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Water Data and Formulas

1 gallon water = 231 cubic inches = 8.333 pounds (@ 65 °F)
1 pound of water = 27.72 cubic inches (@ 65 °F)
1 cubic foot water = 7.5 gallons = 62.4 pounds (salt water weighs approximately 64.3 pounds per cubic foot)
Pounds per square inch at bottom of a column of water = height of column in feet x 0.434 (@ 39 °F)
1 miner's inch = 9 to 12 gallons per minute

Horsepower to Raise Water

$$\text{Horsepower} = \frac{\text{gallons per minute} \times \text{Total Head in Feet}}{3960}$$

(if pumping a liquid other than water, multiply the gallons per minute by the liquids specific gravity)

Gallons Per Minute through a Pipe

$$\text{GPM} = 0.0408 \times \text{Pipe Diameter inches}^2 \times \text{Feet / minute water velocity}$$

Weight of Water in a Pipe

$$\text{Pounds Water} = \text{Pipe Length feet} \times \text{Pipe diameter inches}^2 \times 0.34$$

Gallons per Minute of a Slurry

$$\text{GPM Slurry} = \text{GPM Water} + \frac{4 \times \text{Tons of per hour of solids}}{\text{Specific Gravity of Solids}}$$

Cost to Pump Water - Electric

$$\$ \text{ per hour} = \frac{\text{GPM} \times \text{Head in feet} \times 0.746 \times \text{Rate per KWH}}{3960 \times \text{Pump Efficiency} \times \text{Electric Motor Efficiency}}$$

(70% Pump & 90% Motor Efficiency are good averages)

Cost to Pump Water - Gasoline and Diesel

$$\$ \text{ per hour} = \frac{\text{GPM} \times \text{Head in feet} \times K \times \$ \text{ per gallon fuel}}{3960 \times \text{Pump Efficiency}}$$

K = 0.110 for gasoline or 0.065 for diesel
(K is actually gallons of fuel per horsepower)
(70% Pump Efficiency is a good average value)

Optimum Flow Rate for Water

Optimum flow rate for water in a cylindrical pipe is less than 10 feet per second. Usually Godwin recommends 6 feet per second as a maximum flow with entrenched solids.

Convert Flow (GPM) to Velocity (Feet/Second) in Various Pipe

GPM	Pipe Diameter (Inches)								
	2	3	4	5	6	8	10	12	18
5	0.51	0.23	0.13	0.08	0.06	0.03	0.02	0.01	0.01
10	1.02	0.45	0.26	0.16	0.11	0.06	0.04	0.03	0.01
15	1.53	0.68	0.38	0.24	0.17	0.10	0.06	0.04	0.02
20	2.04	0.91	0.51	0.33	0.23	0.13	0.08	0.06	0.03
30	3.06	1.36	0.77	0.49	0.34	0.19	0.12	0.09	0.04
40	4.08	1.81	1.02	0.65	0.45	0.26	0.16	0.11	0.05
50	5.10	2.27	1.28	0.82	0.57	0.32	0.20	0.14	0.06
60	6.12	2.72	1.53	0.98	0.68	0.38	0.24	0.17	0.08
70	7.14	3.17	1.79	1.14	0.79	0.45	0.29	0.20	0.09
80	8.16	3.63	2.04	1.31	0.91	0.51	0.33	0.23	0.10
90	9.18	4.08	2.30	1.47	1.02	0.57	0.37	0.26	0.11
100	10.20	4.53	2.55	1.63	1.13	0.64	0.41	0.28	0.13
150	15.30	6.80	3.83	2.45	1.70	0.96	0.61	0.43	0.19
200	20.40	9.07	5.10	3.26	2.27	1.28	0.82	0.57	0.25
250	25.50	11.33	6.38	4.08	2.83	1.59	1.02	0.71	0.31
300	30.60	13.60	7.65	4.90	3.40	1.91	1.22	0.85	0.38
400	40.80	18.13	10.20	6.53	4.53	2.55	1.63	1.13	0.50
500	51.00	22.67	12.75	8.16	5.67	3.19	2.04	1.42	0.63
600	61.20	27.20	15.30	9.79	6.80	3.83	2.45	1.70	0.76
700	71.40	31.73	17.85	11.42	7.93	4.46	2.86	1.98	0.88
800	81.60	36.27	20.40	13.06	9.07	5.10	3.26	2.27	1.01
900	91.80	40.80	22.95	14.69	10.20	5.74	3.67	2.55	1.13
1000	102.00	45.33	25.50	16.32	11.33	6.38	4.08	2.83	1.26
1200	122.40	54.40	30.60	19.58	13.60	7.65	4.90	3.40	1.51
1500	153.00	68.00	38.25	24.48	17.00	9.56	6.12	4.25	1.89
2000	204.00	90.67	51.00	32.64	22.67	12.75	8.16	5.67	2.52
3000	306.00	136.00	76.50	48.96	34.00	19.13	12.24	8.50	3.78
4000	408.00	181.33	102.00	65.28	45.33	25.50	16.32	11.33	5.04
5000	510.00	226.67	127.50	81.60	56.67	31.88	20.40	14.17	6.30

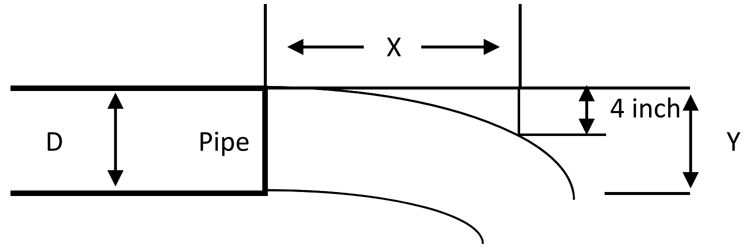
$$\text{Velocity in feet per second} = \frac{0.408 \times \text{USGPM}}{(\text{diameter of pipe in inches})^2}$$

Suction, Head, Vapor Pressure						
Water Temp °F	Vapor Pressure	Suction Lift or Head @ Altitude in Feet				
		0	2000	4000	8000	12000
60	0.6 ft water	20.0	17.5	15.5	11.5	7.5
70	0.8 ft water	19.5	17.0	15.0	11.0	7.0
80	1.2 ft water	19.5	17.0	15.0	11.0	7.0
90	1.6 ft water	19.0	16.5	14.5	10.5	6.5
100	2.2 ft water	18.5	16.0	14.0	10.0	6.0
110	2.9 ft water	17.5	15.0	13.0	9.0	5.0
120	3.9 ft water	16.5	14.0	12.0	8.0	4.0
130	5.1 ft water	15.5	13.0	11.0	7.0	3.0
140	6.7 ft water	14.0	11.5	9.5	5.5	1.5
150	8.6 ft water	12.0	9.5	7.5	3.5	-0.5
160	10.9 ft water	9.5	7.0	5.0	1.0	
170	13.8 ft water	6.5	4.0	2.0	-2.0	
180	17.3 ft water	3.0	0.5	-1.5		
190	21.6 ft water	-1.0	-3.5	-5.5		
200	26.6 ft water	-6.0	-8.5			
210	32.6 ft water	-12.0				
212	34.0 ft water	-13.5				

Note: Positive values indicate suction lift, negative values indicate suction head.

Flow Calculation by Measuring

Horizontal Pipe Discharge

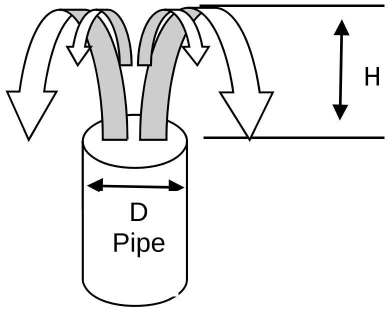


X Distance Inches	Gallons per Minute Discharge for a given Nominal Pipe Diameter D (Inches)											
	1	**1-¼**	**1-½**	**2**	**2-½**	**3**	**4**	**5**	**6**	**8**	**10**	**12**
4	6	10	13	22	31	48	83					
5	7	12	17	27	39	61	104	163				
6	8	15	20	33	47	73	125	195	285			
7	10	17	23	38	55	85	146	228	334	580		
8	11	20	26	44	62	97	166	260	380	665	1060	
9	13	22	30	49	70	110	187	293	430	750	1190	1660
10	14	24	33	55	78	122	208	326	476	830	1330	1850
11	16	27	36	60	86	134	229	360	525	915	1460	2020
12	17	29	40	66	94	146	250	390	570	1000	1600	2220
13	18	31	43	71	102	158	270	425	620	1080	1730	2400
14	20	34	46	77	109	170	292	456	670	1160	1860	2590
15	21	36	50	82	117	183	312	490	710	1250	2000	2780
16	23	39	53	88	125	196	334	520	760	1330	2120	2960
17		41	56	93	133	207	355	550	810	1410	2260	3140
18			60	99	144	220	375	590	860	1500	2390	3330
19				110	148	232	395	620	910	1580	2520	3500
20					156	244	415	650	950	1660	2660	3700
21						256	435	685	1000	1750	2800	3890
22							460	720	1050	1830	2920	4060
23								750	1100	1910	3060	4250
24									1140	2000	3200	4440

When brink depths are greater than 0.5D, the more general purpose Purdue pipe method developed by Greve (1928) should be used, rather than the California pipe method. The Purdue method applies equally well to both partially and completely filled pipes. The Purdue method consists of measuring coordinates of the upper surface of the jet as shown above. If the water in the pipe is flowing at a depth of less than 0.8D at the outlet, the vertical distance, Y, can be measured at the end of the pipe where X = 0. For higher rates of flow, Y, may be measured at horizontal distances, X, from the pipe exit of 6, 12, or 18 inches.

The most accurate results will be obtained when the pipe is truly horizontal. If it slopes upward, the indicated discharge will be too high. If it slopes downward, the indicated discharge will be too low.

Vertical Pipe Discharge



The following formula is an approximation of the output of a vertical pipe.

$GPM = \sqrt{H} \times K \times D^2 \times 5.68$

GPM = gallons per minute
H = height in inches
D = diameter of pipe in inches
K = constant from 0.87 to 0.97 for diameters of
2 to 6 inches and height (H) up to 24 inches

Example: K = 0.97, 6 inch diameter with 10 inch height ≈ 626 GPM

Lawrence and Braunworth (1906) noted that two kinds of flow occur from the end of vertical pipes. With a small rise of water (up to 0.37*d*) above the end of the pipe, the flow acts like a circular weir. When the water rises more than 1.4*d* , jet flow occurs. When the rise is between these values, the mode of flow is in transition. When the height of the jet exceeded 1.4*d* , as determined by sighting over the jet to obtain the maximum rise, the discharge is given by:

$Q = 5.01d^{1.99}h^{0.53}$

where:

Q = rate of flow, gallons per minute
d = inside diamter of the pipe, inches
h = height of jet, inches

When the rise of water above the end of the pipe is less that 0.37*d* , discharge is given by:

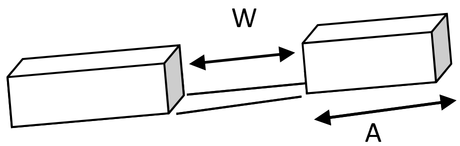
$Q = 6.17d^{1.25}h^{1.35}$

Flow Calculation from a Nozzle

Nozzle Discharge													
Nozzle Pressure lbs/sq in	Gallons per Minute Discharge for a given Nozzle Diameter (Inches)												
	1/16	**⅛**	**3/16**	**¼**	**5/16**	**⅜**	**7/16**	**½**	**9/16**	**⅝**	**¾**	**⅞**	**1**	**1-⅛**
10	0.38	1.48	3.3	5.9	9.24	13.3	18.1	23.6	30.2	36.9	53.3	72.5	94.8	120
15	0.45	1.81	4.1	7.2	11.4	16.3	22.4	28.9	36.7	45.2	65.1	88.7	116	147
20	0.53	2.09	4.7	8.3	13.1	18.7	25.6	33.4	42.4	52.2	75.4	102	134	169
25	0.59	2.34	5.3	9.3	14.6	21.0	28.7	37.3	47.3	58.2	84.0	115	149	189
30	0.64	2.56	5.8	10.2	16.0	23.1	31.4	40.9	51.9	63.9	92.2	126	164	208
35	0.69	2.78	6.2	11.1	17.1	25.0	33.8	44.2	56.1	69.0	99.8	136	177	224
40	0.74	2.96	6.7	11.7	18.4	26.6	36.2	47.3	59.9	73.8	106	145	189	239
45	0.79	3.14	7.1	12.6	19.5	28.2	38.3	50.1	63.4	78.2	113	153	200	254
50	0.83	3.30	7.4	13.2	20.6	29.9	40.5	52.8	67.0	82.5	119	162	211	268
60	0.90	3.62	8.2	14.5	22.6	32.6	44.3	57.9	73.3	90.4	130	177	232	293
70	0.98	3.91	8.8	15.7	24.4	35.3	47.9	62.6	79.3	97.8	141	192	251	317
80	1.05	4.19	9.4	16.8	26.1	37.6	51.2	66.8	84.8	105	151	205	268	339
90	1.11	4.43	10.0	17.7	27.8	40.1	54.5	70.8	90.3	111	160	218	285	360
100	1.17	4.67	10.4	18.7	29.2	42.2	57.3	74.9	95	117	169	229	300	379
120	1.23	5.17	11.5	20.4	31.8	46.0	62.4	81.8	103	128	184	250	327	413
140	1.28	5.70	12.4	22.1	34.4	49.8	67.6	88.3	112	138	199	271	354	447
160	1.32	6.30	13.3	23.6	36.9	53.3	72.3	94.6	120	148	213	289	378	478
180	1.36	6.92	14.1	25.0	39.0	56.4	76.5	100.0	127	156	225	306	400	506
200	1.38	7.52	14.9	26.4	41.1	59.5	81.6	106.0	134	165	238	323	423	535

Note: The above discharge rates are theoretical. Actual values will only be 95% of the above values, depending on such factors as shape of the nozzle, bore smoothness, etc.

Weir Discharge



Height of water flow H

Head	GPM for Width of Weir in Feet			GPM/Foot over
Inches	1	3	5	5 Feet Wide
1	35	107	179	36
1.5	64	197	329	66
2	98	302	506	102
2.5	136	421	705	142
3	178	552	926	187
4	269	845	1420	288
5	369	1174	1978	402
6	476	1534	2592	529
7		1922	3255	667
8		2335	3963	814
9		2769	4713	972
10		3225	5501	1138
12		4189	7181	1496

Based on the Francis formula:

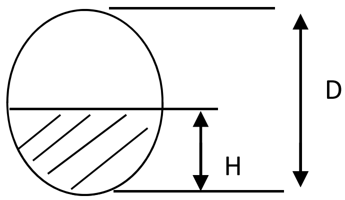
Cu ft/sec water = 3.33 (W - 0.2 H) $H^{1.5}$

H = Height in feet

W = Width in feet

Distance A should be at least 3 H

Volume in a Tank



The following equation can be used to calculate the

Use the formula: Ratio = H / D and then the following table in order to calculate the Depth Factor.

Ratio	Depth Factor	Ratio	Depth Factor
0.02	0.0047728	0.52	0.5254580
0.04	0.0134171	0.54	0.5508752
0.06	0.0244963	0.56	0.5762106
0.08	0.0374780	0.58	0.6014229
0.10	0.0520440	0.60	0.6264700
0.12	0.0679724	0.62	0.6513090
0.14	0.0850946	0.64	0.6758962
0.16	0.1032755	0.66	0.7001861
0.18	0.1224023	0.68	0.7241318
0.20	0.1423785	0.70	0.7476842
0.22	0.1631194	0.72	0.7707919
0.24	0.1845494	0.74	0.7934001
0.26	0.2065999	0.76	0.8154506
0.28	0.2292081	0.78	0.8368806
0.30	0.2523158	0.80	0.8576215
0.32	0.2758682	0.82	0.8775977
0.34	0.2998139	0.84	0.8967245
0.36	0.3241038	0.86	0.9149054
0.38	0.3486910	0.88	0.9320276
0.40	0.3735300	0.90	0.9479560
0.42	0.3985771	0.92	0.9625220
0.44	0.4237894	0.94	0.9755037
0.46	0.4491248	0.96	0.9865829
0.48	0.4745420	0.98	0.9952272
0.50	0.5000000	1.00	1.0000000

Gallons Remaining = Depth Factor x Total Tank Gallons

Capacity of Square Tanks

Contents in Gallons for Depth of Feet

Dimensions (Ft.)	1'	4'	5'	6'	8'	10'	11'	12'
4 x 4	119.68	479	598	718	957	1197	1316	1436
5 x 5	187.00	748	935	1202	1516	1870	2057	2244
6 x 6	269.28	1077	1346	1616	2154	2693	2968	3231
7 x 7	366.52	1466	1833	2199	2922	3665	4032	4398
8 x 8	478.72	1915	2394	2872	3830	4787	5266	5745
9 x 9	605.88	2424	3029	3635	4847	6059	6665	7272
10 x 10	748.08	2992	3740	4488	5984	7480	8228	8976
11 x 11	905.08	3620	4525	5430	7241	9051	9956	10861
12 x 12	1077.12	4308	5386	6463	8617	10771	11848	12925

To find the capacity of a depth not given, multiply the capacity for one foot by the required depth in feet.

Pressure and Equivalent Feet Head of Water

Fresh Water	
Lb. per Sq. In	Feet Head
1	2.31
2	4.62
3	6.93
4	9.24
5	11.54
6	13.85
7	16.16
8	18.47
9	20.78
10	23.09
15	34.63
20	46.18
25	57.72
30	69.27
40	92.36
50	115.45
60	138.54
70	161.63
80	184.72
90	207.81
100	230.90
110	253.98
120	277.07
125	288.62
130	300.16
140	323.25
150	346.34
160	369.43
170	392.52
180	415.61
190	438.90
200	461.78
225	519.51
250	577.24
275	643.03
300	692.69
325	750.41
350	808.13
375	865.89
400	922.58
500	1154.48
1000	2309.00

Salt Water	
Lb. per Sq. In	Feet Head
1	2.25
2	4.50
3	6.75
4	9.00
5	11.25
6	13.50
7	15.75
8	18.00
9	20.25
10	22.50
15	33.75
20	45.00
25	56.25
30	67.50
40	90.00
50	112.50
60	135.00
70	157.50
80	180.00
90	202.50
100	225.00
110	247.50
120	270.00
125	281.25
130	292.50
140	315.00
150	337.50
160	360.00
170	382.50
180	405.00
190	427.50
200	450.00
225	506.25
250	562.50
275	618.75
300	675.00
325	731.25
350	787.50
375	843.75
400	900.00
500	1125.00
1000	2250.00

Feet Head of Water and Equivalent Pressures

Fresh Water	
Feet Head	Lb. per Sq. In
1	0.43
2	0.87
3	1.30
4	1.73
5	2.17
6	2.60
7	3.03
8	3.46
9	3.90
10	4.33
15	8.66
20	12.99
25	17.32
30	21.65
40	25.99
50	30.32
60	34.65
70	38.98
80	43.31
90	47.65
100	51.97
110	56.30
120	60.63
125	64.96
130	69.29
140	73.63
150	77.96
160	82.29
170	86.62
180	97.45
190	108.27
200	119.10
225	129.93
250	140.75
275	151.58
300	173.24
325	216.55
350	259.85
375	303.16
400	346.47
500	389.78
1000	433.09

Salt Water	
Feet Head	Lb. per Sq. In
1	0.44
2	0.88
3	1.32
4	1.76
5	2.20
6	2.64
7	3.08
8	3.52
9	3.96
10	4.40
15	6.60
20	8.80
25	11.00
30	13.20
40	17.60
50	22.00
60	26.40
70	30.80
80	35.20
90	39.60
100	44.00
110	48.40
120	52.80
125	55.00
130	57.20
140	61.60
150	66.00
160	70.40
170	74.80
180	79.20
190	83.60
200	88.00
225	99.00
250	110.00
275	121.00
300	132.00
325	143.00
350	154.00
375	165.00
400	176.00
500	220.00
1000	440.00

<u>Theoretical Horsepower Required to Raise Water to Different Heights</u>

	Feet																					
GPM	5	10	15	20	25	30	35	40	45	50	60	75	90	100	125	150	175	200	250	300	350	400
5	0.006	0.012	0.019	0.025	0.031	0.037	0.044	0.05	0.06	0.06	0.07	0.09	0.11	0.12	0.16	0.15	0.22	0.25	0.31	0.37	0.44	0.50
10	0.012	0.025	0.037	0.050	0.062	0.076	0.087	0.10	0.11	0.12	0.15	0.19	0.22	0.25	0.31	0.37	0.44	0.50	0.62	0.75	0.87	1.00
15	0.019	0.037	0.056	0.075	0.094	0.112	0.131	0.15	0.17	0.19	0.22	0.28	0.34	0.37	0.47	0.56	0.66	0.75	0.94	1.12	1.31	1.50
20	0.025	0.500	0.075	0.100	0.125	0.150	0.175	0.20	0.22	0.25	0.30	0.37	0.45	0.50	0.62	0.75	0.87	1.00	1.25	1.50	1.75	2.00
25	0.031	0.062	0.093	0.125	0.156	0.187	0.219	0.25	0.28	0.31	0.37	0.47	0.56	0.62	0.78	0.94	1.09	1.25	1.56	1.87	2.19	2.50
30	0.037	0.075	0.112	0.150	0.187	0.225	0.262	0.30	0.34	0.37	0.45	0.56	0.67	0.75	0.94	1.12	1.31	1.50	1.87	2.25	2.62	3.00
35	0.043	0.087	0.131	0.175	0.219	0.262	0.306	0.35	0.39	0.44	0.52	0.66	0.79	0.87	1.08	1.31	1.53	1.75	2.19	2.62	3.06	3.50
40	0.050	0.100	0.150	0.200	0.250	0.300	0.350	0.40	0.45	0.50	0.60	0.75	0.90	1.00	1.25	1.50	1.75	2.00	2.50	3.00	3.50	4.00
45	0.066	0.112	0.168	0.225	0.281	0.337	0.394	0.45	0.51	0.56	0.67	0.84	1.01	1.12	1.41	1.69	1.97	2.25	2.81	3.37	3.94	4.50
50	0.062	0.125	0.187	0.250	0.312	0.375	0.437	0.50	0.56	0.62	0.75	0.94	1.12	1.25	1.56	1.87	2.19	2.50	3.12	3.75	4.37	5.00
60	0.075	0.150	0.225	0.300	0.375	0.450	0.525	0.60	0.67	0.75	0.90	1.12	1.35	1.50	1.87	2.25	2.62	3.00	3.75	4.50	5.25	6.00
75	0.093	0.187	0.281	0.375	0.469	0.562	0.656	0.75	0.84	0.94	1.12	1.40	1.69	1.87	2.34	2.81	3.28	3.75	4.69	5.62	6.56	7.50
90	0.112	0.225	0.337	0.450	0.562	0.675	0.787	0.90	1.01	1.12	1.35	1.68	2.02	2.25	2.81	3.37	3.94	4.50	5.62	6.75	7.87	9.00
100	0.125	0.250	0.375	0.500	0.625	0.750	0.875	1.00	1.12	1.25	1.50	1.87	2.25	2.50	3.12	3.75	4.37	5.00	6.25	7.50	8.75	10.00
125	0.156	0.312	0.469	0.625	0.781	0.937	1.094	1.25	1.41	1.56	1.87	2.34	2.81	3.12	3.91	4.69	5.47	6.25	7.81	9.37	10.94	12.50
150	0.187	0.375	0.562	0.750	0.937	1.125	1.312	1.50	1.69	1.87	2.25	2.81	3.37	3.75	4.69	5.62	6.56	7.50	9.37	11.25	13.12	15.00
175	0.219	0.437	0.656	0.875	1.093	1.312	1.531	1.75	1.97	2.19	2.62	3.28	3.94	4.37	5.47	6.56	7.66	8.75	10.94	13.12	15.31	17.50
200	0.250	0.500	0.750	1.000	1.250	1.600	1.750	2.00	2.25	2.50	3.00	3.75	4.50	5.00	6.25	7.50	8.75	10.00	12.50	15.00	17.60	20.00
250	0.312	0.625	0.937	1.250	1.562	1.876	2.187	2.50	2.81	3.12	3.75	4.69	5.62	6.25	7.81	9.37	10.94	12.50	15.72	18.75	21.87	25.00
300	0.375	0.750	1.125	1.500	1.875	2.250	2.625	3.00	3.37	3.75	4.50	5.62	6.75	7.50	9.37	11.25	13.12	15.00	18.75	22.50	26.25	30.00
350	0.437	0.875	1.312	1.750	2.187	2.625	3.062	3.50	3.94	4.37	5.25	6.56	7.87	8.75	10.94	13.12	15.31	17.50	21.87	26.25	30.62	35.00
400	0.500	1.000	1.500	2.000	2.500	3.000	3.500	4.00	4.50	5.00	6.00	7.50	9.00	10.00	12.50	15.00	17.50	20.00	25.00	30.00	35.00	40.00
500	0.625	1.250	1.875	2.500	3.125	3.750	4.375	5.00	5.62	6.25	7.50	9.37	11.25	12.50	15.62	18.76	21.87	25.00	31.25	37.50	43.75	50.00

Engineering Data 1

One horsepower = 33,000 ft. pounds per minute

Cubic feet per second = $\frac{\text{Gallons per Minute}}{449}$

Cubic feet per minute = $\frac{\text{Gallons per Minute}}{7.48}$

Theoretical water horsepower = $\frac{\text{USGPM x Head in Feet x Sp. Gr.}}{3960}$

Theoretical water horsepower = $\frac{\text{USGPM x Head in Pounds}}{1714}$

Velocity in feet per second = $\frac{\text{0.408 x USGPM}}{(\text{diameter of pipe in inches})^2} = \frac{\text{32 x GPM}}{\text{pipe area}}$

One acre-foot = 325.850 US Gallons

1,000,000 US Gallons per Day = 695 US Gallons per Minute

500 Pounds per Hour = 1 US Gallon per Minute

Doubling the diameter of a pipe or cylinder increases its capacity four times.

Friction of liquids in pipes increases as the square of its velocity.

Velocity in feet per minute necessary to discharge a given volume of water in a given time: = $\frac{\text{Cu. Ft. of water x 144}}{\text{area of pipe in sq. inches}}$

Area of required pipe, the volume and velocity of water being given:

= $\frac{\text{No. cu. Ft. of water x 144}}{\text{Vel. In ft. per min.}}$

from this area the size pipe required may be selected from the table of standard pipe dimension.

Engineering Data 2

Atmospheric pressure at sea level is 14.7 pounds per square inch. This pressure with a perfect vacuum will maintain a column of water 33.9 feet high or a column of mercury 29.9 inches. This is the theoretical distance that water may be drawn by suction. In practice, however, pumps should not have a total dynamic suction lift greater than 25 feet.

Net horsepower = the theoretical horsepower necessary to do the work
Net horsepower = barrels per day x pressure x 0.000017
Net horsepower = barrels per hour x pressure x 0.000408
Net horsepower = gallons per minute x pressure x 0.000583

The customary method of indicating specific gravity of petroleum oils in this country is by means of the Baume scale. Since the Baume scale, for specific gravities of liquids lighter than water, increases inversely as the true gravity, the heaviest oil, i.e., that which has the highest true specific gravity, is expressed by the lowest figure of the Baume scale, the lightest by the highest figure.

Areas of circles are to each other as the squares of their diameter:
Circumference: diameter of circle x 3.1416
Area circle: $diameter^2$ x 0.7854
Diameter circle: circumference x 0.31831
Volume of sphere: $diameter^3$ x 0.5236
Square feet: square inches x 0.00695
Cubic feet: cubic inches x 0.00058
Cubic yard: cubic feet x 0.03704
Statute miles: lineal feet x 0.00019
Statute miles: lineal yards x 0.000568
1 gallon = 8.33 pounds
1 liter = 0.2642 gallons
1 cu.ft. = 7.48 gallons and/or 62.35 pounds
1 meter = 3.28 feet
1 millimeter = 0.03937 inches

STATIC HEAD is the vertical distance between the free level of the source of supply and the point of free discharge, or to the level of the free surface of the discharged water.

TOTAL DYNAMIC HEAD is the vertical distance between source of supply and point of discharge when pumping at required capacity, plus velocity head, friction, velocity, entrance and exit losses.

TOTAL DYNAMIC HEAD, as determined on test where suction lift exists, is the reading of a mercury column connected to the suction nozzle of pump, plus the reading of a pressure gauge connected to the discharge nozzle of pump, plus vertical distance between point of attachment of mercury column and center of gauge, plus excess, if any, of velocity head of discharge over velocity head of suction, as measured at points where the instruments are attached, plus head of water resting on mercury column, if any.

Engineering Data 3

TOTAL DYNAMIC HEAD, as determined on test where suction head exists, is the reading of a gauge attached to the discharge nozzle of pump, minus the reading of gauge connected to the suction nozzle of pump, plus or minus vertical distance between centers of the gauges (depending on whether suction gauge is below or above discharge gauge), plus excess, if any, of the velocity head of discharge over velocity head of suction as measured at points where instruments are attached.

TOTAL DYNAMIC DISCHARGE HEAD is the total dynamic head minus dynamic suction lift, or plus dynamic suction head.

SUCTION LIFT exists when the source of supply is below discharge nozzle of pump.

STATIC SUCTION LIFT is the vertical distance from the free level of source of supply to discharge nozzle of pump.

DYNAMIC SUCTION LIFT is the vertical distance from the source of supply, when pumping at required capacity, to discharge nozzle of pump, plus velocity head, entrance, friction and velocity losses; but not including internal pump losses.

DYNAMIC SUCTION LIFT, as determined on test, is the reading of a mercury column connected to suction nozzle of pump, plus vertical distance between point of attachment of mercury column to discharge nozzle of pump, plus head of water resting on mercury column, if any.

SUCTION HEAD (sometimes called HEAD OF SUCTION) exists when source of supply is above discharge nozzle of pump.

STATIC SUCTION HEAD is the vertical distance from the free level of the source of supply to discharge nozzle of pump.

DYNAMIC SUCTION HEAD is the vertical distance from the source of supply, when pumping at required capacity, to discharge nozzle of pump, minus velocity head, entrance, friction and velocity losses; but not minus internal pump losses.

DYNAMIC SUCTION HEAD, as determined on test, is the reading of a gauge connected to suction nozzle of pump, minus vertical distance from center of gauge to discharge nozzle of pump. SUCTION HEAD, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to SUCTION LIFT will prevail.

VELOCITY HEAD (sometimes called "Head due to Velocity"), of water moving with a given velocity, is the equivalent head through which it would have to fall to acquire the same velocity; or the head necessary merely to accelerate the water. Knowing the velocity, we can readily figure the velocity head from the simple formula:

$h = V^2/2g$

In which "g" is the acceleration due to gravity, or 32.16 feet per second; or knowing the head, we can transpose the formula to:

$V = \sqrt{2gh}$ and thus obtain the velocity.

The velocity head is a factor in figuring the total head, but the value is usually small, and in most cases negligible; however, it should be considered when the total head is low and also when the suction lift is high.

Velocity head should be considered in accurate testing also, as it is part of the total head and consequently affects the duty accomplished.

A table, giving the relation between velocity and velocity head, appears in the following and, where the suction and discharge pipes are of the same size, it is only necessary to include in the total head the velocity head generated in the suction piping. If the discharge piping is of different size than the suction piping, which is often the case, then it will be necessary to use the velocity in the discharge pipe for computing the velocity head rather than the velocity in the suction pipe.

In testing a pump, a mercury column is generally used for obtaining dynamic suction lift. The column will show the velocity head combined with entrance head, friction head and static suction lift. On the discharge side, a gauge is usually used, but a gauge will not indicate velocity head, and this must, therefore, be obtained either by calculating the velocity, or taking readings with a Pitotmeter. Inasmuch as the velocity varies considerably at different points in the cross-section of a stream it is important, in using a Pitotmeter, to take a number of readings at different points in the cross-section.

Velocity and Velocity Head

Velocity in Feet per Sec.	Velocity Head in Feet
1	0.02
2	0.06
3	0.14
4	0.25
5	0.39
6	0.59
7	0.76
8	1.00
8.5	1.12
9	1.25
9.5	1.40
10	1.55
10.5	1.70
11	1.87
11.5	2.05
12	2.24
13	2.62
14	3.05
15	3.50

Engineering Data 4

C = Cost in dollars per 1000 gallons
r = Power rate per kilowatt hour (dollars)
HP in = HP input measured at the meter
H = total pumping head
GPH = Gallons per hour discharged by pump

Cost per 1000 gallons of water.

For each foot of head: $C = \frac{746 \times r \times \text{HP in}}{H \times GPH}$

Cost per hour: $C = 0.746 \times r \times \text{HP in}$

Water Requirements

Domestic Use

To supply water for each member of a family for all uses including kitchen, laundry and bath……….	30 gallons per day
To flush toilet..…………………………………………………………………………………………	6 gallons per day
To fill average bathtub………………………………………………………………………………	30 gallons per day
To fill ordinary lavatory…..……………………………………………………………………………	1-1/2 gallons per day
Average shower bath…...……………………………………………………………………………..	30 gallons per day
Continuous flow drinking fountain……..…………………………………………………………….	50 - 100 gallons per day

Water Required by Livestock

Each horse……………………………………………………………………………………………	10 gallons per day
Each cow………………………………………………………………………………………………..	15 gallons per day
Each sheep……………………………………………………………………………………………	3 gallons per day
Each hog………………………………………………………………………………………………	5 gallons per day
Each 100 chickens………………………………………………………………………………..	5 gallons per day

Water Required by Yard Fixtures

1/2" hose and nozzle…………………………………………………………………………………	200 gallons per hour
3/4" hose and nozzle…………………………………………………………………………………	300 gallons per hour
Lawn sprinkler…………………………………………………………………………………………	120 gallons per hour
To sprinkle 100 sq. ft. of lawn (1/4" of water)…………………………………………………………	16 gallons

Note: The above requirements are only approximate, as the consumption of individuals and animals will vary by the seasons and weather conditions.

In selecting the proper size pump, it is essential that the pump capacity be in excess of maximum requirements in order to provide a reserve in the event that water is required from several fixtures at the same time. For example, watering the lawn, drawing a bath, and water used in the kitchen simultaneously, is a common occurrence. It is also advisable to allow for the water level in the well lowering during dry years, thus decreasing pump capacity.

Gravity Sewer Line Bypass: Flow and Pump Sizing Chart

Line Size	% Full	Velocity	Flow (MGD)	Flow (GPM)	Pump Size	Godwin Model
8"	50 %	1' / sec	0.1	80	4"	CD100 M
8"	50 %	2' / sec	0.2	160	4"	CD100 M
8"	100 %	1' / sec	0.2	160	4"	CD100 M
8"	100 %	2' / sec	0.5	320	4"	CD100 M
12"	50 %	1' / sec	0.25	175	4"	CD100 M
12"	50 %	2' / sec	0.5	350	4"	CD100 M
12"	100 %	1' / sec	0.5	350	4"	CD100 M
12"	100 %	2' / sec	1	700	6"	CD150 M
14"	50 %	1' / sec	0.35	245	4"	CD100 M
14"	50 %	2' / sec	0.7	490	6"	CD150 M
14"	100 %	1' / sec	0.7	490	6"	CD150 M
14"	100 %	2' / sec	1.4	980	6"	CD150 M
16"	50 %	1' / sec	0.45	315	4"	CD100 M
16"	50 %	2' / sec	0.9	630	6"	CD150 M
16"	100 %	1' / sec	0.9	630	6"	CD150 M
16"	100 %	2' / sec	1.8	1260	8"	CD225 M
18"	50 %	1' / sec	0.6	403	6"	CD150 M
18"	50 %	2' / sec	1.2	805	6"	CD150 M
18"	100 %	1' / sec	1.2	805	6"	CD150 M
18"	100 %	2' / sec	2.3	1610	8"	CD225 M
20"	50 %	1' / sec	0.7	490	6"	CD150 M
20"	50 %	2' / sec	1.4	980	6"	CD150 M
20"	100 %	1' / sec	1.4	980	6"	CD150 M
20"	100 %	2' / sec	2.8	1960	8"	CD225 M
24"	50 %	1' / sec	1	700	6"	CD150 M
24"	50 %	2' / sec	2	1400	8"	CD225 M
24"	100 %	1' / sec	2	1400	8"	CD225 M
24"	100 %	2' / sec	4	2800	12"	DPC 300
30"	50 %	1' / sec	1.6	1120	8"	CD225 M
30"	100 %	1' / sec	3.2	2240	12"	DPC 300
30"	50 %	2' / sec	3.2	2240	12"	DPC 300
30"	100 %	2' / sec	6.4	4480	12"	DPC 300 (2)
36"	50 %	1' / sec	2.3	1610	8"	CD225 M
36"	100 %	1' / sec	4.6	3220	12"	DPC 300
36"	50 %	2' / sec	4.6	3220	12"	DPC 300
36"	100 %	2' / sec	9.2	6440	12"	DPC 300 (2)
42"	50 %	1' / sec	3.1	2170	12"	DPC 300
42"	100 %	1' / sec	6.2	4340	12"	DPC 300 (2)
42"	50 %	2' / sec	6.2	4340	12"	DPC 300 (2)
42"	100 %	2' / sec	12.4	8680	12"	DPC 300 (3)
48"	50 %	1' / sec	4	2800	12"	DPC 300
48"	100 %	1' / sec	8	5600	12"	DPC 300 (2)
48"	50 %	2' / sec	8	5600	12"	DPC 300 (2)
48"	100 %	2' / sec	16	11200	12"	DPC 300 (4)

54"	50 %	1' / sec	5.1	3570	12"	DPC 300 (2)
54"	100 %	1' / sec	10.2	7140	12"	DPC 300 (2)
54"	50 %	2' / sec	10.2	7140	12"	DPC 300 (2)
54"	100 %	2' / sec	20.4	14280	12"	DPC 300 (5)
60"	50 %	1' / sec	6.5	4550	12"	DPC 300 (2)
60"	100 %	1' / sec	13	9100	12"	DPC 300 (3)
60"	50 %	2' / sec	13	9100	12"	DPC 300 (3)
60"	100 %	2' / sec	26	18200	12"	DPC 300 (5)
72"	50 %	1' / sec	9.25	6475	12"	DPC 300 (2)
72"	100 %	1' / sec	18.5	12950	12"	DPC 300 (4)
72"	50 %	2' / sec	18.5	12950	12"	DPC 300 (4)
72"	100 %	2' / sec	37	25900	12"	DPC 300 (7)