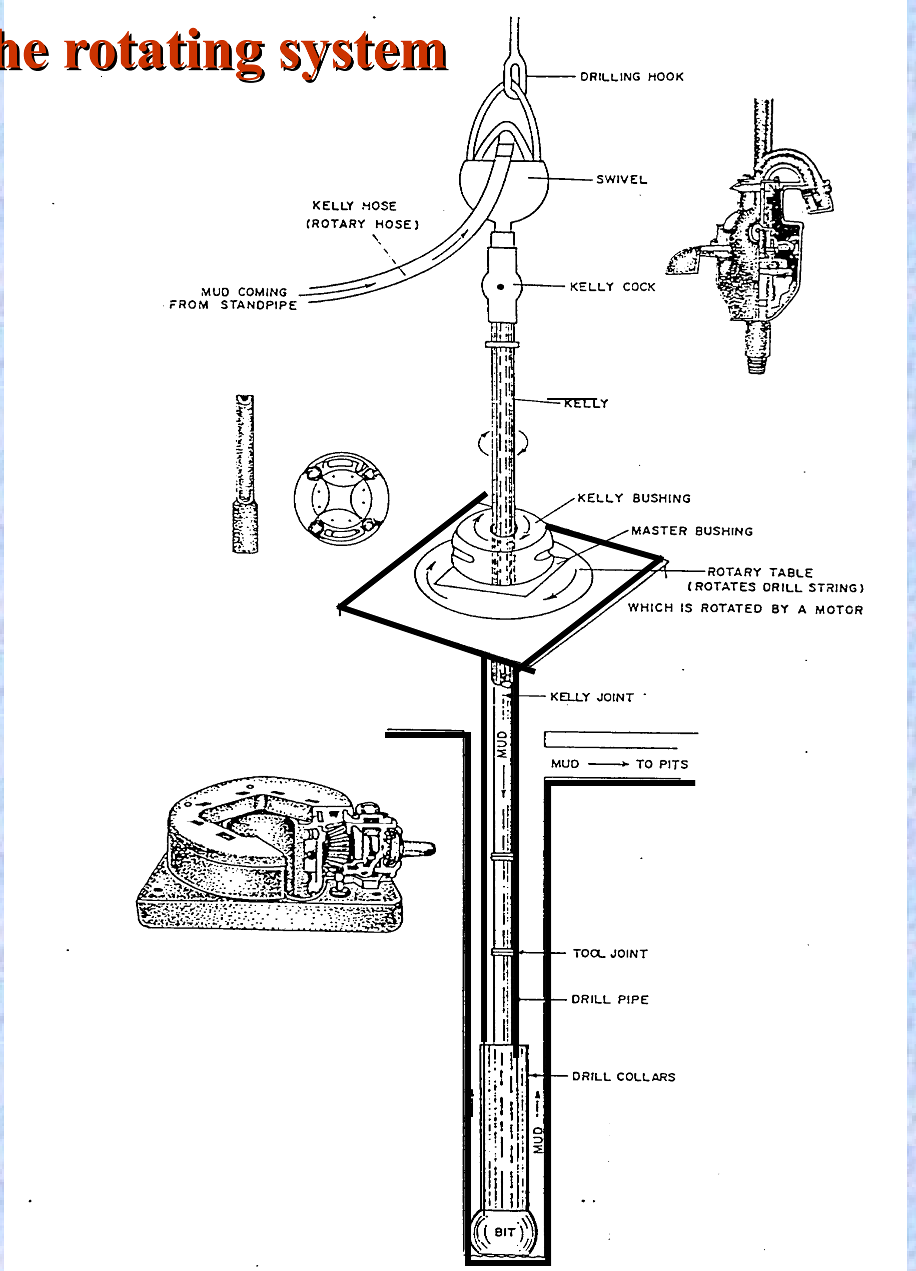
$$= \frac{9.875^2 - 8^2}{1{,}029.4} = 0.0326\, bbl/ft$$

The pump cycles required to circulate mud from the bottom of the hole to the surface is given by

$$= \frac{[0.0704(7{,}000) + 0.0326(500)]}{0.1781\, bbl/cycle} = 2{,}858\, cycles$$

Answer

Components of the rotating system



SLIDES

Equation 4.25(a)

If the drilling fluid is air and the torque required to rotate the bit is low, the radial and tangential stress in the drill pipe may be neglected. For these simplified conditions, the neutral point is the point of zero axis stress. In this case, the minimum length of drill collars L_{dc}, is given by

$$L_{dc} = \frac{F_b}{w_{dc}} \,(\,in\ air)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.45a)$$

F_b = the max. force to be applied to the bit during drilling operation.

W_{dc} = the weight per foot of the drilling collars.