ITT

TTECHWP

Residential Water Systems

Water Products Technical Data and Pump Fundamentals

Goulds Pumps
www.goulds.com

Red Jacket Water Products
www.redjacketwaterproducts.com

Bell & Gossett
www.bellgossett.com

CentriPro
www.centripro.com

Engineered for life

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Pressure Switch Wiring and Adjustments

PUMP FUNDAMENTALS

Friction Loss

SCH 40 – PLASTIC PIPE: FRICTION LOSS (IN FEET OF HEAD) PER 100 FT.

GPM	GPH	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	6"	8"	10"
		ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
1	60	4.25	1.38	.356	.11									
2	120	15.13	4.83	1.21	.38	.10								
3	180	31.97	9.96	2.51	.77	.21	.10							
4	240	54.97	17.07	4.21	1.30	.35	.16							
5	300	84.41	25.76	6.33	1.92	.51	.24							
6	360		36.34	8.83	2.69	.71	.33	.10						
8	480		63.71	15.18	4.58	1.19	.55	.17						
10	600		97.52	25.98	6.88	1.78	.83	.25	.11					
15	900			49.68	14.63	3.75	1.74	.52	.22					
20	1,200			86.94	25.07	6.39	2.94	.86	.36	.13				
25	1,500				38.41	9.71	4.44	1.29	.54	.19				
30	1,800					13.62	6.26	1.81	.75	.26				
35	2,100					18.17	8.37	2.42	1.00	.35	.09			
40	2,400					23.55	10.70	3.11	1.28	.44	.12			
45	2,700					29.44	13.46	3.84	1.54	.55	.15			
50	3,000						16.45	4.67	1.93	.66	.17			
60	3,600						23.48	6.60	2.71	.93	.25			
70	4,200							8.83	3.66	1.24	.33			
80	4,800							11.43	4.67	1.58	.41			
90	5,400							14.26	5.82	1.98	.52			
100	6,000								7.11	2.42	.63	.08		
125	7,500								10.83	3.80	.95	.13		
150	9,000									5.15	1.33	.18		
175	10,500									6.90	1.78	.23		
200	12,000									8.90	2.27	.30		
250	15,000										3.36	.45	.12	
300	18,000										4.85	.63	.17	
350	21,000										6.53	.84	.22	
400	24,000											1.08	.28	
500	30,000											1.66	.42	.14
550	33,000											1.98	.50	.16
600	36,000											2.35	.59	.19
700	42,000												.79	.26
800	48,000												1.02	.33
900	54,000												1.27	.41
950	57,000													.46
1000	60,000													.50

NOTE: See page 5 for website addresses for pipe manufacturers – there are many types of new plastic pipe available now.

Friction Loss

STEEL PIPE: FRICTION LOSS (IN FEET OF HEAD) PER 100 FT.

GPM	GPH	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	5"	6"	8"	10"
		ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
1	60	4.30	1.86	.26											
2	120	15.00	4.78	1.21	.38										
3	180	31.80	10.00	2.50	.77										
4	240	54.90	17.10	4.21	1.30	.34									
5	300	83.50	25.80	6.32	1.93	.51	.24								
6	360		36.50	8.87	2.68	.70	.33	.10							
7	420		48.70	11.80	3.56	.93	.44	.13							
8	480		62.70	15.00	4.54	1.18	.56	.17							
9	540			18.80	5.65	1.46	.69	.21							
10	600			23.00	6.86	1.77	.83	.25	.11	.04					
12	720			32.60	9.62	2.48	1.16	.34	.15	.05					
15	900			49.70	14.70	3.74	1.75	.52	.22	.08					
20	1,200			86.10	25.10	6.34	2.94	.87	.36	.13					
25	1,500				38.60	9.65	4.48	1.30	.54	.19					
30	1,800				54.60	13.60	6.26	1.82	.75	.26					
35	2,100				73.40	18.20	8.37	2.42	1.00	.35					
40	2,400				95.00	23.50	10.79	3.10	1.28	.44					
45	2,700					30.70	13.45	3.85	1.60	.55					
70	4,200					68.80	31.30	8.86	3.63	1.22	.35				
100	6,000						62.20	17.40	7.11	2.39	.63				
150	9,000							38.00	15.40	5.14	1.32				
200	12,000							66.30	26.70	8.90	2.27	.736	.30	.08	
250	15,000							90.70	42.80	14.10	3.60	1.20	.49	.13	
300	18,000								58.50	19.20	4.89	1.58	.64	.16	.0542
350	21,000								79.20	26.90	6.72	2.18	.88	.23	.0719
400	24,000								103.00	33.90	8.47	2.72	1.09	.279	.0917
450	27,000								130.00	42.75	10.65	3.47	1.36	.348	.114
500	30,000								160.00	52.50	13.00	4.16	1.66	.424	.138
550	33,000								193.00	63.20	15.70	4.98	1.99	.507	.164
600	36,000								230.00	74.80	18.60	5.88	2.34	.597	.192
650	39,000									87.50	21.70	6.87	2.73	.694	.224
700	42,000									101.00	25.00	7.93	3.13	.797	.256
750	45,000									116.00	28.60	9.05	3.57	.907	.291
800	48,000									131.00	32.40	10.22	4.03	1.02	.328
850	51,000									148.00	36.50	11.50	4.53	1.147	.368
900	54,000									165.00	40.80	12.90	5.05	1.27	.410
950	57,000									184.00	45.30	14.30	5.60	1.41	.455
1000	60,000									204.00	50.20	15.80	6.17	1.56	.500

Friction Loss

COPPER PIPE: FRICTION LOSS (IN FEET OF HEAD) PER 100 FT.

GPM	GPH	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"
		ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
1	60	6.2	1.8	.39							
2	120	19.6	6.0	1.2							
5	300		30.0	5.8	1.6						
7	420		53.0	11.0	3.2	2.2					
10	600			19.6	5.3	3.9					
15	900			37.0	9.9	6.2	2.1				
18	1,080			55.4	16.1	6.9	3.2				
20	1,200				18.5	10.4	3.9				
25	1,500				27.7	14.3	5.3	1.5			
30	1,800				39.3	18.7	7.6	2.1			
35	2,100				48.5	25.4	10.2	2.8			
40	2,400					30.0	13.2	3.5	1.2		
45	2,700					39.3	16.2	4.2	1.6		
50	3,000						19.4	5.1	1.8		
60	3,600						27.7	6.9	2.5	1.1	
70	4,200						40.0	9.2	3.5	1.4	
75	4,500						41.6	9.9	3.7	1.6	
80	4,800						45.0	11.6	4.2	1.8	
90	5,400						50.8	13.9	4.8	2.2	
100	6,000							16.9	6.2	2.8	
125	7,500							25.4	8.6	3.7	
150	9,000							32.3	11.6	4.8	1.2
175	10,500							41.6	16.2	6.9	1.7
200	12,000							57.8	20.8	9.0	2.2
250	15,000								32.3	13.9	3.5
300	18,000								41.6	18.5	4.6
350	21,000									32.3	5.8
400	24,000									39.3	7.2
450	27,000									44.0	9.2
500	30,000										11.1
750	45,000										23.1
1000	60,000										37.0

RUBBER HOSE: FRICTION LOSS (IN FEET OF HEAD) PER 100 FT.

GPM	Actual Inside Diameter in Inches							
	¾"	1"	1¼"	1½"	2"	2½"	3"	4"
15	70	23	5.8	2.5	.9	.2		
20	122	32	10	4.2	1.6	.5		
25	182	51	15	6.7	2.3	.7		
30	259	72	21.2	9.3	3.2	.9	.2	
40		122	35	15.5	5.5	1.4	.7	
50		185	55	23	8.3	2.3	1.2	
60		233	81	32	11.8	3.2	1.4	
70			104	44	15.2	4.2	1.8	
80			134	55	19.8	5.3	2.5	
90			164	70	25	7	3.5	.7
100			203	85	29	8.1	4	.9
125			305	127	46	12.2	5.8	1.4
150			422	180	62	17.3	8.1	1.6
175				230	85	23.1	10.6	2.5
200				308	106	30	13.6	3.2

GPM	Actual Inside Diameter in Inches							
	¾"	1"	1¼"	1½"	2"	2½"	3"	4"
250					162	44	21	4.9
300					219	62	28	6.7
350					292	83	39	9.3
400						106	49	11.8
500						163	74	17.1
600						242	106	23
700						344	143	30
800						440	182	40
900							224	51
1000							270	63
1250							394	100
1500							525	141
1750								185
2000								230

Friction Loss

EQUIVALENT NUMBER OF FEET STRAIGHT PIPE FOR DIFFERENT FITTINGS

Size of fittings, Inches	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	5"	6"	8"	10"
90° Ell	1.5	2.0	2.7	3.5	4.3	5.5	6.5	8.0	10.0	14.0	15	20	25
45° Ell	0.8	1.0	1.3	1.7	2.0	2.5	3.0	3.8	5.0	6.3	7.1	9.4	12
Long Sweep Ell	1.0	1.4	1.7	2.3	2.7	3.5	4.2	5.2	7.0	9.0	11.0	14.0	
Close Return Bend	3.6	5.0	6.0	8.3	10.0	13.0	15.0	18.0	24.0	31.0	37.0	39.0	
Tee-Straight Run	1	2	2	3	3	4	5						
Tee-Side Inlet or Outlet or Pitless Adapter	3.3	4.5	5.7	7.6	9.0	12.0	14.0	17.0	22.0	27.0	31.0	40.0	
① Ball or Globe Valve Open	17.0	22.0	27.0	36.0	43.0	55.0	67.0	82.0	110.0	140.0	160.0	220.0	
① Angle Valve Open	8.4	12.0	15.0	18.0	22.0	28.0	33.0	42.0	58.0	70.0	83.0	110.0	
Gate Valve-Fully Open	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.7	2.3	2.9	3.5	4.5	
Check Valve (Swing)	4	5	7	9	11	13	16	20	26	33	39	52	65
In Line Check Valve (Spring) or Foot Valve	4	6	8	12	14	19	23	32	43	58			

① There are many new, full port valve designs available today which are more efficient and create much less friction loss, consult with valve suppliers for new data.

Example:

(A) 100 ft. of 2" plastic pipe with one (1) 90° elbow and one (1) swing check valve.

90° elbow – equivalent to	5.5 ft. of straight pipe
Swing check – equivalent to	13.0 ft. of straight pipe
100 ft. of pipe – equivalent to	100 ft. of straight pipe
	118.5 ft. = Total equivalent pipe

Figure friction loss for 118.5 ft. of pipe.

(B) Assume flow to be 80 GPM through 2" plastic pipe.

1. Friction loss table shows 11.43 ft. loss per 100 ft. of pipe.
2. In step (A) above we have determined total ft. of pipe to be 118.5 ft.
3. Convert 118.5 ft. to percentage 118.5 ÷ 100 = 1.185
4. Multiply 11.43
   x 1.185
   13.54455 or 13.5 ft. = Total friction loss in this system.

OFFSET JET PUMP PIPE FRICTION

Where the jet pump is offset horizontally from the well site, add the following distances to the vertical lift to approximate capacity to be received.

PIPE FRICTION FOR OFFSET JET PUMPS

Friction Loss in Feet Per 100 Feet Offset

JET SIZE HP	SUCTION AND PRESSURE PIPE SIZES (in inches)									
	1¼ x 1	1¼ x 1¼	1½ x 1¼	1½ x 1½	2 x 1½	2 x 2	2½ x 2	2½ x 2½	3 x 2½	3 x 3
⅓	12	8	6	4						
½	18	12	8	6	3	2				
¾		22	16	11	6	4				
1			25	16	9	6				
1½	Operations Below Line Not Recommended				13	8	5	3		
2					20	13	7	5		
3							13	9	6	4

NOTE: Friction loss is to be added to vertical lift.

WEBSITE ADDRESSES FOR PIPE MANUFACTURERS, CHECK VALVE INFORMATION AND ITT PUMP COMPANIES

Pipe and Plastic Well Casing Manufacturer's websites:

www.shur-align.com or www.modernproducts.net
- Drop pipe - many types

www.certainteed.com
- Kwik-set® threaded drop pipe in Sch 80 & 120,
- Solvent weld pressure pipe in Sch 40 & 80, class 160 (SDR26), class 200 (SDR 21) and class 315 (SDR 13.5)
- PVC sewer & drain pipe

www.pweaglepipe.com
- PW Eagle PVC Pipe - many types

Check Valve Manufacturer's websites:

www.flomatic.com
- Danfoss Flomatic Valves

www.simmonsmfg.com
- Simmons Mfg.

ITT Corporation:

www.goulds.com
- Goulds Pumps Water and Wastewater Products

www.centripro.com
- CentriPro Accessories, Motors & Control Boxes and Wastewater Panels

Jet and Submersible Pump Selection

PRIVATE RESIDENCES

Outlets	Flow Rate GPM	Total Usage Gallons	Bathrooms in Home			
			1	1½	2-2½	3-4
Shower or Bathtub	5	35	35	35	53	70
Lavatory	4	2	2	4	6	8
Toilet	4	5	5	10	15	20
Kitchen Sink	5	3	3	3	3	3
Automatic Washer	5	35	–	18	18	18
Dishwasher	2	14	–	–	3	3
Normal seven minute* peak demand (gallons)			45	70	98	122
Minimum sized pump required to meet peak demand without supplemental supply		7 GPM (420 GPH)	10 GPM (600 GPH)	14 GPM (840 GPH)	17 GPM (1020 GPH)	

Notes:

Values given are average and do not include higher or lower extremes.

* Peak demand can occur several times during morning and evening hours.

** Count the number of fixtures in a home including outside hose bibs. Supply one gallon per minute each.

YARD FIXTURES

Garden Hose – ½"	3 GPM
Garden Hose – ¾"	6 GPM
Sprinkler– Lawn	3-7 GPM

FARM USE

Horse, Steer	12 Gallons per day
Dry Cow	15 Gallons per day
Milking Cow	35 Gallons per day
Hog	4 Gallons per day
Sheep	2 Gallons per day
Chickens/100	6 Gallons per day
Turkeys/100	20 Gallons per day
Fire	20-60 GPM

PUBLIC BUILDINGS

Pump Capacity Required in U.S. Gallons per Minute per fixture for Public Buildings							
Type of Building	Total Number of Fixtures						
	25 or Less	26-50	51-100	101-200	201-400	401-600	Over 600
Hospitals	1.00	1.00	.80	.60	.50	.45	.40
Mercantile Buildings	1.30	1.00	.80	.71	.60	.54	.48
Office Buildings	1.20	.90	.72	.65	.50	.40	.35
Schools	1.20	.85	.65	.60	.55	.45	
Hotels, Motels	.80	.60	.55	.45	.40	.35	.33
Apartment Buildings	.60	.50	.37	.30	.28	.25	.24

1. For less than 25 fixtures, pump capacity should not be less than 75% of capacity required for 25 fixtures.
2. Where additional water is required for some special process, this should be added to pump capacity.
3. Where laundries or swimming pools are to be supplied, add approximately 10% to pump capacity for either.
4. Where the majority of occupants are women, add approximately 20% to pump capacity.

BOILER FEED REQUIREMENTS

Boiler		Boiler		Boiler		Boiler		Boiler	
HP	GPM	HP	GPM	HP	GPM	HP	GPM	HP	GPM
20	1.38	55	3.80	90	6.21	160	11.1	275	19.0
25	1.73	60	4.14	100	6.90	170	11.7	300	20.7
30	2.07	65	4.49	110	7.59	180	12.4	325	22.5
35	2.42	70	4.83	120	8.29	190	13.1	350	24.2
40	2.76	75	5.18	130	8.97	200	13.8	400	27.6
45	3.11	80	5.52	140	9.66	225	15.5	450	31.1
50	3.45	85	5.87	150	10.4	250	17.3	500	34.5

1. Boiler Horsepower equals 34.5 lb. water evaporated at and from 212ºF, and requires feed water at a rate of 0.069 gpm.

Select the boiler feed pump with a capacity of 2 to 3 times greater than the figures given above at a pressure 20 to 25% above that of boiler, because the table gives equivalents of boiler horsepower without reference to fluctuating demands.

HydroPro and CentriPro Tank Selection

TABLE 1 – TANK MODELS – See your Full Line Catalog Tank Bulletins for a listing of all available models.

Model No.	Total Volume (Gals.)	① Drawdown in Gals. at System Operating Pressure Range of			Max. Drawdown Vol. (Gals.)
		18/40 PSIG	28/50 PSIG	38/60 PSIG	
V6P	2.0	0.8	0.7	0.6	1.2
V15P	4.5	1.8	1.5	1.3	2.7
V25P	8.2	3.3	2.8	2.4	4.5
V45P	13.9	5.6	4.7	4.1	8.4
V45B	13.9	5.6	4.7	4.1	8.4
V45	13.9	5.6	4.7	4.1	8.4
V60B	19.9	8.0	6.8	5.8	12.1
V60	19.9	8.0	6.8	5.8	12.1
V80	25.9	10.4	8.8	7.6	13.9
V80EX	25.9	10.4	8.8	7.6	13.9
V100	31.8	12.8	10.8	9.4	13.8
V100S	31.8	12.8	10.8	9.4	13.8
V140B	45.2	18.2	15.4	13.3	27.3
V140	45.2	18.2	15.4	13.3	27.3
V200B	65.1	26.2	22.1	19.2	39.3
V200	65.1	26.2	22.1	19.2	39.3
V250	83.5	33.6	28.4	25.6	50.8
V260	84.9	34.1	28.9	25.0	44.7
V350	115.9	46.6	39.4	34.1	70.5

Tank Drawdown Pressure Factors Using an "Extra" 2 PSI of Drawdown

Pressure Differential	Factor with extra 2 psi*
18 – 40	.402
28 – 50	.340
38 – 60	.295
48 – 70	.260

To Calculate drawdown capacity multiply: Factor x Tank Volume.

① Drawdown based on a 22 psi differential and Boyle's Law. Temperature, elevation and pressure can all affect drawdown volume.

TABLE 2 – PRESSURE FACTORS

	Pump Cut-In Pressure – PSIG																			
Pump Cut-Out Pressure – PSIG	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115
30	.22																			
35	.30	.20																		
40	.37	.27	.18																	
45	.42	.34	.25	.17																
50	.46	.39	.31	.23	.15															
55	.50	.43	.36	.29	.22	.14														
60	.54	.47	.40	.33	.27	.20	.13													
65		.50	.44	.38	.31	.25	.19	.13												
70		.53	.47	.41	.35	.30	.24	.18	.12											
75			.50	.45	.39	.33	.28	.22	.17	.11										
80			.53	.48	.42	.37	.32	.26	.21	.16	.11									
85				.50	.45	.40	.35	.30	.25	.20	.15	.10								
90				.53	.48	.43	.38	.33	.29	.24	.19	.14	.10							
95					.50	.46	.41	.36	.32	.27	.23	.18	.14	.09						
100					.52	.48	.44	.39	.35	.31	.26	.22	.17	.13	.09					
105						.50	.46	.42	.38	.33	.29	.25	.21	.17	.13	.08				
110						.52	.46	.44	.40	.36	.32	.28	.24	.20	.16	.12				
115							.50	.46	.42	.39	.35	.31	.27	.23	.19	.15	.12	.06		
120							.52	.48	.45	.41	.37	.33	.30	.26	.22	.19	.15	.11		
125								.50	.47	.43	.39	.36	.32	.29	.25	.21	.16	.14	.11	.07

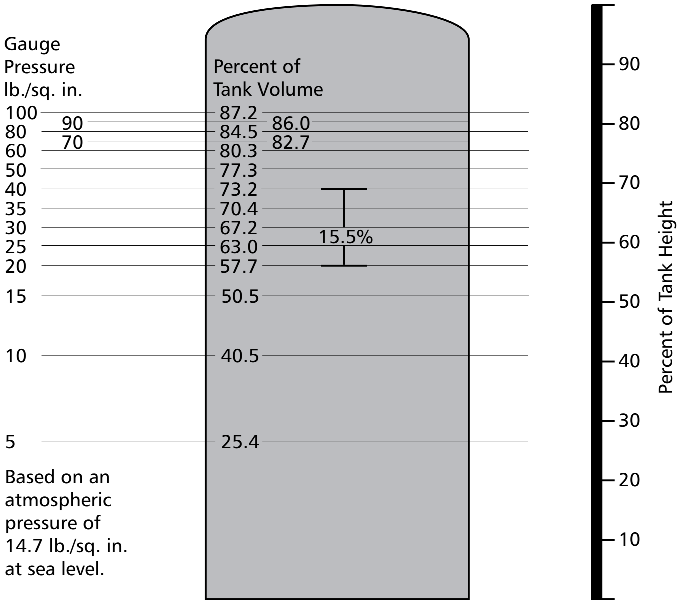
To determine tank drawdown of operating pressure ranges other than those listed in table, use following procedure:
Multiply total tank volume (table 1) by pressure factor (table 4).

Example: Operating range: 35/55
Tank being used: V-200

65.1 = Total volume of tank (table 1)
x .29 Pressure factor (table 4)
18.9 = Drawdown in gallons at 35/55 PSI operating range.

Tank Selection

VERTICAL TANK TABLE



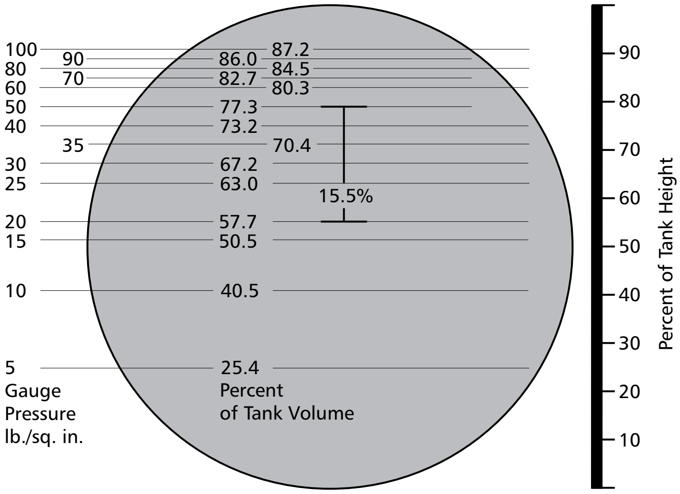
When using large standard galvanized tanks, a constant air cushion is required for proper operation of the water system.

The illustrations show the percent of tank volume as related to the pressure gauge reading. To determine the amount of water you will receive as drawoff from the tank, you should subtract the smaller number from the larger number to get the percentage. Then multiply by the size of the tank to get the gallons drawoff.

Example:

50 lbs. = 77.3
minus 30 lbs. = 67.2
= 10.1%
x 120 gallon size (size of tank)
= 12.12 gallons drawoff

HORIZONTAL TANK TABLE



Tank Selection

CAPACITIES OF TANKS OF VARIOUS DIMENSIONS

Dia. in inches	Length of Cylinder																	
	1"	1'	5'	6'	7'	8'	9'	10'	11'	12'	13'	14'	15'	16'	17'	18'	20'	22'	24'
1		0.04	0.20	0.24	0.28	0.32	0.36	0.40	0.44	0.48	0.52	0.56	0.60	0.64	0.68	0.72	0.80	0.88	0.96
2	0.01	0.16	0.80	0.96	1.12	1.28	1.44	1.60	1.76	1.92	2.08	2.24	2.40	2.56	2.72	2.88	3.20	3.52	3.84
3	0.03	0.37	1.84	2.20	2.56	2.92	3.30	3.68	4.04	4.40	4.76	5.12	5.48	5.84	6.22	6.60	7.36	8.08	8.80
4	0.05	0.65	3.26	3.92	4.58	5.24	5.88	6.52	7.18	7.84	8.50	9.16	9.82	10.5	11.1	11.8	13.0	14.4	15.7
5	0.08	1.02	5.10	6.12	7.14	8.16	9.18	10.2	11.2	12.2	13.3	14.3	15.3	16.3	17.3	18.4	20.4	22.4	24.4
6	0.12	1.47	7.34	8.80	10.3	11.8	13.2	14.7	16.1	17.6	19.1	20.6	22.0	23.6	25.0	26.4	29.4	32.2	35.2
7	0.17	2.00	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	34.0	36.0	40.0	44.0	48.0
8	0.22	2.61	13.0	15.6	18.2	20.8	23.4	26.0	28.6	31.2	33.8	36.4	39.0	41.6	44.2	46.8	52.0	57.2	62.4
9	0.28	3.31	16.5	19.8	23.1	26.4	29.8	33.0	36.4	39.6	43.0	46.2	49.6	52.8	56.2	60.0	66.0	72.4	79.2
10	0.34	4.08	20.4	24.4	28.4	32.6	36.8	40.8	44.8	48.8	52.8	56.8	61.0	65.2	69.4	73.6	81.6	89.6	97.6
11	0.41	4.94	24.6	29.6	34.6	39.4	44.4	49.2	54.2	59.2	64.2	69.2	74.0	78.8	83.8	88.8	98.4	104.0	118.0
12	0.49	5.88	29.4	35.2	41.0	46.8	52.8	58.8	64.6	70.4	76.2	82.0	87.8	93.6	99.6	106.0	118.0	129.0	141.0
13	0.57	6.90	34.6	41.6	48.6	55.2	62.2	69.2	76.2	83.2	90.2	97.2	104.0	110.0	117.0	124.0	138.0	152.0	166.0
14	0.67	8.00	40.0	48.0	56.0	64.0	72.0	80.0	88.0	96.0	104.0	112.0	120.0	128.0	136.0	144.0	160.0	176.0	192.0
15	0.77	9.18	46.0	55.2	64.4	73.6	82.8	92.0	101.0	110.0	120.0	129.0	138.0	147.0	156.0	166.0	184.0	202.0	220.0
16	0.87	10.4	52.0	62.4	72.8	83.2	93.6	104.0	114.0	125.0	135.0	146.0	156.0	166.0	177.0	187.0	208.0	229.0	250.0
17	0.98	11.8	59.0	70.8	81.6	94.4	106.0	118.0	130.0	142.0	153.0	163.0	177.0	189.0	201.0	212.0	236.0	260.0	283.0
18	1.10	13.2	66.0	79.2	92.4	106.0	119.0	132.0	145.0	158.0	172.0	185.0	198.0	211.0	224.0	240.0	264.0	290.0	317.0
19	1.23	14.7	73.6	88.4	103.0	118.0	132.0	147.0	162.0	177.0	192.0	206.0	221.0	235.0	250.0	265.0	294.0	324.0	354.0
20	1.36	16.3	81.6	98.0	114.0	130.0	147.0	163.0	180.0	196.0	212.0	229.0	245.0	261.0	277.0	294.0	326.0	359.0	392.0
21	1.50	18.0	90.0	108.0	126.0	144.0	162.0	180.0	198.0	216.0	238.0	252.0	270.0	288.0	306.0	324.0	360.0	396.0	432.0
22	1.65	19.8	99.0	119.0	139.0	158.0	178.0	198.0	218.0	238.0	257.0	277.0	297.0	317.0	337.0	356.0	396.0	436.0	476.0
23	1.80	21.6	108.0	130.0	151.0	173.0	194.0	216.0	238.0	259.0	281.0	302.0	324.0	346.0	367.0	389.0	432.0	476.0	518.0
24	1.96	23.5	118.0	141.0	165.0	188.0	212.0	235.0	259.0	282.0	306.0	330.0	353.0	376.0	400.0	424.0	470.0	518.0	564.0
25	2.12	25.5	128.0	153.0	179.0	204.0	230.0	255.0	281.0	306.0	332.0	358.0	383.0	408.0	434.0	460.0	510.0	562.0	612.0
26	2.30	27.6	138.0	166.0	193.0	221.0	248.0	276.0	304.0	331.0	359.0	386.0	414.0	442.0	470.0	496.0	552.0	608.0	662.0
27	2.48	29.7	148.0	178.0	208.0	238.0	267.0	297.0	326.0	356.0	386.0	416.0	426.0	476.0	504.0	534.0	594.0	652.0	712.0
28	2.67	32.0	160.0	192.0	224.0	256.0	288.0	320.0	352.0	384.0	416.0	448.0	480.0	512.0	544.0	576.0	640.0	704.0	768.0
29	2.86	34.3	171.0	206.0	240.0	274.0	309.0	343.0	377.0	412.0	446.0	480.0	514.0	548.0	584.0	618.0	686.0	754.0	824.0
30	3.06	36.7	183.0	220.0	257.0	294.0	330.0	367.0	404.0	440.0	476.0	514.0	550.0	588.0	624.0	660.0	734.0	808.0	880.0
32	3.48	41.8	209.0	251.0	293.0	334.0	376.0	418.0	460.0	502.0	544.0	586.0	628.0	668.0	710.0	752.0	836.0	920.0	1004.0
34	3.93	47.2	236.0	283.0	330.0	378.0	424.0	472.0	520.0	566.0	614.0	660.0	708.0	756.0	802.0	848.0	944.0	1040.0	1132.0
36	4.41	52.9	264.0	317.0	370.0	422.0	476.0	528.0	582.0	634.0	688.0	740.0	792.0	844.0	898.0	952.0	1056.0	1164.0	1268.0

Capacities, in U.S. Gallons, of cylinders of various diameters and lengths.

Volume $= \frac{\pi d^2}{4}$ x H (Cylinder), L x W x H (Cube)

Centrifugal Pump Fundamentals

NET POSITIVE SUCTION HEAD (NPSH) AND CAVITATION

The Hydraulic Institute defines NPSH as the total suction head in feet absolute, determined at the suction nozzle and corrected to datum, less the vapor pressure of the liquid in feet absolute. Simply stated, it is an analysis of energy conditions on the suction side of a pump to determine if the liquid will vaporize at the lowest pressure point in the pump.

The pressure which a liquid exerts on its surroundings is dependent upon its temperature. This pressure, called vapor pressure, is a unique characteristic of every fluid and increases with increasing temperature. When the vapor pressure within the fluid reaches the pressure of the surrounding medium, the fluid begins to vaporize or boil. The temperature at which this vaporization occurs will decrease as the pressure of the surrounding medium decreases.

A liquid increases greatly in volume when it vaporizes. One cubic foot of water at room temperature becomes 1700 cu. ft. of vapor at the same temperature.

It is obvious from the above that if we are to pump a fluid effectively, we must keep it in liquid form. NPSH is simply a measure of the amount of suction head present to prevent this vaporization at the lowest pressure point in the pump.

NPSH Required is a function of the pump design. As the liquid passes from the pump suction to the eye of the impeller, the velocity increases and the pressure decreases. There are also pressure losses due to shock and turbulence as the liquid strikes the impeller. The centrifugal force of the impeller vanes further increases the velocity and decreases the pressure of the liquid. The NPSH Required is the positive head in feet absolute required at the pump suction to overcome these pressure drops in the pump and maintain the liquid above its vapor pressure. The NPSH Required varies with speed and capacity within any particular pump. Pump manufacturer's curves normally provide this information.

NPSH Available is a function of the system in which the pump operates. It is the excess pressure of the liquid in feet absolute over its vapor pressure as it arrives at the pump suction. Fig. 4 shows four typical suction systems with the NPSH Available formulas applicable to each. It is important to correct for the specific gravity of the liquid and to convert all terms to units of "feet absolute" in using the formulas.

In an existing system, the NPSH Available can be determined by a gage reading on the pump suction. The following formula applies:

$$NPSH_A = P_B - V_P \pm Gr + h_V$$

Where Gr = Gage reading at the pump suction expressed in feet (plus if above atmospheric, minus if below atmospheric) corrected to the pump centerline.

h_v = Velocity head in the suction pipe at the gage connection, expressed in feet.

Cavitation is a term used to describe the phenomenon which occurs in a pump when there is insufficient NPSH Available. The pressure of the liquid is reduced to a value equal to or below its vapor pressure and small vapor bubbles or pockets begin to form. As these vapor bubbles move along the impeller vanes to a higher pressure area, they rapidly collapse.

The collapse, or "implosion" is so rapid that it may be heard as a rumbling noise, as if you were pumping gravel. The forces during the collapse are generally high enough to cause minute pockets of fatigue failure on the impeller vane surfaces. This action may be progressive, and under severe conditions can cause serious pitting damage to the impeller.

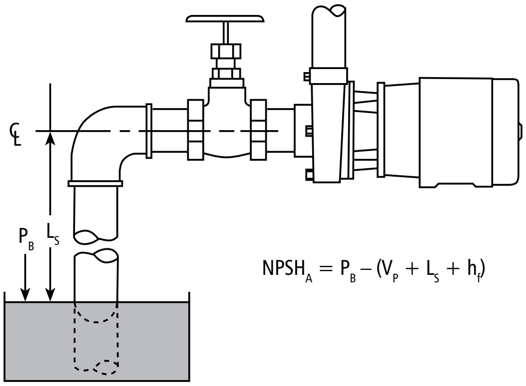
The accompanying noise is the easiest way to recognize cavitation. Besides impeller damage, cavitation normally results in reduced capacity due to the vapor present in the pump. Also, the head may be reduced and unstable and the power consumption may be erratic. Vibration and mechanical damage such as bearing failure can also occur as a result of operating in cavitation.

The only way to prevent the undesirable effects of cavitation is to insure that the NPSH Available in the system is greater than the NPSH Required by the pump.

Centrifugal Pump Fundamentals

NET POSITIVE SUCTION HEAD (NPSH) AND CAVITATION

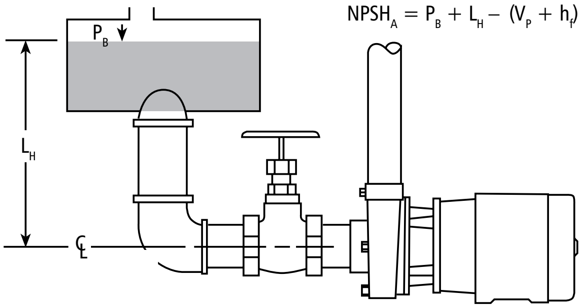
4a SUCTION SUPPLY OPEN TO ATMOSPHERE
– with Suction Lift



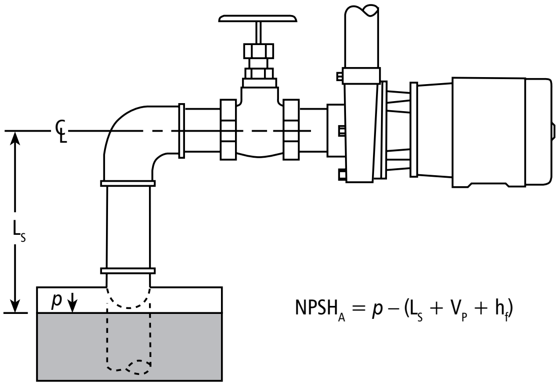
$NPSH_A = P_B - (V_P + L_S + h_f)$

4b SUCTION SUPPLY OPEN TO ATMOSPHERE
– with Suction Head

$NPSH_A = P_B + L_H - (V_P + h_f)$



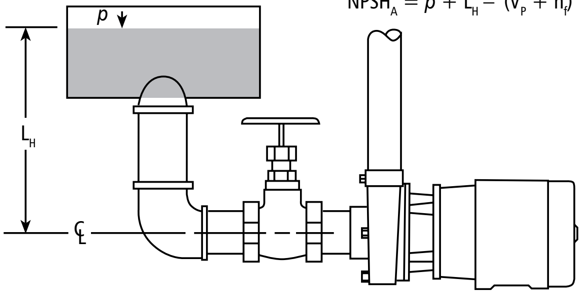
4c CLOSED SUCTION SUPPLY
– with Suction Lift



$NPSH_A = p - (L_S + V_P + h_f)$

4d CLOSED SUCTION SUPPLY
– with Suction Head

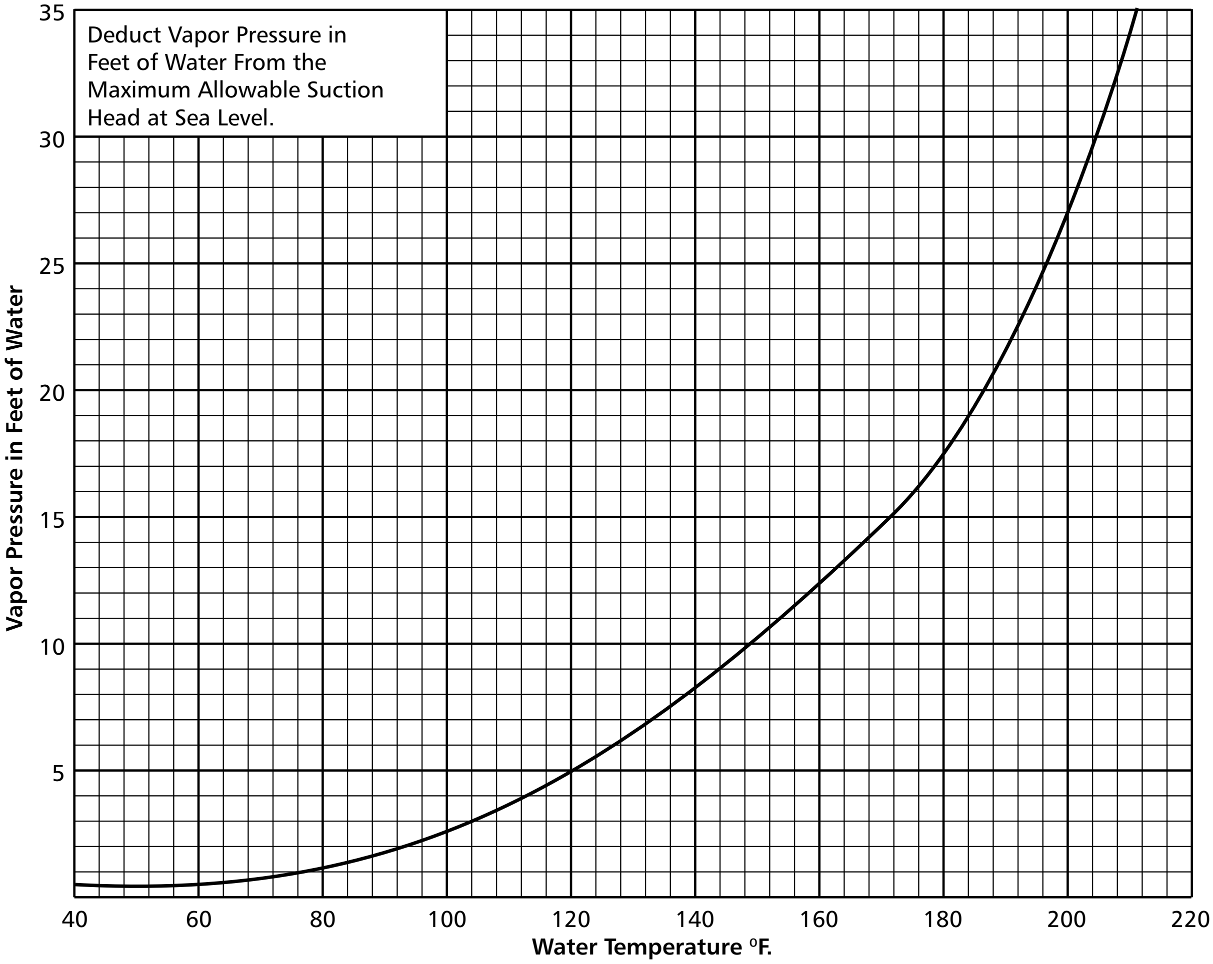
$NPSH_A = p + L_H - (V_P + h_f)$



P_B = Barometric pressure, in feet absolute.
V_P = Vapor pressure of the liquid at maximum pumping temperature, in feet absolute (see next page).
p = Pressure on surface of liquid in closed suction tank, in feet absolute.
L_S = Maximum static suction lift in feet.
L_H = Minimum static suction head in feet.
h_f = Friction loss in feet in suction pipe at required capacity.
Note: See page 23, atmospheric pressure chart.

Centrifugal Pump Fundamentals

VAPOR PRESSURE OF WATER



Electrical Data

NEMA CONTROL PANEL ENCLOSURES

Enclosure Rating	Explanation
NEMA 1 General Purpose	To prevent accidental contact with enclosed apparatus. Suitable for application indoors where not exposed to unusual service conditions.
NEMA 2 Driptight	To prevent accidental contact, and in addition, to exclude falling moisture or dirt.
NEMA 3 Weatherproof (Weatherproof Resistant)	Protection against specified weather hazards. Suitable for use outdoors.
NEMA 3R Raintight	Protects against entrance of water from a beating rain. Suitable for general outdoor application not requiring sleetproof.
NEMA 4 Watertight	Designed to exclude water applied in form of hose stream. To protect against stream of water during cleaning operations, etc.
NEMA 4X Watertight & Corrosion Resistant	Designed to exclude water applied in form of hose stream. To protect against stream of water during cleaning operations, etc. Corrosion Resistant.
NEMA 5 Dusttight	Constructed so that dust will not enter enclosed case. Being replaced in some Dust Tight equipment by NEMA 12.
NEMA 6 Watertight, Dusttight	Intended to permit enclosed apparatus to be operated successfully when temporarily submerged in water.
NEMA 7 Hazardous Locations Class I	Designed to meet application requirements of National Electrical Code for Class 1, Hazardous Locations (explosive atmospheres). Circuit interruption occurs in air.
NEMA 8 Hazardous Locations A, B, C or D Class II – Oil Immersed	Identical to NEMA 7 above, except the apparatus is immersed in oil.
NEMA 9 Class II – Hazardous Locations	Designed to meet application requirements of National Electrical Code for Class II Hazardous Locations (combustible dusts, etc.). E, F and G.
NEMA 10 Bureau of Mines Permissible	Meets requirements of U.S. Bureau of Mines. Suitable for use in coal mines.
NEMA 11 Dripproof Corrosion Resistant	Provides oil immersion of apparatus such that it is suitable for application where equipment is subject to acid or other corrosive fumes.
NEMA 12 Driptight, Dusttight	For use in those industries where it is desired to exclude dust, lint, fibers and flyings, or oil or Industrial coolant seepage.

Determining Water Level

Install ⅛" or ¼" tubing long enough to be 10' to 15' below low water level. Measure the tubing length as it is lowered into the well.

Once the tubing is fixed in a stationary position at the top, connect an air line and pressure gauge. Add air to the tubing until the pressure gauge reaches a point that it doesn't read any higher. Take a gauge reading at this point.

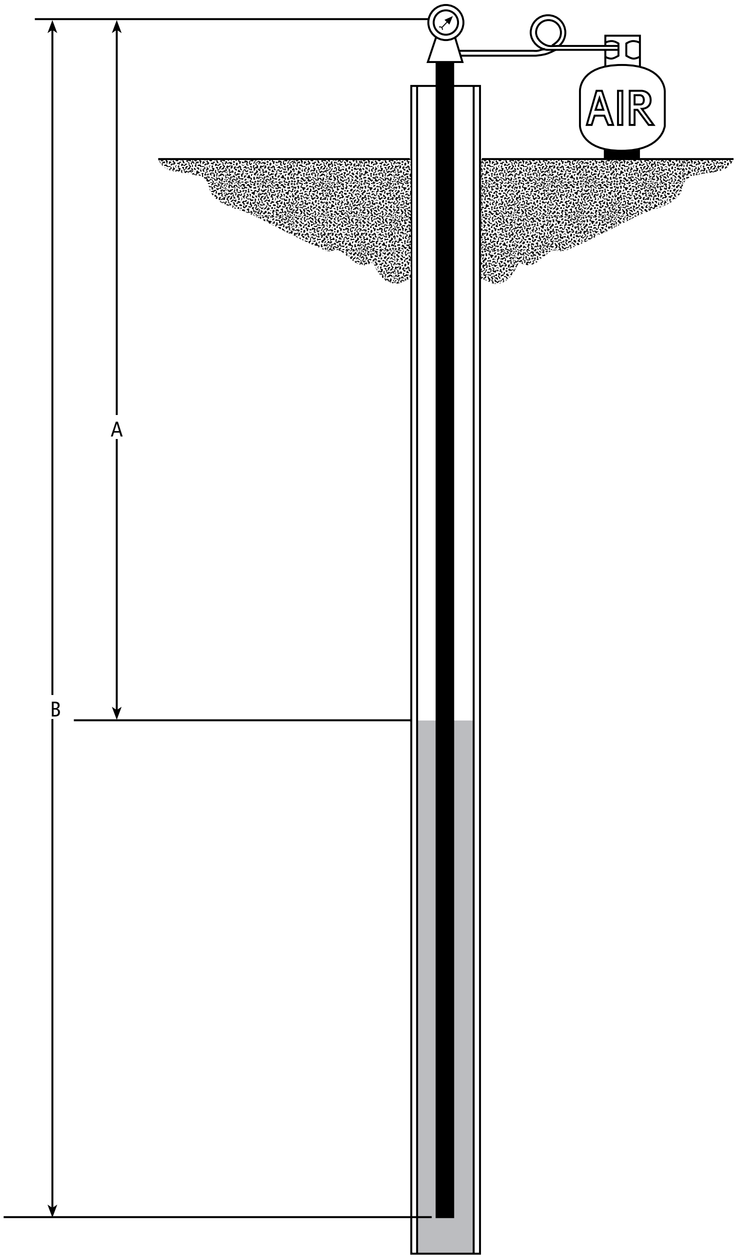
A. Depth to water (to be determined).

B. Total length of air line (in feet).

C. Water pressure on air tubing. Gauge reads in pounds. Convert to feet by multiplying by 2.31.

Example:
If the air tube is 100' long, and the gauge reads 20 lbs.
20 lbs. x 2.31 = 46.2 ft.
Length of tube = 100 ft.
minus 46.2 ft. = 53.8 ft.

Depth to water (A) would be 53.8 ft.



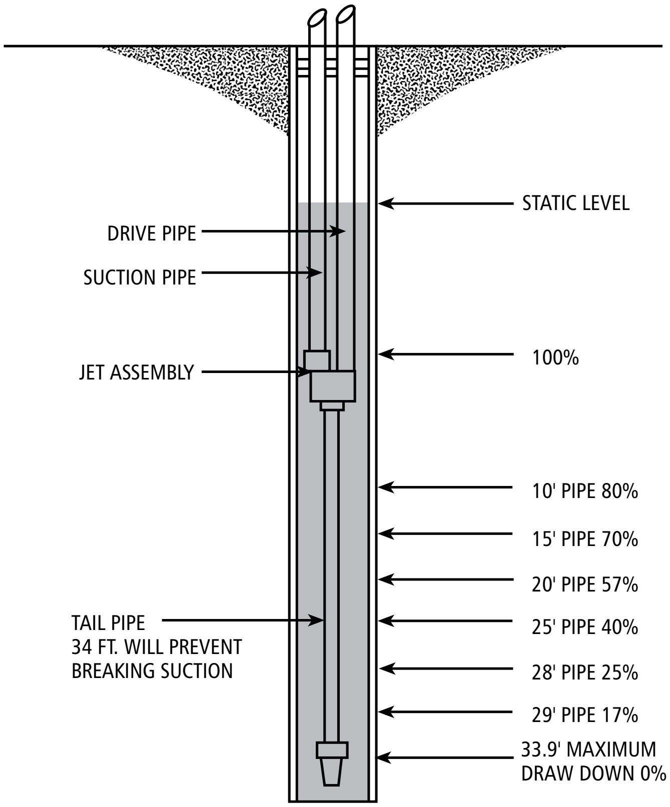
Tail Pipe

HOW TO USE TAIL PIPE ON DEEP WELL JET PUMPS

Pipe below the jet, or “tail pipe” as it is commonly known, is used when you have a weak deep well. Under normal conditions, the jet assembly with the foot valve attached is lowered into the well. You receive your rated capacity at the level you locate the jet assembly. On a weak well, as the water level lowers to the level of the foot valve (attached to the bottom of the jet assembly), air enters the system. By adding 34' of tail pipe below the jet assembly with the foot valve attached to the bottom of the 34' length of pipe, it will not be possible to pull the well down and allow air to enter the system. The drawing indicates the approximate percentage of rated capacity you will receive with tail pipe.

Using a tail pipe, the pump delivery remains at 100% at sea level of the rated capacity down to the jet assembly level. If water level falls below that, flow decreases in proportion to drawdown as shown in the illustration. When pump delivery equals well inflow, the water level remains constant until the pump shuts off.

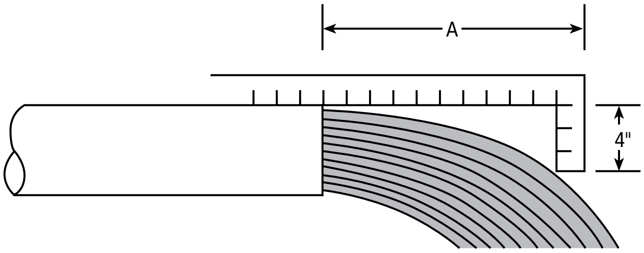
This rule can also be used when determining suction pipe length on shallow well systems.



Determining Flow Rates

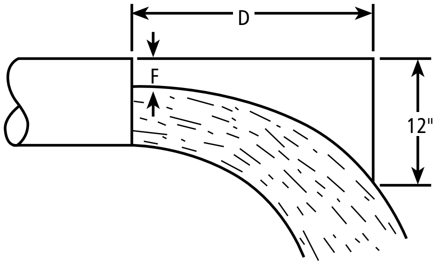
FULL PIPE FLOW – CALCULATION OF DISCHARGE RATE USING HORIZONTAL OPEN DISCHARGE FORMULA

An L-shaped measuring square can be used to estimate flow capacity, using the chart below. As shown in illustration, place 4" side of square so that it hangs down and touches the water. The horizontal distance shown "A" is located in the first column of the chart and you read across to the pipe diameter (ID) to find the gallons per minute discharge rate.



Example: A is 8" from a 4" ID pipe
= a discharge rate of 166 GPM.

PIPE NOT RUNNING FULL – CALCULATION OF DISCHARGE RATE USING AREA FACTOR METHOD



Flow From Horizontal Pipe (Not Full)

Flow (GPM) = A x D x 1.093 x F
A = Area of pipe in square inches
D = Horizontal distance in inches
F = Effective area factor from chart
Area of pipe equals inside Dia.^{2} x 0.7854

Example: Pipe inside diameter = 10 in.
D = 20 in.
F = 2½ in.
A = 10 x 10 x 0.7854 = 78.54 square in.

$$R\,\% = \frac{F}{D} = \frac{2\frac{1}{2}}{10} = 25\,\%$$

F = 0.805
Flow = 78.54 x 20 x 1.039 x 0.805 = 1314 GPM

Ratio F/D = R %	Eff. Area Factor F	Ratio F/D = R %	Eff. Area Factor F
5	0.981	55	0.436
10	0.948	60	0.373
15	0.905	65	0.312
20	0.858	70	0.253
25	0.805	75	0.195
30	0.747	80	0.142
35	0.688	85	0.095
40	0.627	90	0.052
45	0.564	95	0.019
50	0.500	100	0.000

DISCHARGE RATE IN GALLONS PER MINUTE/NOMINAL PIPE SIZE (ID)

Horizontal Dist. (A) Inches	Pipe Diameter											
	1"	1¼"	1½"	2"	2½"	3"	4"	5"	6"	8"	10"	12"
4	5.7	9.8	13.3	22.0	31.3	48.5	83.5					
5	7.1	12.2	16.6	27.5	39.0	61.0	104	163				
6	8.5	14.7	20.0	33.0	47.0	73.0	125	195	285			
7	10.0	17.1	23.2	38.5	55.0	85.0	146	228	334	380		
8	11.3	19.6	26.5	44.0	62.5	97.5	166	260	380	665	1060	
9	12.8	22.0	29.8	49.5	70.0	110	187	293	430	750	1190	1660
10	14.2	24.5	33.2	55.5	78.2	122	208	326	476	830	1330	1850
11	15.6	27.0	36.5	60.5	86.0	134	229	360	525	915	1460	2100
12	17.0	29.0	40.0	66.0	94.0	146	250	390	570	1000	1600	2220
13	18.5	31.5	43.0	71.5	102	158	270	425	620	1080	1730	2400
14	20.0	34.0	46.5	77.0	109	170	292	456	670	1160	1860	2590
15	21.3	36.3	50.0	82.5	117	183	312	490	710	1250	2000	2780
16	22.7	39.0	53.0	88.0	125	196	334	520	760	1330	2120	2960
17		41.5	56.5	93.0	133	207	355	550	810	1410	2260	3140
18			60.0	99.0	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	
22							460	720	1050	1830	2920	
23								750	1100	1910	3060	
24									1140	2000	3200	

Determining Flow Rates

THEORETICAL DISCHARGE OF NOZZLES IN U.S. GALLONS PER MINUTE

Head		Velocity of Discharge Feet Per Second	Diameter of Nozzle in Inches								
Pounds	Feet		1/16	⅛	3/16	¼	⅜	½	⅝	¾	⅞
10	23.1	38.6	0.37	1.48	3.32	5.91	13.3	23.6	36.9	53.1	72.4
15	34.6	47.25	0.45	1.81	4.06	7.24	16.3	28.9	45.2	65.0	88.5
20	46.2	54.55	0.52	2.09	4.69	8.35	18.8	33.4	52.2	75.1	102
25	57.7	61.0	0.58	2.34	5.25	9.34	21.0	37.3	58.3	84.0	114
30	69.3	66.85	0.64	2.56	5.75	10.2	23.0	40.9	63.9	92.0	125
35	80.8	72.2	0.69	2.77	6.21	11.1	24.8	44.2	69.0	99.5	135
40	92.4	77.2	0.74	2.96	6.64	11.8	26.6	47.3	73.8	106	145
45	103.9	81.8	0.78	3.13	7.03	12.5	28.2	50.1	78.2	113	153
50	115.5	86.25	0.83	3.30	7.41	13.2	29.7	52.8	82.5	119	162
55	127.0	90.4	0.87	3.46	7.77	13.8	31.1	55.3	86.4	125	169
60	138.6	94.5	0.90	3.62	8.12	14.5	32.5	57.8	90.4	130	177
65	150.1	98.3	0.94	3.77	8.45	15.1	33.8	60.2	94.0	136	184
70	161.7	102.1	0.98	3.91	8.78	15.7	35.2	62.5	97.7	141	191
75	173.2	105.7	1.01	4.05	9.08	16.2	36.4	64.7	101	146	198
80	184.8	109.1	1.05	4.18	9.39	16.7	37.6	66.8	104	150	205
85	196.3	112.5	1.08	4.31	9.67	17.3	38.8	68.9	108	155	211
90	207.9	115.8	1.11	4.43	9.95	17.7	39.9	70.8	111	160	217
95	219.4	119.0	1.14	4.56	10.2	18.2	41.0	72.8	114	164	223
100	230.9	122.0	1.17	4.67	10.5	18.7	42.1	74.7	117	168	229
105	242.4	125.0	1.20	4.79	10.8	19.2	43.1	76.5	120	172	234
110	254.0	128.0	1.23	4.90	11.0	19.6	44.1	78.4	122	176	240
115	265.5	130.9	1.25	5.01	11.2	20.0	45.1	80.1	125	180	245
120	277.1	133.7	1.28	5.12	11.5	20.5	46.0	81.8	128	184	251
125	288.6	136.4	1.31	5.22	11.7	20.9	47.0	83.5	130	188	256
130	300.2	139.1	1.33	5.33	12.0	21.3	48.0	85.2	133	192	261
135	311.7	141.8	1.36	5.43	12.2	21.7	48.9	86.7	136	195	266
140	323.3	144.3	1.38	5.53	12.4	22.1	49.8	88.4	138	199	271
145	334.8	146.9	1.41	5.62	12.6	22.5	50.6	89.9	140	202	275
150	346.4	149.5	1.43	5.72	12.9	22.9	51.5	91.5	143	206	280
175	404.1	161.4	1.55	6.18	13.9	24.7	55.6	98.8	154	222	302
200	461.9	172.6	1.65	6.61	14.8	26.4	59.5	106	165	238	323

Note:
The actual quantities will vary from these figures, the amount of variation depending upon the shape of nozzle and size of pipe at the point where the pressure is determined. With smooth taper nozzles the actual discharge is about 94 percent of the figures given in the tables.

Determining Flow Rates

THEORETICAL DISCHARGE OF NOZZLES IN U.S. GALLONS PER MINUTE (continued)

Head		**Velocity of Discharge Feet Per Second**	**Diameter of Nozzle in Inches**								
Pounds	**Feet**		**1**	**1⅛**	**1¼**	**1⅜**	**1½**	**1¾**	**2**	**2¼**	**2½**
10	23.1	38.6	94.5	120	148	179	213	289	378	479	591
15	34.6	47.25	116	147	181	219	260	354	463	585	723
20	46.2	54.55	134	169	209	253	301	409	535	676	835
25	57.7	61.0	149	189	234	283	336	458	598	756	934
30	69.3	66.85	164	207	256	309	368	501	655	828	1023
35	80.8	72.2	177	224	277	334	398	541	708	895	1106
40	92.4	77.2	188	239	296	357	425	578	756	957	1182
45	103.9	81.8	200	253	313	379	451	613	801	1015	1252
50	115.5	86.25	211	267	330	399	475	647	845	1070	1320
55	127.0	90.4	221	280	346	418	498	678	886	1121	1385
60	138.6	94.5	231	293	362	438	521	708	926	1172	1447
65	150.1	98.3	241	305	376	455	542	737	964	1220	1506
70	161.7	102.1	250	317	391	473	563	765	1001	1267	1565
75	173.2	105.7	259	327	404	489	582	792	1037	1310	1619
80	184.8	109.1	267	338	418	505	602	818	1070	1354	1672
85	196.3	112.5	276	349	431	521	620	844	1103	1395	1723
90	207.9	115.8	284	359	443	536	638	868	1136	1436	1773
95	219.4	119.0	292	369	456	551	656	892	1168	1476	1824
100	230.9	122.0	299	378	467	565	672	915	1196	1512	1870
105	242.4	125.0	306	388	479	579	689	937	1226	1550	1916
110	254.0	128.0	314	397	490	593	705	960	1255	1588	1961
115	265.5	130.9	320	406	501	606	720	980	1282	1621	2005
120	277.1	133.7	327	414	512	619	736	1002	1310	1659	2050
125	288.6	136.4	334	423	522	632	751	1022	1338	1690	2090
130	300.2	139.1	341	432	533	645	767	1043	1365	1726	2132
135	311.7	141.8	347	439	543	656	780	1063	1390	1759	2173
140	323.3	144.3	354	448	553	668	795	1082	1415	1790	2212
145	334.8	146.9	360	455	562	680	809	1100	1440	1820	2250
150	346.4	149.5	366	463	572	692	824	1120	1466	1853	2290
175	404.1	161.4	395	500	618	747	890	1210	1582	2000	2473
200	461.9	172.6	423	535	660	790	950	1294	1691	2140	2645

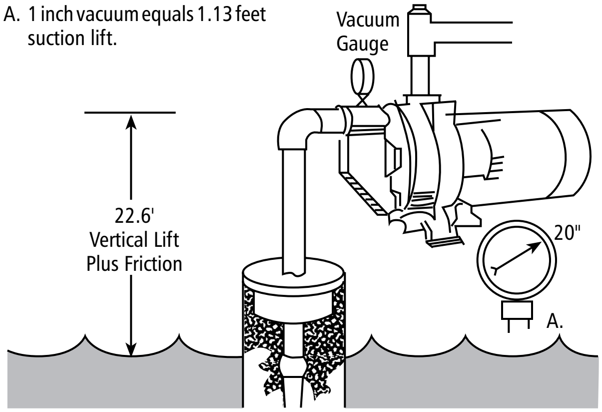
Note:
The actual quantities will vary from these figures, the amount of variation depending upon the shape of nozzle and size of pipe at the point where the pressure is determined. With smooth taper nozzles the actual discharge is about 94 percent of the figures given in the tables.

Terms and Usable Formulas

CALCULATING SUCTION LIFT

Suction lift is measured with a vacuum gauge. The gauge can be calibrated in feet suction lift or inches vacuum.

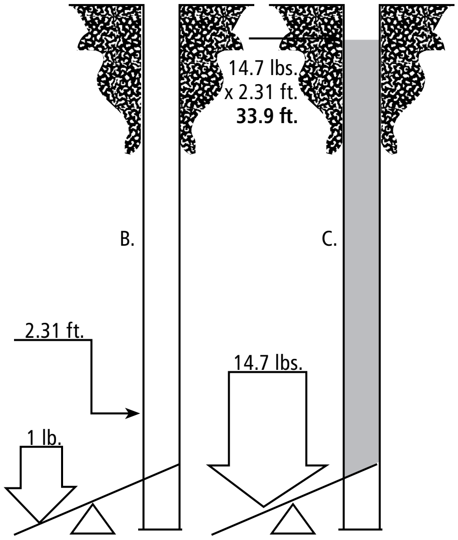
A. 1 inch vacuum equals 1.13 feet suction lift.



A reading of 20" on a vacuum gauge placed on the suction side of the pump would tell you that you had a vacuum or suction lift of 22.6 feet.

20" x 1.13' = 22.6 feet

C. Atmospheric pressure of 14.7 x 2.31 = 33.9 feet which is the maximum suction lift at sea level.



A vacuum gauge indicates total suction lift (vertical lift + friction loss = total lift) in inches of mercury. 1" on the gauge = 1.13 ft. of total suction lift (based on pump located at sea level).

RULE OF THUMB

Practical suction lift at sea level is 25 ft. Deduct 1 ft. of suction lift for each 1000 ft. of elevation above sea level.

Shallow Well System

Install vacuum gauge in shallow well adapter. When pump is running, the gauge will show no vacuum if the end of suction pipe is not submerged or there is a suction leak. If the gauge shows a very high vacuum (22 inches or more), this indicates that the end of suction pipe is buried in mud, the foot valve or check valve is stuck closed or the suction lift exceeds capability of pump.

High Vacuum (22 inches or more)
- Suction pipe end buried in mud
- Foot valve or check valve stuck closed
- Suction lift exceeds capability of the pump

Low Vacuum (or 0 vacuum)
- Suction pipe not submerged
- Suction leak

Terms and Usable Formulas

The term “head” by itself is rather misleading. It is commonly taken to mean the difference in elevation between the suction level and the discharge level of the liquid being pumped. Although this is partially correct, it does not include all of the conditions that should be included to give an accurate description.

■ **Friction Head:** The pressure expressed in lbs./sq. in. or feet of liquid needed to overcome the resistance to the flow in the pipe and fittings.

■ **Suction Lift:** Exists when the source of supply is below the center line of the pump.

■ **Suction Head:** Exists when the source of supply is above the center line of the pump.

■ **Static Suction Lift:** The vertical distance from the center line of the pump down to the free level of the liquid source.

■ **Static Suction Head:** The vertical distance from the center line of the pump up to the free level of the liquid source.

■ **Static Discharge Head:** The vertical elevation from the center line of the pump to the point of free discharge.

■ **Dynamic Suction Lift:** Includes static suction lift, friction head loss and velocity head.

■ **Dynamic Suction Head:** Includes static suction head minus friction head minus velocity head.

■ **Dynamic Discharge Head:** Includes static discharge head plus friction head plus velocity head.

■ **Total Dynamic Head:** Includes the dynamic discharge head plus dynamic suction lift or minus dynamic suction head.

■ **Velocity Head:** The head needed to accelerate the liquid. Knowing the velocity of the liquid, the velocity head loss can be calculated by a simple formula Head = $V^2/2g$ in which g is acceleration due to gravity or 32.16 ft./sec. Although the velocity head loss is a factor in figuring the dynamic heads, the value is usually small and in most cases negligible. See table.

BASIC FORMULAS AND SYMBOLS

Formulas

$$\text{GPM} = \frac{\text{Lb./Hr.}}{500 \times \text{Sp. Gr.}}$$

$$H = \frac{2.31 \times \text{psi}}{\text{Sp. Gr.}}$$

$$H = \frac{1.134 \times \text{In. Hg.}}{\text{Sp. Gr.}}$$

$$H_v = \frac{V^2}{2g} = 0.155\,V^2$$

$$V = \frac{\text{GPM} \times 0.321}{A} = \frac{\text{GPM} \times 0.409}{(\text{I.D.})^2}$$

$$\text{BHP} = \frac{\text{GPM} \times H \times \text{Sp. Gr.}}{3960 \times \text{Eff.}}$$

$$\text{Eff.} = \frac{\text{GPM} \times H \times \text{Sp. Gr.}}{3960 \times \text{BHP}}$$

$$N_s = \frac{N\sqrt{\text{GPM}}}{H^{3/4}}$$

$$H = \frac{V^2}{2g}$$

Symbols

GPM = gallons per minute
Lb. = pounds
Hr. = hour
Sp. Gr. = specific gravity
H = head in feet
psi = pounds per square inch
In. Hg. = inches of mercury
h_v = velocity head in feet
V = velocity in feet per second
g = 32.16 ft./sec.^{2} (acceleration of gravity)
A = area in square inches (πr^2) (for a circle or pipe)
ID = inside diameter in inches
BHP = brake horsepower
Eff. = pump efficiency expressed as a decimal
N_s = specific speed
N = speed in revolutions per minute
D = impeller in inches

Approximate Cost of Operating Electric Motors

Motor HP	*Average kilowatts input or cost based on 1 cent per kilowatt hour		Motor HP	*Av. kw input or cost per hr. based on 1 cent per kw hour
	1 Phase	3 Phase		3 Phase
⅓	.408		20	16.9
½	.535	.520	25	20.8
¾	.760	.768	30	26.0
1	1.00	.960	40	33.2
1½	1.50	1.41	50	41.3
2	2.00	1.82	60	49.5
3	2.95	2.70	75	61.5
5	4.65	4.50	100	81.5
7½	6.90	6.75	125	102
10	9.30	9.00	150	122
			200	162

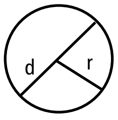
Terms and Usable Formulas

BASIC FORMULAS AND SYMBOLS

Temperature conversion

DEG. C = (DEG. F – 32) x .555

DEG. F = (DEG. C x 1.8) + 32



CIRCLE

Area of a Circle

A = area; C = circumference. D = diameter

A = πr^2; π = 3.14 r = radius

C = $2\pi r$

Water Horsepower = $\frac{\text{GPM x 8.33 x Head}}{33000} = \frac{\text{GPM x Head}}{3960}$

Where:

GPM = Gallons per Minute

8.33 = Pounds of water per gallon

33000 = Ft. Lbs. per minute in one horsepower

Head = Difference in energy head in feet (field head).

Laboratory BHP = $\frac{\text{Head x GPM x Sp. Gr.}}{\text{3960 x Eff.}}$

Field BHP = Laboratory BHP + Shaft Loss

Total BHP = Field BHP + Thrust Bearing Loss

Where:

GPM = Gallons per Minute

Head = Lab. Head (including column loss)

Eff. = Lab. Eff. of Pump Bowls

Shaft Loss = HP loss due to mechanical friction of lineshaft bearings

Thrust Bearing Loss = HP Loss in driver thrust bearings (See (1) below under Misc.)

Input Horsepower = $\frac{\text{Total BPH}}{\text{Motor Eff.}}$

Motor Eff. from Motor mfg. (as a decimal)

Field Efficiency = $\frac{\text{Water Horsepower}}{\text{Total BHP}}$

Water HP as determined above

Total BHP as determined above

Overall Plant Efficiency = $\frac{\text{Water Horsepower}}{\text{Input Horsepower}}$

(See (2) below under Misc.)

Water HP as determined above

Input HP as determined above

Electrical

Input Horsepower = $\frac{\text{BHP}}{\text{Mot. Eff.}} = \frac{\text{4.826 x K x M x R}}{\text{T}} = \frac{\text{1.732 x E x I x PF}}{746}$

BHP = Brake Horsepower as determined above

Mot. Eff. = Rated Motor Efficiency

K = Power Company Meter Constant

M = Power Company Meter Multiplier, or Ratio of Current and Potential Transformers connected with meter

R = Revolutions of meter disk

T = Time in Sec. for R

E = Voltage per Leg applied to motor

I = Amperes per Leg applied to motor

PF = Power factor of motor

1.732 = Factor for 3-phase motors. This reduces to 1 for single phase motors

Kilowatt input to Motor = .746 x I.H.P. = $\frac{\text{1.732 x E x I x PF}}{1000}$

KW-Hrs. Per 1000 Gallons of Cold Water Pumped Per Hour = $\frac{\text{HD in ft. x 0.00315}}{\text{Pump Eff. x Mot. Eff.}}$

Miscellaneous

(1) **Thrust Bearing Loss** = .0075 HP per 100 RPM per 1000 lbs. thrust.*

(2) **Overall Plant Efficiency sometimes referred to as "Wire to Water" Efficiency**

***Thrust (in lbs.)** = (thrust constant (k) laboratory head) + (setting in feet x shaft wt. per ft.)

Note: Obtain thrust constant from curve sheets

Discharge Head (in feet of fluid pumped) = $\frac{\text{Discharge Pressure (psi) x 2.31}}{\text{Sp. Gr. of Fluid Pumped}}$

Affinity Laws

The affinity laws express the mathematical relationship between several variables involved in pump performance. They apply to all types of centrifugal and axial flow pumps. They are as follows:

Q = Capacity, GPM
H = Total Head, Feet
BHP = Brake Horsepower
N = Pump Speed, RPM
D = Impeller Diameter (in.)

Use equations 1 through 3 when *speed changes* and *impeller diameter* remains constant

1. $\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$
2. $\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2$
3. $\frac{BHP_1}{BHP_2} = \left(\frac{N_1}{N_2}\right)^3$

Use equations 4 through 6 with *impeller diameter changes* and *speed* remains constant

4. $\frac{Q_1}{Q_2} = \frac{D_1}{D_2}$
5. $\frac{H_1}{H_2} = \left(\frac{D_1}{D_2}\right)^2$
6. $\frac{BHP_1}{BHP_2} = \left(\frac{D_1}{D_2}\right)^3$

To illustrate the use of these laws, lets look at a particular point (1) on a pump curve (figure 1). The diameter of the impeller for this curve is 6 inches. We will determine by the use of the Affinity Laws what happens to this point if we trim the impeller to 5 inches.

From the 6 inch diameter curve we obtain the following information:

D_1 = 6" Dia.	D_2 = 5" Dia.
Q_1 = 200 GPM	Q_2 = TBA
H_1 = 100 Ft.	H_2 = TBA
BHP_1 = 7.5 HP	BHP_2 = TBA

The equations 4 through 6 above with speed (N) held constant will be used and rearranged to solve for the following:

Equation 4 $Q_2 = \frac{D_2}{D_1} \times Q_1$

Equation 5 $H_2 = \left(\frac{D_2}{D_1}\right)^2 \times H_1$

Equation 6 $BHP_2 = \left(\frac{D_2}{D_1}\right)^3 \times BHP_1$

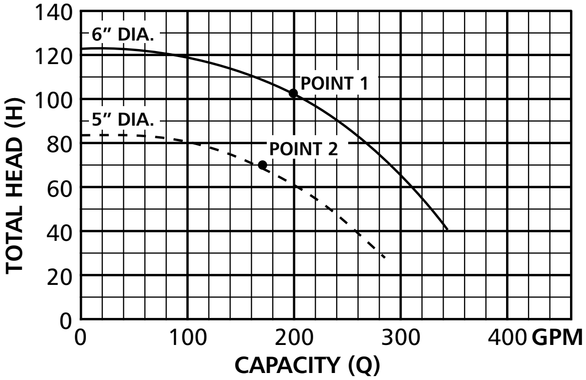
The 6 inch information is put into the formulas and the new 5 inch diameter point is calculated:

$$\mathbf{Q_2} = \frac{5\text{" dia.}}{6\text{" dia.}} \times 200\text{ GPM} = \mathbf{167\ GPM}$$

$$\mathbf{H_2} = \left(\frac{5\text{" dia.}}{6\text{" dia.}}\right)^2 \times 100\text{ Ft.} = \mathbf{69\ Ft.}$$

$$\mathbf{BHP_2} = \left(\frac{5\text{" dia.}}{6\text{" dia.}}\right)^3 \times 7.5\text{ BHP} = \mathbf{4.3\ BHP}$$

FIGURE 1



The 5 inch diameter Head/Capacity performance point can be plotted on the graph (figure 1; point 2). By taking additional Head/Capacity points on the 6" diameter curve line and using this procedure, a new Head/Capacity curve line can be produced for the 5 inch diameter impeller. This same procedure and equations 1 through 3 can be used when pump speed changes and the impeller diameter remains constant.

Calculating impeller trim using Affinity Laws:

Example:
Assume a requirement of 225 GPM at 160' of Head (point 2, figure 2). Note this point falls between 2 existing curve lines with standard impeller diameters. To determine the trimmed impeller diameter to meet our requirement, draw a line from the required point (point 2) perpendicular to an existing curve line (point 1). Notice point 1 has an impeller diameter (D_1) of 6¾" and produces 230 GPM (Q_1) at 172' TDH (H_1).

Applying Affinity Law 5 to solve for our new impeller diameter (D_2).

Point 1 (Known)

D_1 = 6¾" Dia. Impeller
H_1 = 172' TDH
Q_1 = 230 GPM

Point 2 (Unknown)

D_2 = Unknown
H_2 = 160' TDH
Q_2 = 225 GPM

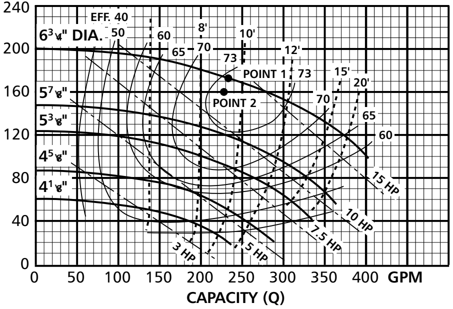
Rearranging law 5 to solve for D_2:

$$D_2 = D_1 \times \sqrt{\frac{H_2}{H_1}}$$

$$D_2 = 6.75 \times \sqrt{\frac{160}{172}}$$

$$D_2 = 6.55 = 6\tfrac{9}{16}"$$

FIGURE 2



Determine that the new impeller will meet the required capacity:

Rearranging law 4 to solve for Q_2:

$$Q_2 = \frac{D_2}{D_1} \times Q_1 = \frac{6.55}{6.75} \times 230 = 223$$

Conversion Charts

Decimal and Millimeter Equivalents of Fraction

Inches		Millimeters	Inches		Millimeters
Fractions	Decimals		Fractions	Decimals	
1/64	.015625	.397	33/64	.515625	13.097
1/32	.03125	.794	17/32	.53125	13.494
3/64	.046875	1.191	35/64	.546875	13.891
1/16	.0625	1.588	9/16	.5625	14.288
5/64	.078125	1.984	37/64	.578125	14.684
3/32	.09375	2.381	19/32	.59375	15.081
7/64	.109375	2.778	39/64	.609375	15.487
1/8	.125	3.175	5/8	.625	15.875
9/64	.140625	3.572	41/64	.640625	16.272
5/32	.15625	3.969	21/32	.65625	16.669
11/64	.171875	4.366	43/64	.671875	17.066
3/16	.1875	4.763	11/16	.6875	17.463
13/64	.203125	5.159	45/64	.703125	17.859
7/32	.21875	5.556	23/32	.71875	18.256
15/64	.234375	5.953	47/64	.734375	18.653
1/4	.250	6.350	3/4	.750	19.050
17/64	.265625	6.747	49/64	.765625	19.447
9/32	.28125	7.144	25/32	.78125	19.844
19/64	.296875	7.541	51/64	.796875	20.241
5/16	.3125	7.938	13/16	.8125	20.638
21/64	.328125	8.334	53/64	.828125	21.034
11/32	.34375	8.731	27/32	.84375	21.431
23/64	.359375	9.128	55/64	.859375	21.828
3/8	.375	9.525	7/8	.875	22.225
25/64	.390625	9.922	57/64	.890625	22.622
13/32	.40625	10.319	29/32	.90625	23.019
27/64	.421875	10.716	59/64	.921875	23.416
7/16	.4375	11.113	15/16	.9375	23.813
29/64	.453125	11.509	61/64	.953125	24.209
15/32	.46875	11.906	31/32	.96875	24.606
31/64	.484375	12.303	63/64	.984375	25.003
1/2	.500	12.700	1	1.000	25.400

Atmospheric Pressure, Barometer Reading and Boiling Point of Water at Various Altitudes

Altitude		Barometer Reading		Atmos. Press.		Boiling Pt. of Water °F
Feet	Meters	In. Hg.	Mm. Hg.	Psia	Ft. Water	
- 1000	- 304.8	31.0	788	15.2	35.2	213.8
- 500	- 152.4	30.5	775	15.0	34.6	212.9
0	0.0	29.9	760	14.7	33.9	212.0
+ 500	+ 152.4	29.4	747	14.4	33.3	211.1
+ 1000	304.8	28.9	734	14.2	32.8	210.2
1500	457.2	28.3	719	13.9	32.1	209.3
2000	609.6	27.8	706	13.7	31.5	208.4
2500	762.0	27.3	694	13.4	31.0	207.4
3000	914.4	26.8	681	13.2	30.4	206.5
3500	1066.8	26.3	668	12.9	29.8	205.6
4000	1219.2	25.8	655	12.7	29.2	204.7
4500	1371.6	25.4	645	12.4	28.8	203.8
5000	1524.0	24.9	633	12.2	28.2	202.9
5500	1676.4	24.4	620	12.0	27.6	201.9
6000	1828.8	24.0	610	11.8	27.2	201.0
6500	1981.2	23.5	597	11.5	26.7	200.1
7000	2133.6	23.1	587	11.3	26.2	199.2
7500	2286.0	22.7	577	11.1	25.7	198.3
8000	2438.4	22.2	564	10.9	25.2	197.4
8500	2590.8	21.8	554	10.7	24.7	196.5
9000	2743.2	21.4	544	10.5	24.3	195.5
9500	2895.6	21.0	533	10.3	23.8	194.6
10000	3048.0	20.6	523	10.1	23.4	193.7
15000	4572.0	16.9	429	8.3	19.2	184.0

Head and Pressure Equivalents

1. Feet Head of Water and Equivalent Pressures
To change head in feet to pressure in pounds, multiply by .434

Feet Head	PSI	Feet Head	PSI	Feet Head	PSI	Feet Head	PSI
1	.43	30	12.99	140	60.63	300	129.93
2	.87	40	17.32	150	64.96	325	140.75
3	1.30	50	21.65	160	69.29	350	151.58
4	1.73	60	25.99	170	73.63	400	173.24
5	2.17	70	30.32	180	77.96	500	216.55
6	2.60	80	34.65	190	82.29	600	259.85
7	3.03	90	38.98	200	86.62	700	303.16
8	3.46	100	43.31	225	97.45	800	346.47
9	3.90	110	47.64	250	108.27	900	389.78
10	4.33	120	51.97	275	119.10	1000	433.09
20	8.66	130	56.30	-	-	-	-

2. Pressure and Equivalent Feet Head of Water
To change pounds pressure to feet head, multiply by 2.3

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

Conversion Charts

English measures – unless otherwise designated, are those used in the United States.

Gallon – designates the U.S. gallon. To convert into the Imperial gallon, multiply the U.S. gallon by 0.83267. Likewise, the word ton designates a short ton, 2,000 pounds.

Multiply	By	To Obtain
Acres	43,560	Square feet
Acres	4047	Square meters
Acres	1.562×10^{3}	Square miles
Acres	4840	Square yards
Atmospheres	76.0	Cms. of mercury
Atmospheres	29.92	Inches of mercury
Atmospheres	33.90	Feet of water
Atmospheres	10,332	Kgs./sq. meter
Atmospheres	14.70	Lbs./sq. inch
Atmospheres	1.058	Tons/sq. ft.
Barrels-Oil	42	Gallons-Oil
Barrels-Beer	31	Gallons-Beer
Barrels-Whiskey	45	Gallons-Whiskey
Barrels/Day-Oil	0.02917	Gallons/Min-Oil
Bags or sacks-cement	94	Pounds-cement
Board feet	144 sq. in. x 1 in.	Cubic inches
B.T.U./min.	12.96	Foot-lbs./sec.
B.T.U./min.	0.02356	Horsepower
B.T.U./min.	0.01757	Kilowatts
B.T.U./min.	17.57	Watts
Centimeters	0.3937	Inches
Centimeters	0.01	Meters
Centimeters	10	Millimeters
Cubic feet	2.832×10^{4}	Cubic cms.
Cubic feet	1728	Cubic inches
Cubic feet	0.02832	Cubic meters
Cubic feet	0.03704	Cubic yards
Cubic feet	7.48052	Gallons
Cubic feet	28.32	Liters
Cubic feet	59.84	Pints (liq.)
Cubic feet	29.92	Quarts (liq.)
Cubic feet/min.	472.0	Cubic cms./sec.
Cubic feet/min.	0.1247	Gallons/sec.
Cubic feet/min.	0.4719	Liters/sec.
Cubic feet/min.	62.43	Lbs. of water/min.
Cubic feet/sec.	0.646317	Millions gals./day
Cubic feet/sec.	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
Cubic inches	5.787×10^{-4}	Cubic feet
Cubic inches	1.639×10^{-5}	Cubic meters
Cubic inches	2.143×10^{-5}	Cubic yards

Properties of water – it freezes at 32ºF., and is at its maximum density at 39.2ºF. In the multipliers using the properties of water, calculations are based on water at 39.2ºF. in a vacuum, weighing 62.427 pounds per cubic foot, or 8.345 pounds per U.S. gallon.

Multiply	By	To Obtain
Cubic inches	4.329×10^{-3}	Gallons
Cubic inches	1.639×10^{-2}	Liters
Cubic inches	0.03463	Pints (liq.)
Cubic inches	0.01732	Quarts (liq.)
Cubic yards	764,544.86	Cubic centimeters
Cubic yards	27	Cubic feet
Cubic yards	46,656	Cubic inches
Cubic yards	0.7646	Cubic meters
Cubic yards	202.0	Gallons
Cubic yards	764.5	Liters
Cubic yards	1616	Pints (liq.)
Cubic yards	807.9	Quarts (liq.)
Cubic yards/min.	0.45	Cubic feet/sec.
Cubic yards/min.	3.366	Gallons/sec.
Cubic yards/min.	12.74	Liters/sec.
Fathoms	6	Feet
Feet	30.48	Centimeters
Feet	12	Inches
Feet	0.3048	Meters
Feet	1/3	Yards
Feet of water	0.0295	Atmospheres
Feet of water	0.8826	Inches of mercury
Feet of water	304.8	Kgs./sq. meter
Feet of water	62.43	Lbs./Sq. ft.
Feet of water	0.4335	Lbs./sq. inch
Feet/min.	0.5080	Centimeters/sec.
Feet/min.	0.01667	Feet/sec.
Feet/min.	0.01829	Kilometers/hr.
Feet/min.	0.3048	Meters/min.
Feet/min.	0.01136	Miles/hr.
Feet/sec.	30.48	Centimeters/sec.
Feet/sec.	1.097	Kilometers/hr.
Feet/sec.	0.5924	Knots
Feet/sec.	18.29	Meters/min.
Feet/sec.	0.6818	Miles/hr.
Feet/sec.	0.01136	Miles/min.
Feet/sec./sec.	30.48	Cms./sec./sec.
Feet/sec./sec.	0.3048	Meters/sec./sec.
Foot-pounds	1.286×10^{3}	British Thermal Units
Foot-pounds	5.050×10^{7}	Horsepower-hrs.
Foot-pounds	3.240×10^{4}	Kilogram-calories

Conversion Charts

Multiply	By	To Obtain
Foot-pounds	0.1383	Kilogram-meters
Foot-pounds	3.766 x 10^{7}	Kilowatt-hours
Gallons	3785	Cubic centimeters
Gallons	0.1337	Cubic feet
Gallons	231	Cubic inches
Gallons	3.785 x 10^{-3}	Cubic meters
Gallons	4.951 x 10^{-3}	Cubic yards
Gallons	3.785	Liters
Gallons	8	Pints (liq.)
Gallons	4	Quarts (liq.)
Gallons-Imperial	1.20095	U.S. gallons
Gallons-U.S.	0.83267	Imperial gallons
Gallons water	8.345	Pounds of water
Gallons/min.	2.228 x 10^{-3}	Cubic feet/sec.
Gallons/min.	0.06308	Liters/sec.
Gallons/min.	8.0208	Cu. ft./hr.
Gallons/min.	.2271	Meters^{3}/hr.
Grains/U.S. gal.	17.118	Parts/million
Grains/U.S. gal.	142.86	Lbs./million gal.
Grains/Imp. gal.	14.254	Parts/million
Grams	15.43	Grains
Grams	.001	Kilograms
Grams	1000	Milligrams
Grams	0.03527	Ounces
Grams	2.205 x 10^{-3}	Pounds
Horsepower	42.44	B.T.U./min.
Horsepower	33,000	Foot-lbs./min.
Horsepower	550	Foot-lbs./sec.
Horsepower	1.014	Horsepower (metric)
Horsepower	0.7457	Kilowatts
Horsepower	745.7	Watts
Horsepower (boiler)	33,493	B.T.U./hr.
Horsepower (boiler)	9.809	Kilowatts
Horsepower-hours	2546	B.T.U.
Horsepower-hours	1.98 x 10^{6}	Foot-lbs.
Horsepower-hours	2.737 x 10^{5}	Kilogram-meters
Horsepower-hours	0.7457	Kilowatt-hours
Inches	2.540	Centimeters
Inches of mercury	0.03342	Atmospheres
Inches of mercury	1.133	Feet of water
Inches of mercury	345.3	Kgs./sq. meter
Inches of mercury	70.73	Lbs./sq. ft.
Inches of mercury (32°F)	0.491	Lbs./sq. inch
Inches of water	0.002458	Atmospheres
Inches of water	0.07355	Inches of mercury
Inches of water	25.40	Kgs./sq. meter
Inches of water	0.578	Ounces/sq. inch
Inches of water	5.202	Lbs. sq. foot
Inches of water	0.03613	Lbs./sq. inch
Kilograms	2.205	Lbs.

Multiply	By	To Obtain
Kilograms	1.102 x 10^{-3}	Tons (short)
Kilograms	10^{3}	Grams
Kiloliters	10^{3}	Liters
Kilometers	10^{5}	Centimeters
Kilometers	3281	Feet
Kilometers	10^{3}	Meters
Kilometers	0.6214	Miles
Kilometers	1094	Yards
Kilometers/hr.	27.78	Centimeters/sec.
Kilometers/hr.	54.68	Feet/min.
Kilometers/hr.	0.9113	Feet/sec.
Kilometers/hr.	.5399	Knots
Kilometers/hr.	16.67	Meters/min.
Kilowatts	56.907	B.T.U./min.
Kilowatts	4.425 x 10^{4}	Foot-lbs./min.
Kilowatts	737.6	Foot-lbs./sec.
Kilowatts	1.341	Horsepower
Kilowatts	10^{3}	Watts
Kilowatt-hours	3414.4	B.T.U.
Kilowatt-hours	2.655 x 10^{6}	Foot-lbs.
Kilowatt-hours	1.341	Horsepower-hrs.
Kilowatt-hours	3.671 x 10^{5}	Kilogram-meters
Liters	10^{3}	Cubic centimeters
Liters	0.03531	Cubic feet
Liters	61.02	Cubic inches
Liters	10^{-3}	Cubic meters
Liters	1.308 x 10^{-3}	Cubic yards
Liters	0.2642	Gallons
Liters	2.113	Pints (liq.)
Liters	1.057	Quarts (liq.)
Liters/min.	5.886 x 10^{-4}	Cubic ft./sec.
Liters/min.	4.403 x 10^{-3}	Gals./sec.
Lumber Width (in.) x $\frac{\text{Thickness (in.)}}{12}$	Length (ft.)	Board feet
Meters	100	Centimeters
Meters	3.281	Feet
Meters	39.37	inches
Meters	10^{-3}	Kilometers
Meters	10^{3}	Millimeters
Meters	1.094	Yards
Miles	1.609 x 10^{5}	Centimeters
Miles	5280	Feet
Miles	1.609	Kilometers
Miles	1760	Yards
Miles/hr.	44.70	Centimeters/sec.
Miles/hr.	88	Feet/min.
Miles/hr.	1.467	Feet/sec.
Miles/hr.	1.609	Kilometers/hr.
Miles/hr.	0.8689	Knots

Conversion Charts

Multiply	By	To Obtain
Miles/hr.	26.82	Meters/min.
Miles/min.	2682	Centimeters/sec.
Miles/min.	88	Feet/sec.
Miles/min.	1.609	Kilometers/min.
Miles/min.	60	Miles/hr.
Ounces	16	Drams
Ounces	437.5	Grains
Ounces	0.0625	Pounds
Ounces	28.3495	Grams
Ounces	2.835×10^{-5}	Tons (metric)
Parts/million	0.0584	Grains/U.S. gal.
Parts/million	0.07015	Grains/Imp. gal.
Parts/million	8.345	Lbs./million gal.
Pounds	16	Ounces
Pounds	256	Drams
Pounds	7000	Grains
Pounds	0.0005	Tons (short)
Pounds	453.5924	Grams
Pounds of water	0.01602	Cubic feet
Pounds of water	27.68	Cubic inches
Pounds of water	0.1198	Gallons
Pounds of water/min.	2.670×10^{-4}	Cubic ft./sec.
Pounds/cubic foot	0.01602	Grams/cubic cm.
Pounds/cubic foot	16.02	Kgs./cubic meters
Pounds/cubic foot	5.787×10^{-4}	Lbs./cubic inch
Pounds/cubic inch	27.68	Grams/cubic cm.
Pounds/cubic inch	2.768×10^{4}	Kgs./cubic meter
Pounds/cubic inch	1728	Lbs./cubic foot
Pounds/foot	1.488	Kgs./meter
Pounds/inch	1152	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
Pounds/sq. foot	4.882	Kgs./sq. meter
Pounds/sq. foot	6.944×10^{-3}	Pounds/sq. inch
Pounds/sq. inch	0.06804	Atmospheres
PSI	2.307	Feet of water
PSI	2.036	Inches of mercury
PSI	703.1	Kgs./sq. meter
Quarts (dry)	67.20	Cubic inches
Quarts (liq.)	57.75	Cubic inches
Square feet	2.296×10^{-5}	Acres
Square feet	929.0	Square centimeters
Square feet	144	Square inches
Square feet	0.09290	Square meters
Square feet	3.587×10^{-4}	Square miles
Square feet	1/9	Square yards
$\frac{1}{\text{sq. ft./gal./min.}}$	8.0208	Overflow rate (ft./hr.)
Square inches	6.452	Square centimeters
Square inches	6.944×10^{-3}	Square feet
Square inches	645.2	Square millimeters

Multiply	By	To Obtain
Square kilometers	247.1	Acres
Square kilometers	10.76×10^{6}	Square feet
Square kilometers	10^{6}	Square meters
Square kilometers	0.3861	Square miles
Square kilometers	1.196×10^{6}	Square yards
Square meters	2.471×10^{-4}	Acres
Square meters	10.76	Square feet
Square meters	3.861×10^{-7}	Square miles
Square meters	1.196	Square yards
Square miles	640	Acres
Square miles	27.88×10^{6}	Square feet
Square miles	2.590	Square kilometers
Square miles	3.098×10^{6}	Square yards
Square yards	2.066×10^{-4}	Acres
Square yards	9	Square feet
Square yards	0.8361	Square meters
Square yards	3.228×10^{-7}	Square miles
Temp (°C)+273	1	Abs. temp. (°C)
Temp. (°C)+17.78	1.8	Temp. (°F)
Temp. (°F)+460	1	Abs. temp. (°F)
Temp. (°F)-32	5/9	Temp (°C)
Tons (metric)	10^{3}	Kilograms
Tons (metric)	2205	Pounds
Tons (short)	2000	Pounds
Tons (short)	32,000	Ounces
Tons (short)	907.1843	Kilograms
Tons (short)	0.89287	Tons (long)
Tons (short)	0.90718	Tons (metric)
Tons of water/24 hrs.	83.333	Pounds water/hr.
Tons of water/24 hrs.	0.16643	Gallons/min.
Tons of water/24 hrs.	1.3349	Cu. ft./hr.
Watts	0.05686	B.T.U./min.
Watts	44.25	Foot-lbs./min.
Watts	0.7376	Foot-lbs./sec.
Watts	1.341×10^{-3}	Horsepower
Watts	0.01434	Kg.-calories/min.
Watts	10^{-3}	Kilowatts
Watt-hours	3.414	B.T.U.
Watt-hours	2655	Foot-lbs.
Watt-hours	1.341×10^{-3}	Horsepower-hrs.
Watt-hours	0.8604	Kilogram-calories
Watt-hours	367.1	Kilogram-meters
Watt-hours	10^{-3}	Kilowatt-hours
Yards	91.44	Centimeters
Yards	3	Feet
Yards	36	Inches
Yards	0.9144	Meters

Pipe Volume and Velocity

STORAGE OF WATER IN VARIOUS SIZE PIPES

Pipe Size	Volume in Gallons per Foot	Pipe Size	Volume in Gallons per Foot
1¼	.06	6	1.4
1½	.09	8	2.6
2	.16	10	4.07
3	.36	12	5.87
4	.652		

MINIMUM FLOW TO MAINTAIN 2FT./SEC. *SCOURING VELOCITY IN VARIOUS PIPES

Pipe Size	Minimum GPM	Pipe Size	Minimum GPM
1¼	9	6	180
1½	13	8	325
2	21	10	500
3	46	12	700
4	80		

* Failure to maintain or exceed this velocity will result in clogged pipes. Based on schedule 40 nominal pipe.

STORAGE OF WATER IN VARIOUS SIZES OF WELLS

$$\frac{D^2}{24.5} = \text{Gals. of Storage per Foot}$$

Where: D = Inside diameter of well casing in inches

Examples:

2" Casing = .16 Gals. per ft. Storage	8" Casing = 2.6 Gals. per ft. Storage
3" Casing = .36 Gals. per ft. Storage	10" Casing = 4.07 Gals. per ft. Storage
4" Casing = .652 Gals. per ft. Storage	12" Casing = 5.87 Gals. per ft. Storage
5" Casing = 1.02 Gals. per ft. Storage	14" Casing = 7.99 Gals. per ft. Storage
6" Casing = 1.4 Gals. per ft. Storage	16" Casing = 10.44 Gals. per ft. Storage

Jet Pump Motor Data and Electrical Components

A.O. SMITH MOTOR DATA

GP Number	Where Used	A.O. Smith	HP	Volts	Phase	Service Factor	Max. Load Amps	Watts	Circuit Breaker
J04853	J05, HB705	C48J2DB11C3HF	½	115/230	1	1.6	10.8/5.4	880	25/15
J05853	JL07N, HSJ07, XSH07, HB	C48K2DB11A4HH	¾	115/230	1	1.5	14.8/7.4	1280	30/15
J06853	JL10N, HSJ10, SJ10, XSH10, HB	C48L2DB11A4HH	1	115/230	1	1.4	16.2/8.1	1440	30/20
J07858	HSJ15, SJ15, HB, XSH15	C48M2DB11A1HH	1½	115/230	1	1.3	20.0/10.0	1866	40/20
J08854	HSJ20, HSC20, XSH20	K48N2DB11A2HH	2	115/230	1	1.2	22.6/11.3	2100	25/15
② J09853	XSH30, GT30	C56P2U11A3HH	3	230	1	1.15	17.2	3280	30
② J04853L	J5(S), GB	C48A93A06	½	115/230	1	1.6	10.8/5.4	968	25/15
② J05853L	J7(S), GB, GT07, (H)SJ07, HSC07	C48A94A06	¾	115/230	1	1.5	14.8/7.4	1336	30/15
② J06853L	J10(S), GB, GT10, (H)SJ10, HSC10	C48A95A06	1	115/230	1	1.4	16.2/8.1	1592	30/20
② J07858L	J15(S), GB, GT15, HSJ15, HSC15	C48M2DC11A1	1½	115/230	1	1.3	21.4/10.7	1950	40/20
①② J08854L	HSJ20, GB, GT20, HSC20	K48A34A06	2	230	1	1.2	12.9	2100	25
SFJ04853	JB05	S48A90A06	½	115/230	1	1.6	9.4/4.7	900	20/10
SFJ05853	JB07	C48A77A06	¾	115/230	1	1.5	13.6/6.8	1160	25/15
SFJ06853	JB10	C48A78A06	1	115/230	1	1.4	15.8/7.9	1400	30/20
② SFJ04860	JRS5, JRD5, JB05	C48C04A06	½	115/230	1	1.6	12.6/6.3	990	25/15
② SFJ05860	JRS7, JRD7, JB07	C48C05A06	¾	115/230	1	1.5	14.8/7.4	1200	30/15
② SFJ06860	JRS10, JRD10, JB10	C48C06A06	1	115/230	1	1.4	16.2/8.1	1400	30/20

① Effective July, 1998, 230 V only.

② Current production motor

ELECTRICAL COMPONENTS

GP Motor Model	A.O. Smith Motor Model	Motor Overload with Leads			Run Capacitor and MFD	Start Capacitor MFD Rating	Switch⑤
		④ Old Number	③ New Number	T.I. Number			
J04853	C48J2DB11C3HF	614246 71		MET38ABN		610807 1: 124/148	629002 2
J05853	C48K2DB11A4HH	614246 20		CET63ABN		610807 2: 161/192	629002 2
J06853	C48L2DB11A4HH	614246 9		CET52ABN		610807 2: 161/192	629002 2
J07858	C48M2DB11A1HH	614246 79		CET38ABM		610807 2: 161/192	629002 2
J08854	K48N2DB11A2HH	611307 29		BRT44ABM	614529 4: 25	610807 1: 124/148	629002 2
J09853	C56P2U11A3HH	611106 22	611106 36	BRB2938		610807 32: 189/227	629002 2
J04853L	C48A93A06	614246 98	627121 43	MET39ABN-CL		610807 1:124/148	629002 2
J05853L	C48A94A06	614246 20	627121 38	CET63ABN		610807 2:161/192	629002 2
J06853L	C48A95A06	614246 9	627121 7	CET52ABN		610807 2:161/192	629002 2
J07858L	C48C53A06		611123 21	BRT45ABM		610807 7:189/227	629002 2
J08854L	K48A34A06	616861 10	627119 10	CET31ABN	623450 8: 30	610807 33: 64-77	629002 2
SFJ04853	S48A90A06	621863 1		MEJ38ABN		N/A	3945C91A01
SFJ05853	C48A77A06	621863 4		CET55ABN		610807 2: 161/192	3945C91A01
SFJ06853	C48A78A06	621863 5		CET49ABN		610807 2: 161/192	3945C91A01
SFJ04860	C48C04A06	614246 67	627121 48	MET36ABN		610807 2: 161/192	629002 2
SFJ05860	C48C05A06	614246 20	627121 38	CET63ABN		610807 2: 161/192	629002 2
SFJ06860	C48C06A06	614246 9	627121 7	CET52ABN		610807 2: 161/192	629002 2

③ These new overload part numbers are for use with the new plastic terminal board with the quick change voltage plug.

④ Use this suffix if your motor has the old style brown terminal board without quick change voltage plug.

⑤ 629002 2 replaces 614234 1, 2, and 6.

Jet Pump Motor Wiring A.O. Smith Motors

TERMINAL BOARD AND VOLTAGE CHANGE PLUG

A change has been made to use a new terminal board on the A.O. Smith two compartment motor models. This terminal board is used on both dual voltage and single voltage motors.

FEATURES

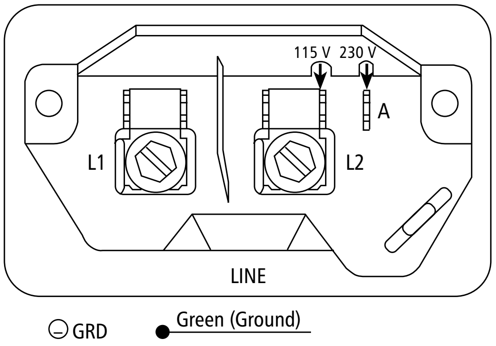
- **Voltage Plug:** Dual voltage motors use a voltage plug that retains the terminals for the Black and Black Tracer leads. To change voltage, lift the black plug and align the arrow with the desired voltage on terminal board. See Figure 1 for an example of the dual voltage connection diagram.
- **Screws with ¼" drive:** The terminal screw accepts either a ¼" nut driver or a slotted screw driver.
- **Line Wire Connection:** The space under the screw will accept #16, #14, #12, #10, or #8 wire. The rib at the bottom edge of the screw allows the wire to be placed straight into the space under the screw. This rib retains the wire under the head of the screw and for #12, #10, or #8 wire it is not necessary to wrap the wire around the screw.
- ½ HP wired 115 V, ¾ HP and up wired 230 V at factory.
- **Quick Connect Terminals:** Each terminal has provision for ¼" quick connect terminals in addition to the screw.
- **Molded Plastic Material:** The terminal board is made from an extremely tough white plastic material with L1, L2, and A markings molded into the board.
- **Lead Channel:** A channel adjacent to the conduit hole directs wiring to the top of the board.
- **Governor Guard:** An integral backplate prevents leads from entering the area around the governor.
- **Ground Guard:** To prevent the bare ground wire from touching the "live" L2 terminal, the ground wire must be placed above this guard.

VOLTAGE CHANGES ARE MADE INSIDE THE MOTOR COVER NOT IN THE PRESSURE SWITCH.

WARNING:
DISCONNECT POWER SOURCE BEFORE CHECKING. DO NOT MAKE ANY CHANGES WITH POWER ON.

CAPACITOR START INDUCTION RUN – SINGLE SPEED (NEW STYLE – AFTER APRIL, 1999)

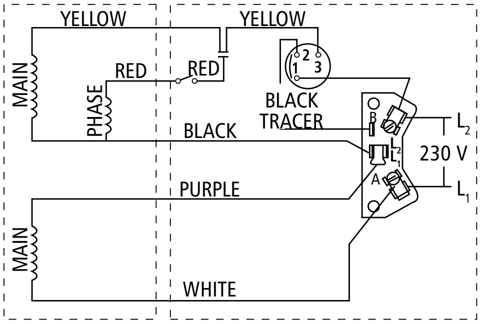
FIGURE 1

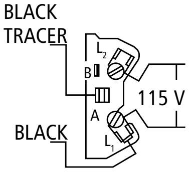


Align black plug to 115 V or 230 V arrow.

½ HP wired 115 V, ¾ HP and up wired 230 V at factory.

CAPACITOR START INDUCTION RUN – SINGLE SPEED (OLD STYLE – UP TO APRIL, 1999)





"Black Tracer" is a black and white wire

TO WIRE FOR 230 V:
BLACK TRACER TO B
BLACK TO A

TO WIRE FOR 115 V:
BLACK TRACER TO A
BLACK TO L_1

Emerson Motor Wiring

115/230 VOLTAGE CONNECTIONS

115 Voltage	230 Voltage
Black — A	Black — 1
Wht./Blk. Tracer — 1	Wht./Blk. Tracer — B
Line 1 — 2	Line 1 — 2
Line 2 — A	Line 2 — A
(Blue — 3)	(Blue — 3)

TO CHANGE MOTOR VOLTAGE:

Models without a Switch

115V to 230V	230V to 115V
Move Wht./Blk. tracer to B	Move Blk. to A
Move Blk. to 1	Move Wht./Blk. tracer to 1

Models with Voltage Change Switch

- Move toggle switch between 115V or 230V.

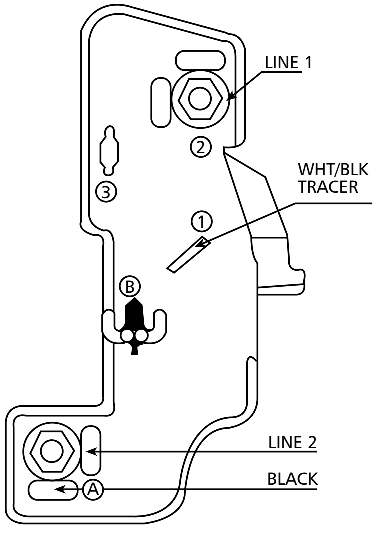
CONNECTIONS

A – has 2 male connectors and 1 screw connector

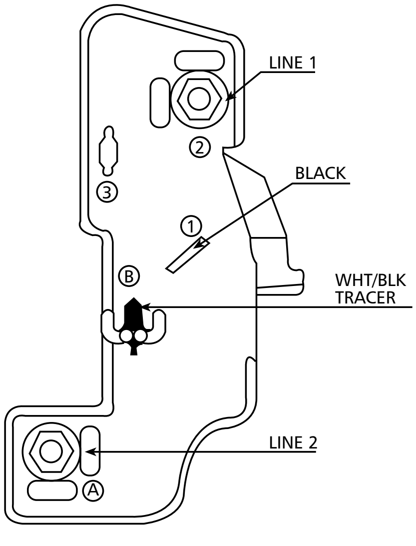
2 – has 2 male connectors and 1 screw connector

B – is a dummy terminal used to hold the Wht./Blk. Tracer for 230V wiring

115 VOLTAGE



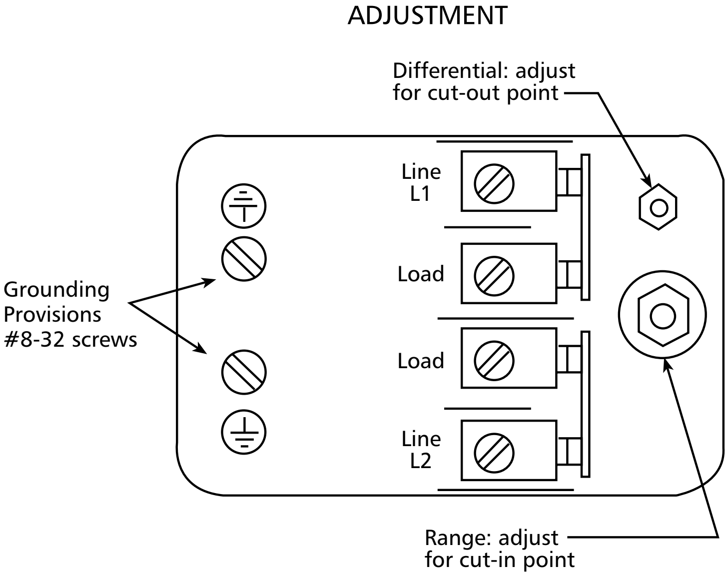
230 VOLTAGE



Motor is non-reversible CCW rotation shaft end.
Supply connections, use wires sized on the basis of 60ºC ampacity and rated minimum 90ºC.

Pressure Switch Wiring and Adjustments

CENTRIPRO AND SQUARE "D" SWITCHES

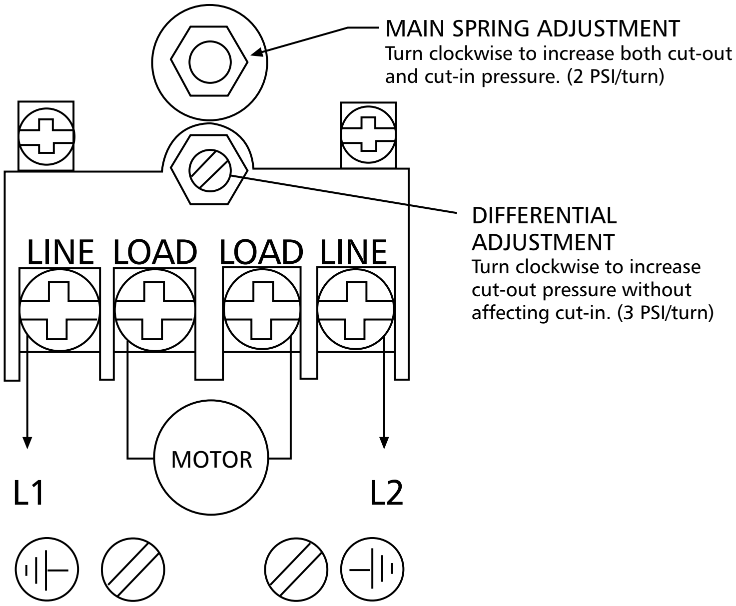


Adjust in proper sequence:

1. CUT-IN: Turn nut down for higher cut-in pressure, or up for lower cut-in.
2. CUT-OUT: Turn nut down for higher cut-out pressure, or up for lower cut-out.

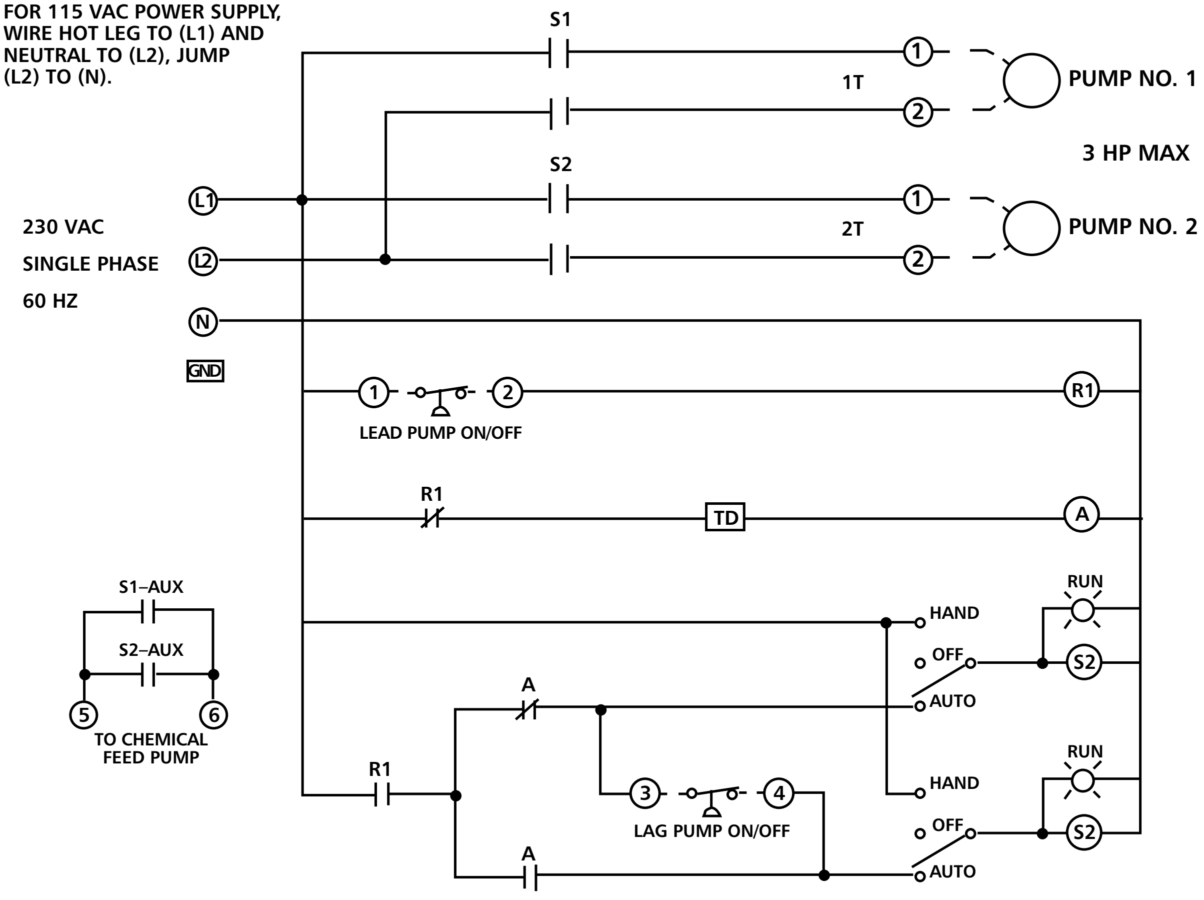
CAUTION: TO AVOID DAMAGE, DO NOT EXCEED THE MAXIMUM ALLOWABLE SYSTEM PRESSURE. CHECK SWITCH OPERATION AFTER RESETTING.

HUBBELL (FURNAS) PRO CONTROL SWITCH



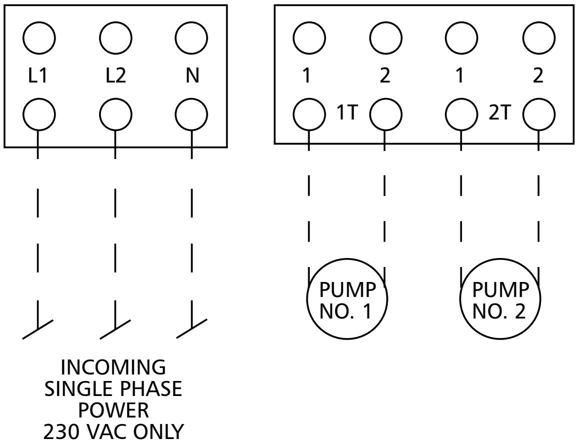
Wiring Diagrams AWA501/AWA502

FACTORY WIRED FOR 230 VAC.
FOR 115 VAC POWER SUPPLY,
WIRE HOT LEG TO (L1) AND
NEUTRAL TO (L2), JUMP
(L2) TO (N).

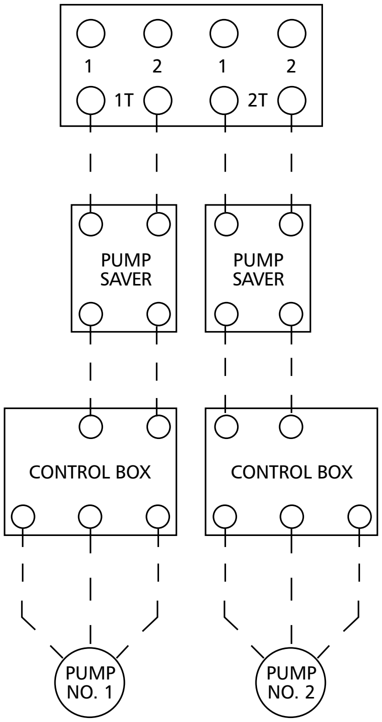


Wiring Diagrams Power/Pump Connections: AWA501/AWA502

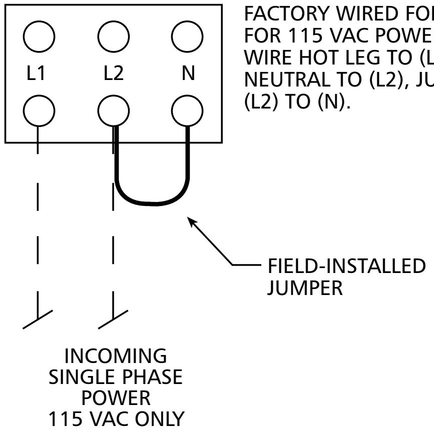
POWER CONNECTION 230 VOLT AWA501, AWA502



OPTIONAL CENTRIPRO CONTROL BOX AND PUMPSAVER WITH AWA501 AND AWA502 ONLY

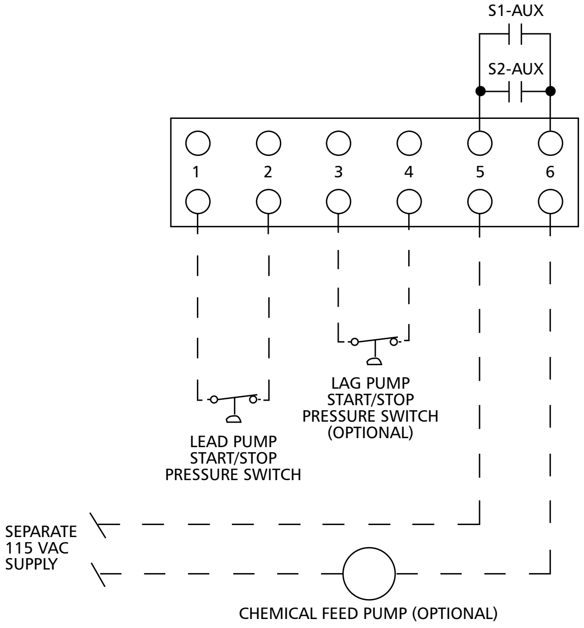


POWER CONNECTION AWA501 115 VOLT



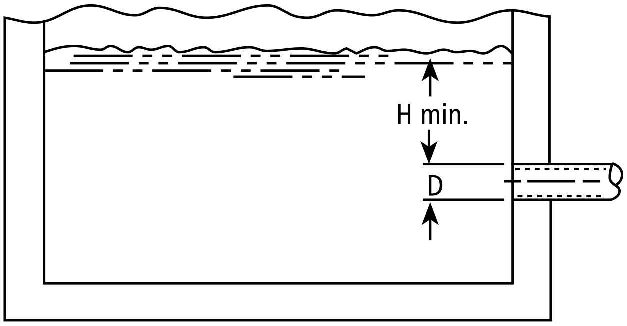
FACTORY WIRED FOR 230 VAC. FOR 115 VAC POWER SUPPLY, WIRE HOT LEG TO (L1) AND NEUTRAL TO (L2), JUMP (L2) TO (N).

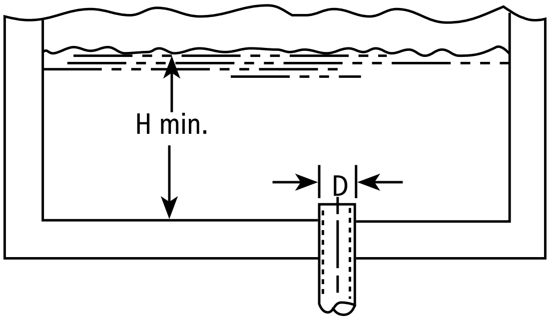
FIELD CONNECTIONS: AWA501, AWA502

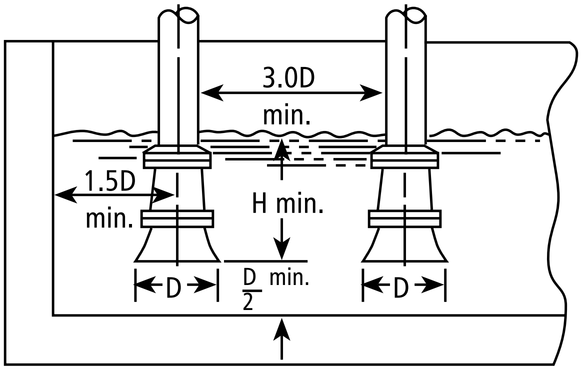


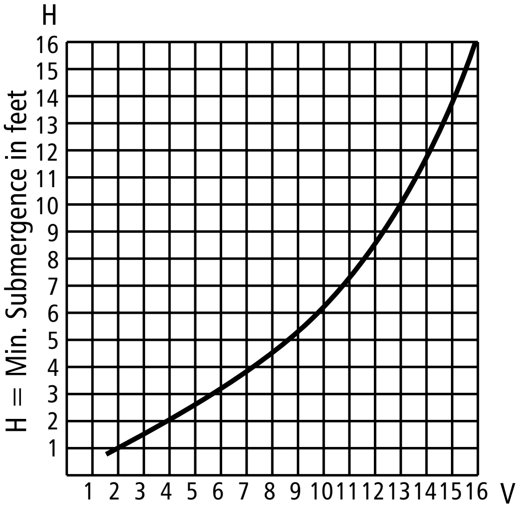
To Prevent a Suction Vortex

- Insure that the size and minimum liquid submergence, over the suction inlet, is sufficient to prevent air from entering suction through a suction vortex. See typical intake piping arrangement in following diagrams.









V = Velocity in feet per second = $\frac{\text{Quan. (GPM) x 0.321}}{\text{Area (inches)}^2}$ or $\frac{\text{GPM x 0.4085}}{D^2}$

Operation and Maintenance Submersible Pump Check Valves

OPERATION

Check valves are designed to give years of trouble free operation without maintenance when properly installed and in a properly selected pumping application with regards to flow and maximum system pressures.

CONSTRUCTION

Check valve bodies have been constructed to handle the rated system flow and pressures as stated and in addition support the weight of the submersible pump, pipe and the water in the riser pipe. In addition the valves have been uniquely designed to absorb some of the hydraulic water shocks associated with well water pumping when the check valve installation instruction are followed below.

IMPORTANT INSTALLATION INSTRUCTIONS

If the installation instructions are not followed warranty or any warranty claims may be void.

NOTE: On initial system start-up gradual priming of vertical water column is recommended to avoid valve damage due to water shock.

It is very important to install a check valve properly to help insure a trouble free water system. If the installation instructions are not followed warranty or any warranty claims may be void. On the back of this page is a diagram of a typical submersible valve installation (Fig. 1).

A. **Pipe flow:** When selecting a submersible check valve insure that the valve is sized properly to flows normally not to exceed 10 feet per second. Higher flow velocities will increase friction losses, hydraulic shocks and the possibility of destructive water hammer (explained below in more detail) leading to severe system failure.

B. **System pressure:** It is important to take the total system hydraulics into the calculation and not only the pump's well setting when selecting valve type and model. In general, valves are pressure rated 400 psi or 920 feet of water pressure. This does not mean that a valve can be set at a well depth of 920 feet. To elevate and reduce the hydraulic shocks in the riser pipe it is recommended that a check valve be installed every 200 feet in the riser pipe. See Recommend Check Valve Installation chart below.

C. **Prior to installing check valve:** Make sure that the check valve is free from defects and that the valve's spring-loaded poppet mechanism is operating freely. Remove any foreign material (IE. PIPE DOPE) from valve seat.

D. Install check valve vertically with arrow pointed up in direction of liquid flow.

E. In submersible pump applications, the first check valve should be installed directly on the discharge head of the pump or maximum one pipe length (20 feet) above pump.

F. If the pump has a built-in check valve, the second check valve should be installed no more than 25 feet above the lowest pumping level in the well.

Submersible pump setting in well	Recommended Check Valve Installation
200 feet or less	One check valve on pump discharge and one on
200 feet to 600 feet	One check valve on pump discharge and additional check valves installed at maximum 200 ft intervals and one at the surface of well.
600 feet to 800 feet For deeper settings contact factory	One check valve on pump discharge and additional check valves installed at maximum 200 ft intervals and one at the surface of well.

Operation and Maintenance Submersible Pump Check Valves

WATER HAMMER

Water pumped and flowing through a piping system has a certain amount of energy (weight x velocity). If the pumping is stopped, the water continues to move and its remaining energy must be absorbed in some way. This absorption of energy can sometimes create undesirable noise and/or damage. This is called water hammer.

Water hammer can destroy piping systems, valves and related equipment. Water hammer varies in intensity depending on the velocity with which the water is traveling when the pump shuts down. It is very important for the installer to realize water hammer potential, and he must take this into consideration when sizing the system and deciding what material the valves should be made from.

It has been proven that for every foot per second of velocity 54 psi of backpressure is created. This means, in a 1" pipe, a flow of only 10 gpm could create a back pressure of 370 psi or more when the pump shuts down and the water column reverses. In a 4" pipe, a flow of 350 gpm could create a backpressure of 860 psi. This does not take in consideration the weight of the water column in the well. Check valves are designed to help lessen the sometimes-damaging effects of water hammer on piping and related equipment.

Check valve installation instructions provided courtesy of Danfoss Flomatic Corp.

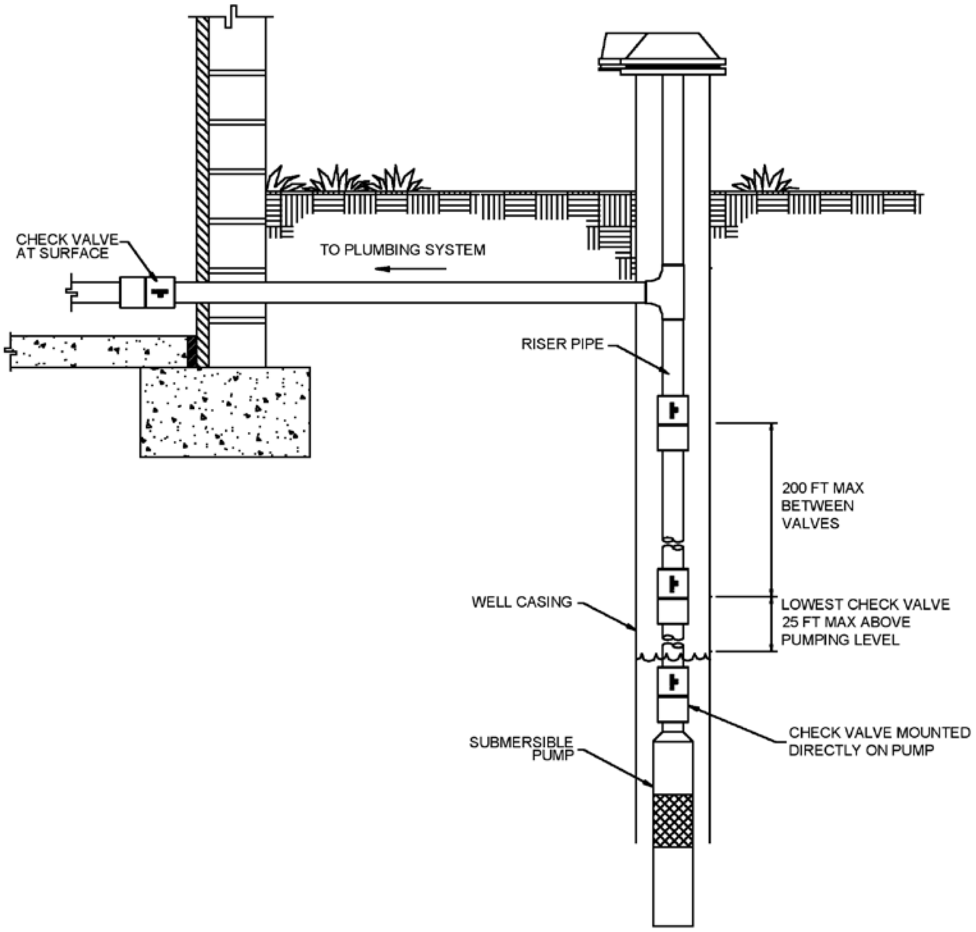


Figure 1

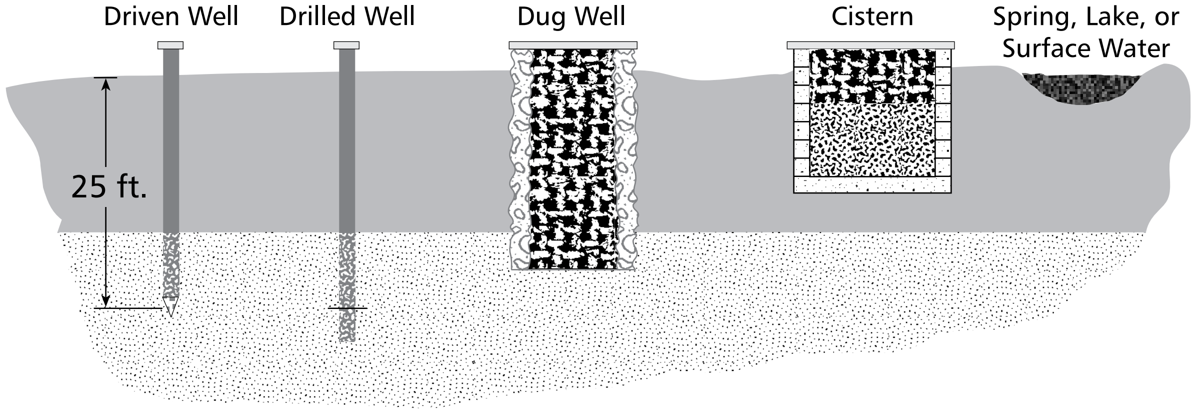
Sources of Water

A source of water or a well is often referred to as shallow or deep. These terms are referring to the depth of the water source or well.

A shallow well is one where the water is within 25 feet of the ground surface.

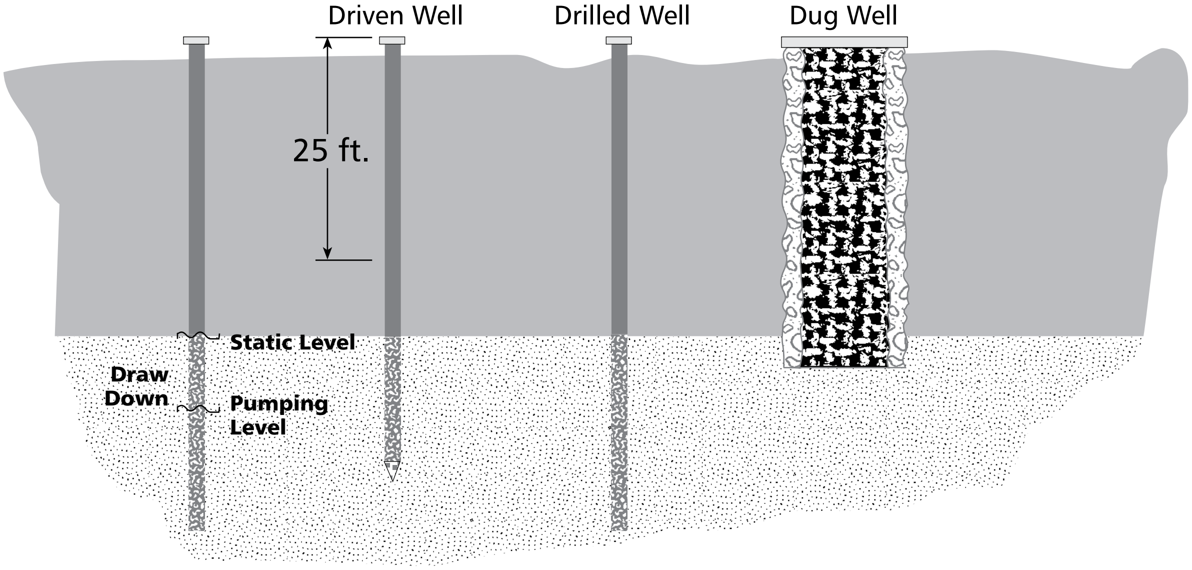
A deep well is where the static water level is more than 25 feet down.

The standing water level in a well is called the static level. This is the water level when the pump is not operating. When the pump comes on and is running there often is a change in the water level. This is referred to as drawdown. The drawdown occurs and the water level reaches what is referred to as the pumping level. This is the operating level of the pump. The lowest level to which the water will drop is the level from which it must be pumped.



A SHALLOW WELL

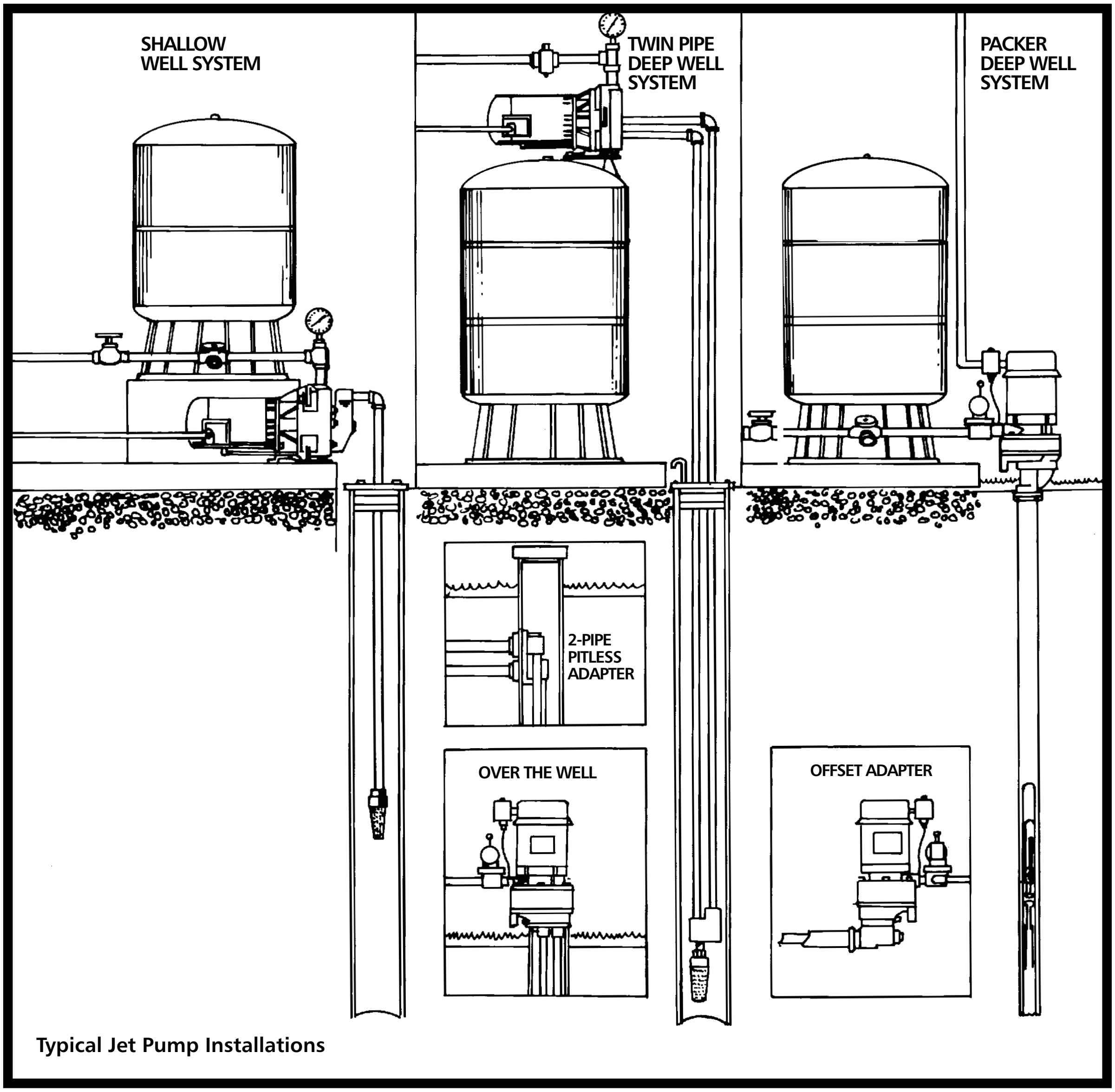
Is any source of water where the water is within 25 feet of ground level. When water is pumped from a well the water level will draw down. The lowest level to which it will drop is the level from which it must be pumped.



A DEEP WELL

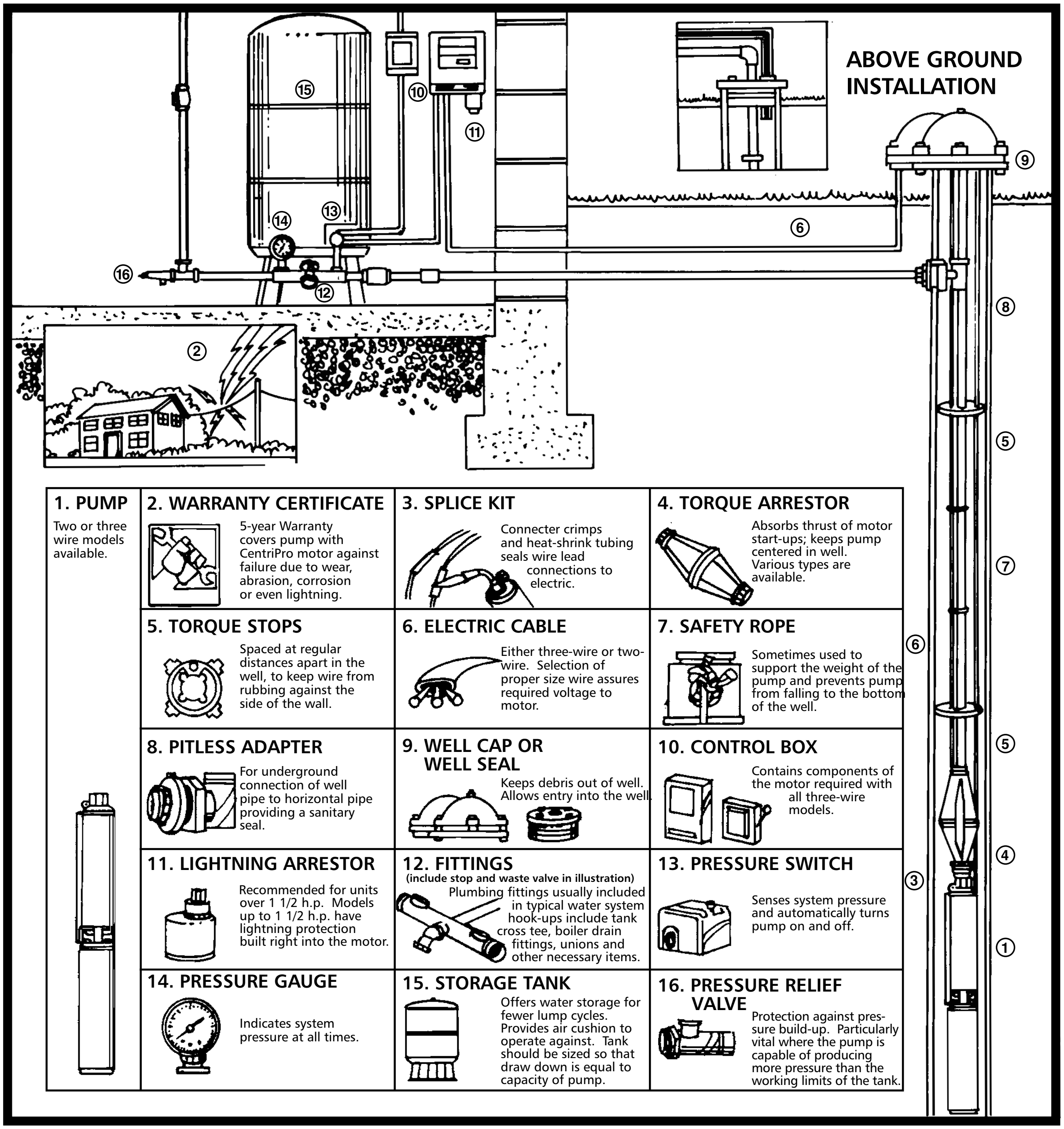
Is any source of water where the low water level is more than 25 feet below the ground level.

Jet Pumps Typical Installations



Typical Jet Pump Installations

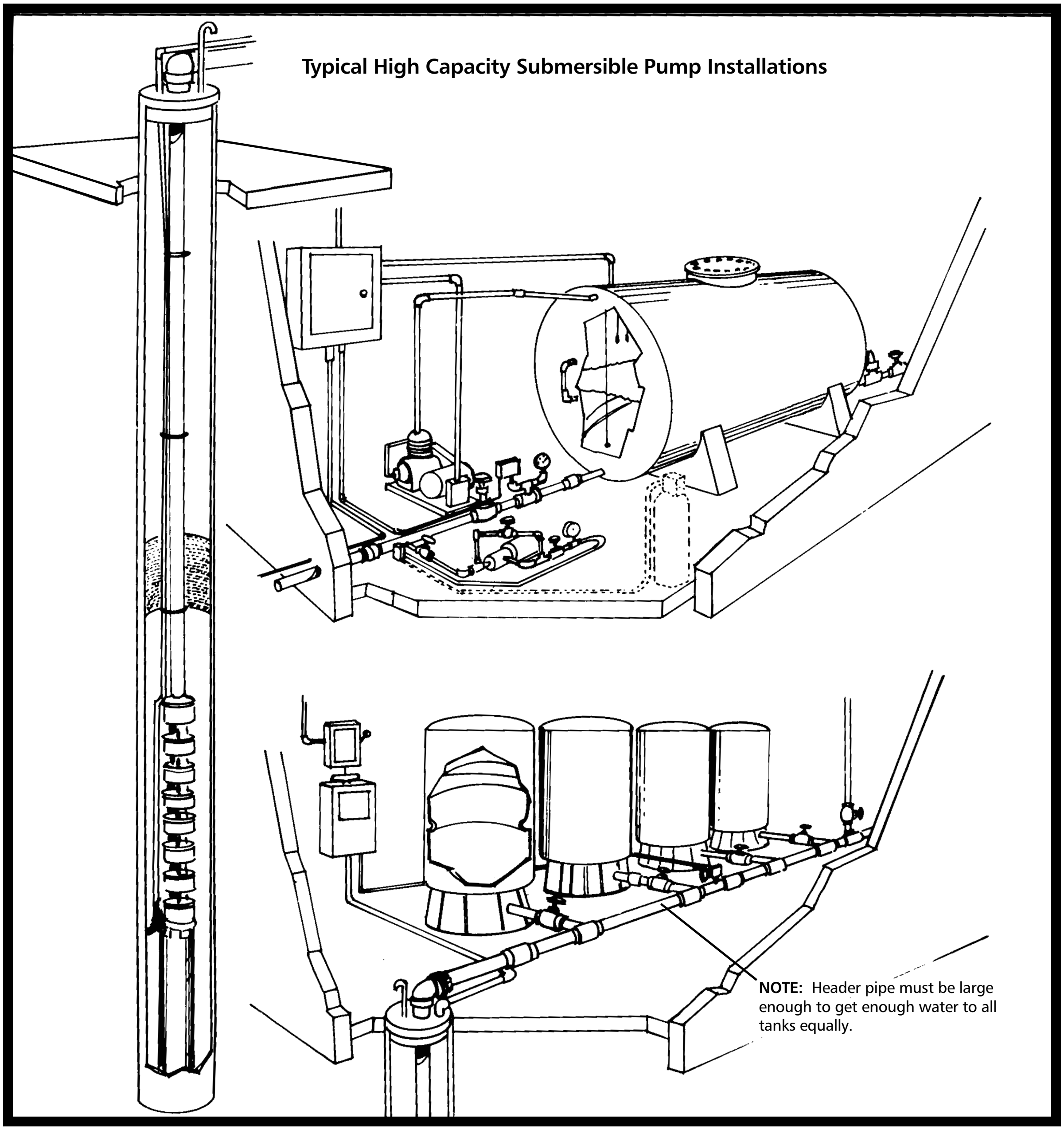
4" Submersibles Typical Installations



1. PUMP Two or three wire models available.	**2. WARRANTY CERTIFICATE** 5-year Warranty covers pump with CentriPro motor against failure due to wear, abrasion, corrosion or even lightning.	**3. SPLICE KIT** Connecter crimps and heat-shrink tubing seals wire lead connections to electric.	**4. TORQUE ARRESTOR** Absorbs thrust of motor start-ups; keeps pump centered in well. Various types are available.
	5. TORQUE STOPS Spaced at regular distances apart in the well, to keep wire from rubbing against the side of the wall.	**6. ELECTRIC CABLE** Either three-wire or two-wire. Selection of proper size wire assures required voltage to motor.	**7. SAFETY ROPE** Sometimes used to support the weight of the pump and prevents pump from falling to the bottom of the well.
	8. PITLESS ADAPTER For underground connection of well pipe to horizontal pipe providing a sanitary seal.	**9. WELL CAP OR WELL SEAL** Keeps debris out of well. Allows entry into the well.	**10. CONTROL BOX** Contains components of the motor required with all three-wire models.
	11. LIGHTNING ARRESTOR Recommended for units over 1 1/2 h.p. Models up to 1 1/2 h.p. have lightning protection built right into the motor.	**12. FITTINGS** **(include stop and waste valve in illustration)** Plumbing fittings usually included in typical water system hook-ups include tank cross tee, boiler drain fittings, unions and other necessary items.	**13. PRESSURE SWITCH** Senses system pressure and automatically turns pump on and off.
	14. PRESSURE GAUGE Indicates system pressure at all times.	**15. STORAGE TANK** Offers water storage for fewer lump cycles. Provides air cushion to operate against. Tank should be sized so that draw down is equal to capacity of pump.	**16. PRESSURE RELIEF VALVE** Protection against pressure build-up. Particularly vital where the pump is capable of producing more pressure than the working limits of the tank.

High Capacity Submersible Pumps Typical Installations

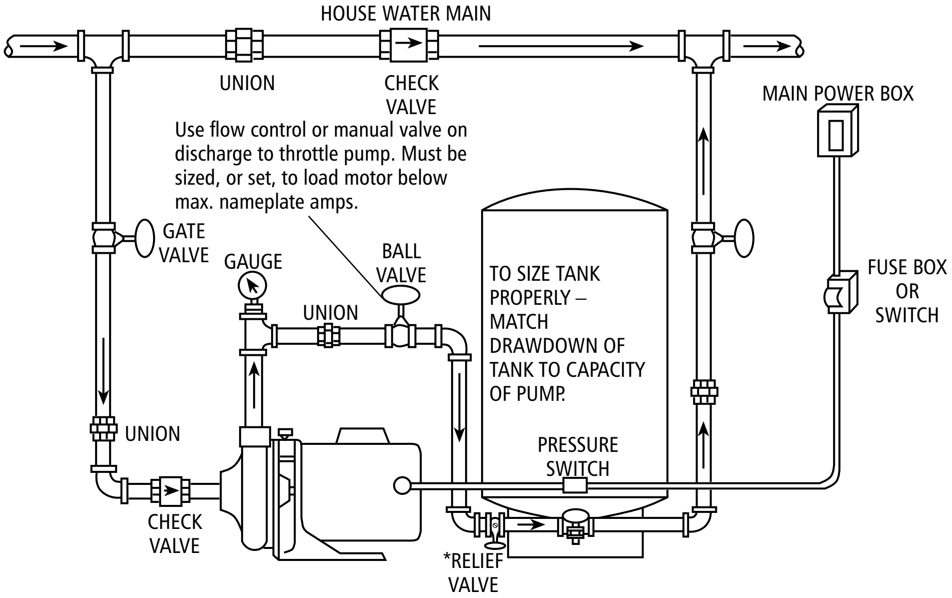
Typical High Capacity Submersible Pump Installations



NOTE: Header pipe must be large enough to get enough water to all tanks equally.

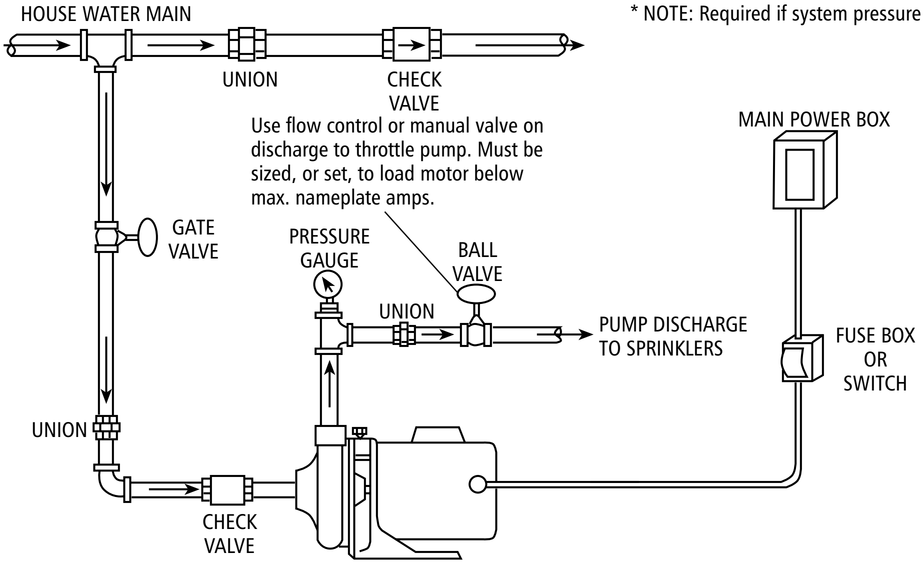
Centrifugal Booster Pump Installations

AUTOMATIC OPERATION



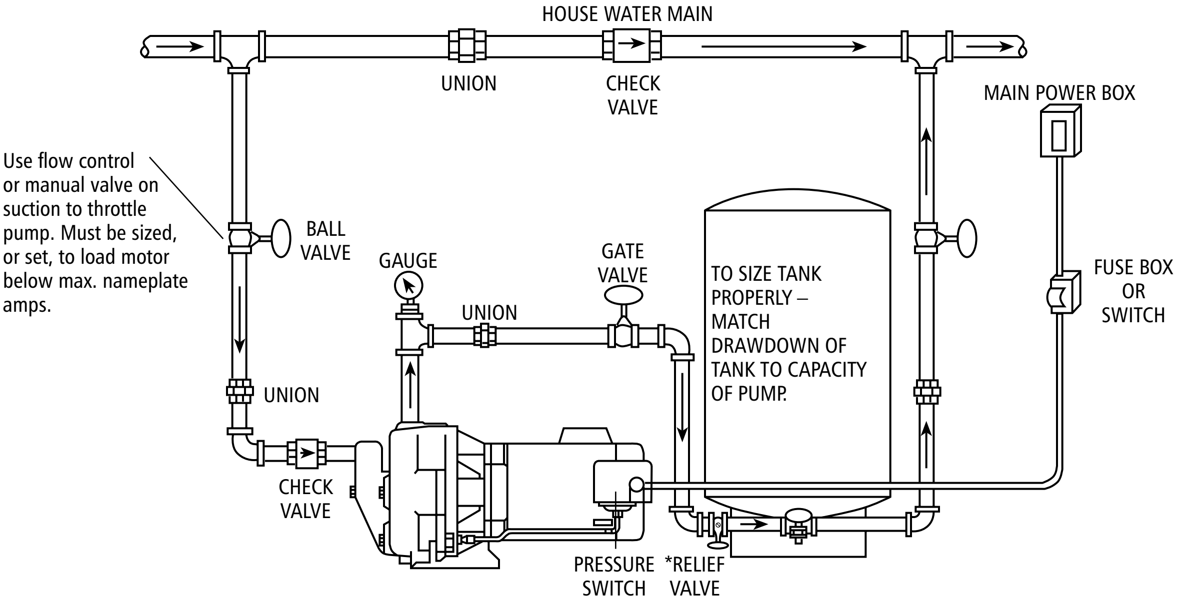
* NOTE: Required if system pressure can exceed 100 PSI.

MANUAL OPERATION



Jet Booster Pump Installations

AUTOMATIC OPERATION
JET PUMP - SHALLOW WELL OR CONVERTIBLE WITH INJECTOR



* NOTE: Required if system pressure can exceed 100 PSI.

SIZING THE BOOSTER PUMP

Booster system pumps are sized the same as shallow well jet pumps with the exception being, we add the incoming city pressure to what the pump provides. The required flow is determined by the number of bathrooms or number of fixtures being used at any given time. City water is supplied under pressure, low incoming pressure is caused by undersized, crushed or severely corroded pipes or large elevation differences, such as a hill, between the city water line and the house.

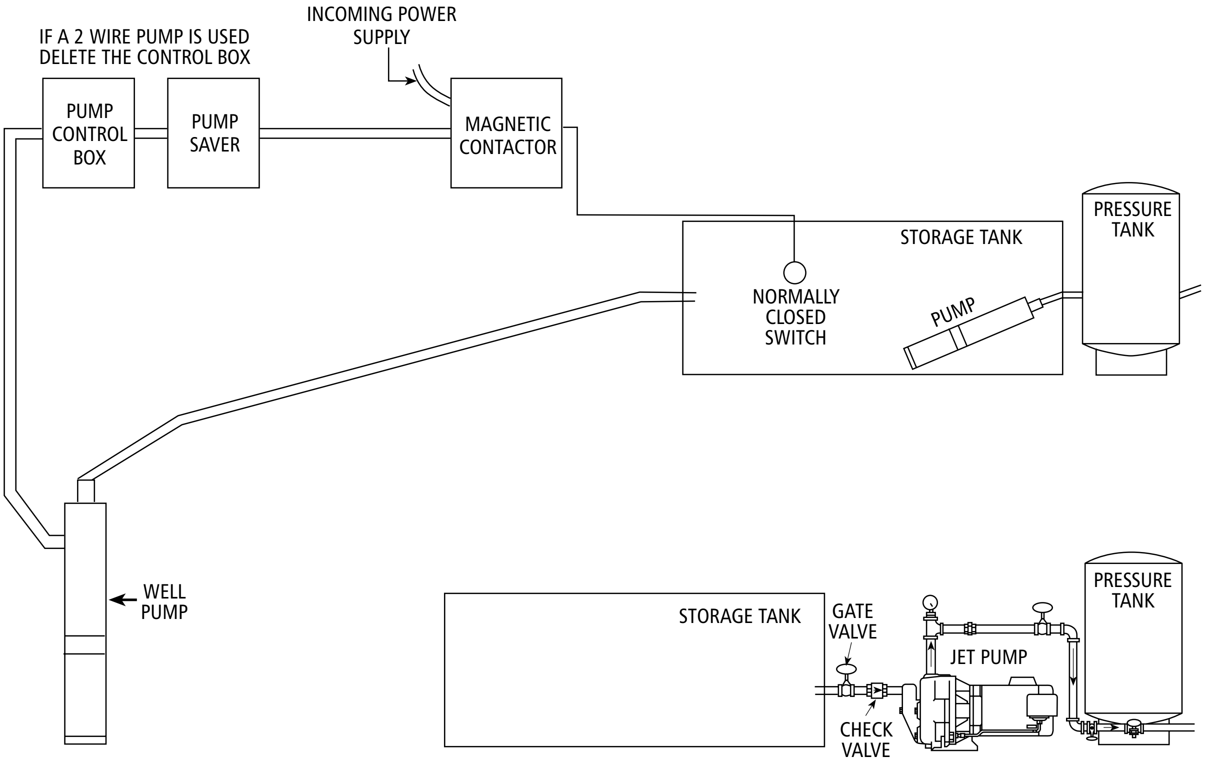
Verify the incoming pressure with the water flowing to find the “dynamic suction pressure”, static pressure is what you see with no water flowing. Use the dynamic suction pressure to calculate pump performance and selection. The J5S and the high pressure version, J5SH are very popular as booster pumps. The J5SH is a good choice for booster applications because of its narrow flow range and higher pressure capability. In the absence of performance data for 0’ we use the 5’ Total Suction Lift performance data. Add the incoming dynamic pressure to the pump’s discharge pressure to find the total discharge pressure. Make a chart showing the flow, incoming dynamic pressure, pump discharge pressure and total discharge pressure for each job. It would look like this if using a J5SH pump with 15 PSI of incoming dynamic pressure:

Flow Rate GPM	Pump Discharge Pressure (PSI)	Incoming Dynamic Pressure (PSI)	Total Discharge Pressure (PSI)
11.5	20	15	35
11.3	30	15	45
11	40	15	55
7.7	50	15	65
4.8	60	15	75
0	83	15	98

Low Yield Well Components

COMPONENTS FOR A LOW YIELD WELL WITH A BOOSTER SYSTEM

- Submersible or jet pump to fill atmospheric tank
- Storage tank - usually at least a 500 gallon size
- Magnetic contactor - makes wiring simple and fast
- Normally closed float switch for automatic operation
- Booster pump - sub or jet to pressurize water from storage tank
- Pressure tank sized for 1 minute minimum pump cycle
- Pressure switch
- Check valve and gate valve between the open storage tank and jet pump, or a gate valve between the submersible and pressure tank



Types of Pumps – Jet Systems

The first question with Jet Pumps is what is the suction chamber and how is the vacuum created.

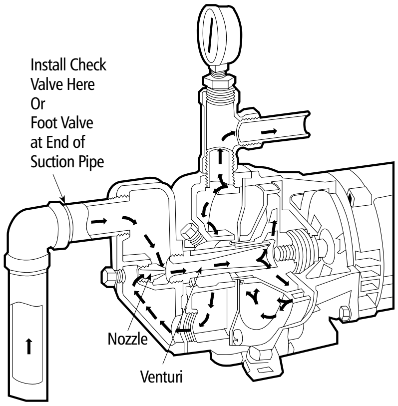
The Jet Assembly itself forms the suction chamber and the vacuum is created by the very high velocity of a stream of water passing through the jet. Basically, the jet assembly is composed of two parts. First, a nozzle which produces the high velocity stream of water. This high velocity stream of water is injected through a small compartment which is the suction chamber, thereby causing the vacuum. Obviously, the suction pipe is connected to this compartment or suction chamber. The vacuum caused by the jet permits the greater pressure of atmosphere on the surface of a body of water to force water into the suction chamber.

The second basic part of the Jet Assembly is the venturi tube. It is installed in the discharge of the suction chamber. Its function is to convert the velocity of the water into pressure. This is accomplished by the shape of its water passage. Perhaps you can best visualize this by thinking of a nozzle in reverse. The nozzle speeds up the flow of the drive water converting pressure into velocity and when it has passed through the suction chamber, the venturi slows it down again converting the velocity back into pressure.

“Drive water” is that water which is piped under pressure to the jet assembly or suction chamber. The discharge from the suction chamber or jet assembly is composed of both the drive water and that water pumped from the well. The total amount pumped from the well can be used as discharge from the system and is the output or capacity.

SHALLOW WELL JET PUMP

From the foregoing discussion it is obvious that the operation of the Jet system is dependent on the combined functions of both the Jet Assembly or suction chamber and the centrifugal pump. Also, that these two main components of the system are entirely separate and their locations with respect to each other is a matter of design.



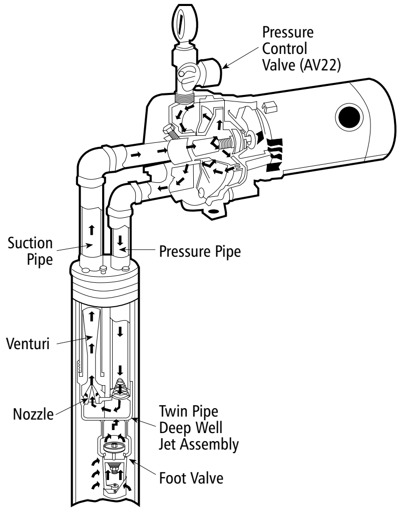
In shallow well jet pumps the jet assembly is built into the pump casing as in the Goulds Pumps J5S. Or, the jet assembly, shallow well adapters, can be bolted to the centrifugal pump. In either case there is only one pipe extending into the well . . . the suction pipe.

DEEP WELL JET PUMP

The only basic or fundamental difference between Shallow Well and Deep Well Jet Pumps is the location of the Jet Assembly. It must always be located in such a position that the total suction lift between it and the pumping level of the water to be pumped does not exceed that which can be overcome by the pressure of atmosphere. This, of course, means that when this pumping level is at a distance lower than the ground level which cannot be overcome by atmospheric pressure, the Jet Assembly must be located at least five feet below the low water in the well.

We must have a closed compartment in which to install the nozzle and the venturi and to form the suction chamber. This part is called the jet body. Its shape is such that it will fit into the casing of a drilled well and the pipe connections are located for accessibility. There are two on the top side, one for connection to the pressure pipe which supplies the drive water, the other for connection to the suction pipe which returns both the drive water and the water pumped from the well. For this reason, this connection is one pipe size larger than that for the pressure pipe. Water from the well enters through a third opening which is on the bottom side of the jet body.

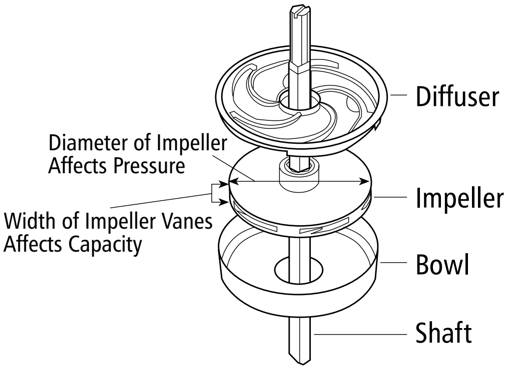
The last accessory for the Jet System is the pressure control valve. It is a valve installed in the discharge piping from the centrifugal pump between the pump and the tank; in the pump when the pump is mounted on a tank. Used only in deep well systems, its purpose it to assure a minimum operating pressure for the jet.



SUBMERSIBLE PUMP

Submersible pumps are so named because the whole unit, pump and motor is designed to be operated under water. This means the pump does not have to be primed. Once installed and turned on, water flows up the pipe.

The pump end is a multistage (many impellers) centrifugal pump, close coupled to a submersible electric motor. All of the impellers of the multistage submersible rotate in the same direction by a single shaft. Each impeller sits in a bowl and the flow from the impeller is directed to the next impeller through a diffuser. These three parts (bowl, impeller and diffuser) are known as a stage.



The capacity of a multistage centrifugal pump (submersible) is largely determined by the width of the impeller and diffuser, regardless of the number of stages. The pressure is determined by the diameter of the impeller, the speed at which it rotates and the number of impellers. The diameter is limited to the size of wells drilled. Most submersibles are designed to fit in four or six inch wells (or larger).

A ½ HP pump with seven impellers (designed for capacity) would deliver more water at 80' than a ½ HP pump with 15 impellers (designed for pressure) but the latter pump would be able to raise water from a greater depth.

Well water enters the unit through screened openings at the middle of the unit between the pump and motor. There is only one pipe connection which is at the top of the pump. This is the discharge pipe. A check valve is located at the top of the unit to prevent water from the system draining back when the pump isn't running.

Submersible pumps are so much more efficient than jet pumps and the installation so much simpler that a submersible pump should be considered first for all pump applications where the physical dimensions of the source of the water will accommodate the unit in a submerged position.

Example: 60 ft. pumping level;
30-50 lbs. Pressure.

½ HP submersible	11 gpm
½ HP jet system	6 gpm

CENTRIFUGAL PUMP

The centrifugal pump does two things. It circulates the drive water at the pressure required to produce the necessary velocity in the Jet. It also boosts the pressure of that water being pumped from the well delivering it through the discharge of the system at a satisfactory service pressure. Since the one return pipe from the jet assembly contains both these quantities of water, this return pipe is connected direct to the suction opening of the centrifugal pump. The action of the centrifugal pump can be thought of as that of a paddlewheel. The impeller is a multi-vane (or blade) wheel and its design is such that its size, shape and speed impart sufficient energy to the water in the system to circulate it at the desired rate.

As the water is discharged from the centrifugal pump, it is divided. The drive water, or that amount required to operate the Jet is piped directly to the Jet through the pressure pipe. It is continuously recirculated so long as the centrifugal pump is running. That amount pumped from the well is discharged from the centrifugal pump directly into the tank and is the capacity of the system.

Centrifugal Pump Characteristics

- Impeller attached to a Motor/Driver
- Impeller draws the HP off the Motor/Driver
- Flexible machine; capable of a range of performances at good efficiencies
- Will overload motor (pumps max. capacity)
- Limited Suction Lift capability (15-25')
- Impeller makes own pressure (PSI)
- Adds its pressure to any incoming pressure
- Poor air-handling capability (Cavitation, loss of suction/prime, and air-binding)

Accessories

When applying a pump to any specific problem pertaining to domestic water supply, our objective in practically every case should be to provide automatic running water under pressure – a water service comparable to that which might be expected from connection to a city water main. But, a pump alone can hardly perform the several necessary functions. Certain other accessories are necessary, and the combination of them all forms what we call a water system.

MOTORS

The first accessory is the drive medium which on practically all water systems of today is an electric motor. You should remember that some of our pumps, in particular the jet pumps in large motor sizes and submersible pumps, are furnished with motors of current characteristics as specified. Therefore, when ordering these, we must be advised the electrical characteristics.

PRESSURE SWITCH

The next accessory required is a pressure switch to start and stop the motor automatically at a predetermined pressure. A tube connects the switch to some point in the system on the discharge side of the pump. The pressure in the system then acts directly on a diaphragm in the switch which in turn actuates the contacts in the switch.

PRESSURE TANKS

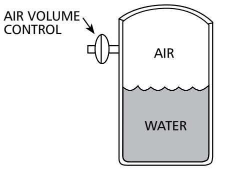
The rate at which water can be used in a home, school, motel, or any other place can be as little as one gallon a minute (60 gallons per hour) (brushing teeth or rinsing hands). Or the maximum can be hundreds or thousands of gallons per hour depending on the number of water using fixtures and, or appliances in use at the same time.

A pump capable of delivering a capacity equal to the maximum demand cannot necessarily be throttled to the minimum demand.

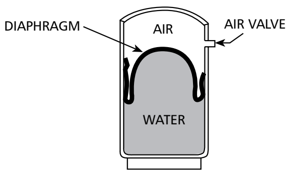
The main purposes of a pressure tank are to pressurize the system to make it operate automatically and to properly cycle the pump to properly cool the motor. This prevents excessive short cycling (too rapid starting and stopping). The pump capacity and size motor should always be considered. The larger a motor is in horsepower the more starting power required; therefore, the less frequently it should be started.

It is good practice to size the tank to require the pump to run at least one minute per cycle when using fractional horsepower motors and two to three minutes for larger motors.

There are two basic types of tanks in use today:



Conventional or Galvanized Type
Requires an air volume control device to keep proper amount of air cushion in the tank.



Sealed Diaphragm Type
Water and air are permanently separated by sealed diaphragm; therefore, the amount of air never changes. The amount of draw-off also never changes.

RELIEF VALVE

As a precaution or protection against the possibility of the switch becoming stuck at some time allowing the pump to continue running after sufficient pressure has been obtained, a relief valve is necessary with all systems capable of developing pressures in excess of the working limits of the tank. A relief valve is a spring controlled valve located somewhere close to or in the pump on the discharge side, or on the tank. The tension of the spring is so adjusted that it will permit the valve to open and allow the water to escape if the pressure in the system exceeds by more than about 10 lbs. That at which the pressure switch is set to cut off the current to the motor.

FOOT VALVE

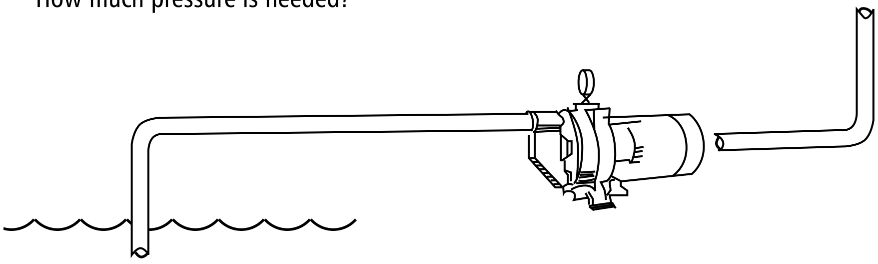
A foot valve is a combination check valve and strainer.

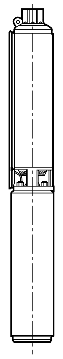
The 3 Basic Questions

1 Capacity Needed
How big must the pump be?

2 Well Conditions
Is a shallow or deep well pump needed?

3 Discharge Conditions
How much pressure is needed?





The illustration above poses a typical water system problem. The source of water is in nearly all cases lower than the house or building. This is why a pump is needed – to raise the water up to the faucets and fixtures. These are the three questions to be considered:

1 Capacity Needed
How much water in gallons per hour or gallons per minute are needed? This determines what size pump to use.

2 Well Conditions
What is the total suction lift? What is meant by “total suction”? We learn from this what to expect from a shallow well pump and when and why to use a deep well pump.

3 Discharge Conditions
How much pressure is needed at the pump? How much pressure will result at the faucet?

Whenever and wherever a pump is to be used, the correct answers to these three questions will tell the actual pumping conditions or specifically – what is required of the pump. With this information, you can always select the right pump from the catalog.

1 *Capacity Needed*

How much water is available? How much water is needed? How large must the pump be?

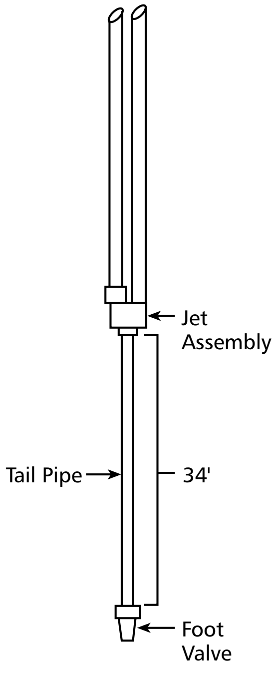
LIMITING FACTORS

How much water is available? Before we select a pump based on need we must determine if the supply is adequate. Many areas have what we refer to as low yield wells, Well recovery rates may be as low as 1 GPM or less.

A typical low yield (1 – 2 GPM) well, cannot supply the 10-12 GPM required by an average home. If we pump at 12 GPM and the water enters the well at 2 GPM we will soon run the pump dry. This system would require a pump protection device to turn the pump off when it runs out of water.

Fortunately some low yield wells have a great deal of water stored in the well due to high static water levels. There are 500' deep wells with static water levels, when not being pumped, of 20'. A 4" well casing stores approximately .652 gallons per foot or 1.4 gallons per foot in a 6" well. In this case, a 4" well stores 312 gallons and a 6" stores 672 gallons. It is possible to use a 7 or 10 GPM pump and not over pump the well due to the large amount of water stored in the casing. While lawn watering and daily multiple loads of laundry are out of the question, this application could provide a cost effective, reliable water supply without the use of large expensive storage tanks and booster pumps. The customer should be made aware of the limitations of the well and the options available.

If using a deep well jet pump in a low yield well you should use a 34' tail pipe on the bottom of the jet assembly. This will prevent over pumping a deep well. See the section on Using Tail Pipes in the Technical Manual of your catalog.



Another weak well scenario is to select a submersible pump sized for a maximum pumping depth somewhat less than the actual depth at which the pump will be installed. It will then be impossible for the pump to over pump the well and run dry. Another option is to install a low water level cut off system with electrodes to turn the pump off at a predetermined level. It can be set up to automatically reset when the water level rises. Unlike totally electronic protection devices the electrodes must be installed in the well.

If the source of supply is a deep cased well, the casing diameter and depth to water are limiting factors in how much water can be pumped. A 2" casing cannot accommodate a submersible pump. A 2" diameter limits you to a deep well jet pump with a packer or single pipe system. A 2" packer system can supply approximately 3.3 GPM from a 200' water level at 30 PSI. However, a submersible pump in a 4" diameter, 200' deep well can easily supply over 60 GPM at 60 PSI. Therefore, we can see that small diameter wells limit the available flow that can be supplied. Small diameter, deep wells equal low capacity pumps. They also dictate the pump style that can be used.

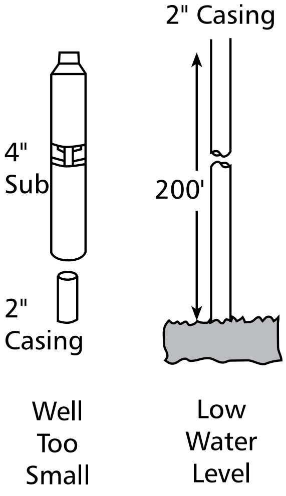
Example:

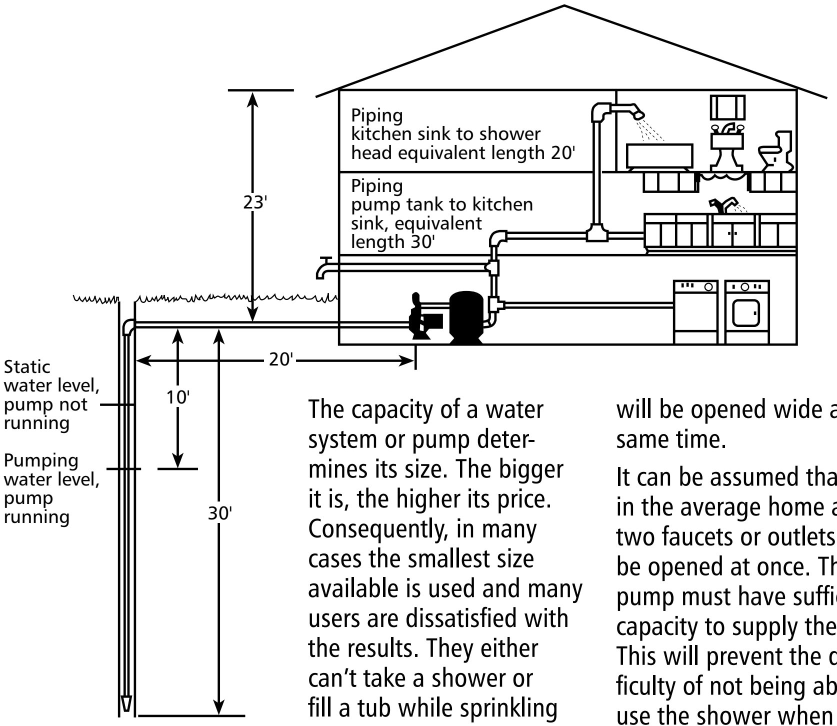
Customer has a 2" well casing with a 100' pumping level. What is the correct pump and what will it produce?

The maximum pump capacity is about 9 GPM using a 2" packer assembly with a 2 HP, 2 stage jet pump.

In cases where we have no limiting factors, where we have all the water required and a well that will accommodate a reasonably sized pump. We can proceed to determine the correct capacity needed to satisfy the customers requirements.

Physical Restrictions





DEMAND

The capacity required of the pump is determined by the number of continuously flowing demands (showers, sprinkling, filling a tub or stock trough, etc.) which are likely to be in use at the same time with consideration given to a minimum rate of flow from each of these outlets which can be considered as satisfactory.

APPROXIMATE WATER SUPPLY REQUIREMENTS

Home Fixtures

Filling Ordinary Lavatory – 2 gal.
Filling avg. Bath Tub – 30 gal.
Flushing Water Closet – 6 gal.
Each Shower Bath – Up to 60 gal.
Dishwashing Machine –
  15 gal./load
Automatic Laundry Machine –
  Up to 50 gal./load
Backwashing Domestic Water Softener – Up to 100 gal.

Yard Fixtures

½" Hose with Nozzle – 3 gpm
¾" Hose with Nozzle – 5 gpm
Lawn Sprinkler – 2 gpm

The capacity of a water system or pump determines its size. The bigger it is, the higher its price. Consequently, in many cases the smallest size available is used and many users are dissatisfied with the results. They either can’t take a shower or fill a tub while sprinkling the lawn, or if a toilet is flushed when taking a shower, the shower diminishes to a dribble, or some similar interruption occurs. The trouble of course is that the too small pump can’t deliver water fast enough to supply the demand – its capacity is too little.

Determining how much capacity is required is not an exact science. The objective is to provide a water service similar to that available from a good city water system. This provides practically an unlimited rate of flow from any or all the faucets or other outlets either one at a time or all used at the same time. A home water system can provide this type service but there are few domestic well that will furnish such a quantity and it isn’t at all likely that all the faucets in a home will be opened wide at the same time.

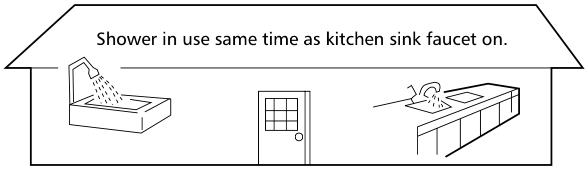
It can be assumed that in the average home any two faucets or outlets may be opened at once. The pump must have sufficient capacity to supply them. This will prevent the difficulty of not being able to use the shower when the kitchen sink is in use, and vice versa.

The rate of flow from a faucet or fixture depends on its type and size, the length and size of pipe supplying it and the difference in elevation between it and the pump or tank. Furthermore, it is impossible to determine by sight the exact rate of flow being delivered from a faucet.

It has been determined by test and by observation that the smallest or minimum rate of flow from a faucet should be about three gallons per minute (3 GPM). Any less than this approaches what appears to be a dribble; somewhat more is much more satisfactory. According to this, if a pump or water system in a home is to supply two faucets or outlets such as a shower and a kitchen sink at the same time, its capacity should be two times three or six gallons per minute (360 gallons per hour).

This of course is not always practical. The capacity of pumps changes with pumping conditions such as pumping level of the water and the operating pressure. Accordingly, it is good practice to provide a pump capacity for the average home of from 10 to 12 gpm when available.

The water from the pump or tank will not necessarily flow to fixtures or faucets at the rates just discussed. This is determined by the resistance to water flow in the house plumbing and is explained in the third step of the procedure – Discharge Conditions. It should, however, be obvious now that in order to use water from more than one outlet at a time, the capacity of the pump should be greater than the rate of flow in GPM available from any one faucet.



2 continuous uses require 6 GPM minimum
The capacity required of the pump is determined by the number of continuous use outlets in use at the same time. You can't use water at one or a number of outlets any faster than the pump supplies it.

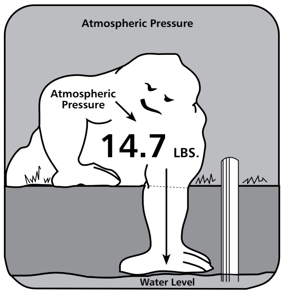
2 *Well Conditions*

The level of the water to be pumped is practically always below ground. It can be only a few feet as in a spring, shallow well, pond, etc., or it can be many feet as in a deep well. If we could always locate the pumping mechanism in the water, as we do with submersible pumps, our problem would be simpler because then the water would flow into the pump. However, standard electric motors and switches are not designed for submerged operation. Therefore they must be located above ground. This poses the question: How does the water get into the pump?

We call it suction, but what is it? What actually makes the water flow uphill into the pump?

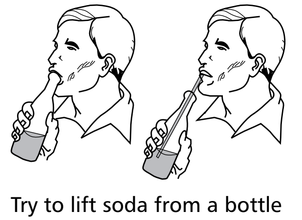
How high can we raise water by suction?

1. The atmosphere all around us has weight and therefore exerts pressure equal to about 14.7 lbs. per square inch at sea level.



When the pressure of atmosphere is removed from inside of a pump the resulting condition is a vacuum or partial vacuum. It is also called suction.

The vacuum or suction chamber of a pump is piped (suction pipe) to a source of water. The surface of the water should be exposed to the pressure of atmosphere. When the pump operates it develops an unbalanced pressure condition due to the suction or vacuum it produces. This unbalanced pressure (14.7 lbs. per sq. in. atmospheric pressure on the surface of the water with vacuum or absence of pressure in the pump) causes water from the source to flow up the suction pipe into the pump. From this we can determine how high water can be raised by suction.



Try to lift soda from a bottle by closing your mouth over the mouth of the bottle. It can't be done. When you use a straw, it is easy – you are creating a partial vacuum in your mouth, exposing the surface liquid to atmospheric pressure, the difference in pressure raises the liquid.

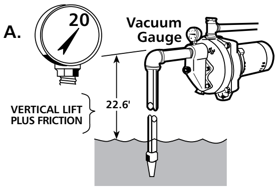
First, let's consider terms of measurement and their relation to each other.

Pressure is usually expressed in pounds per square inch (PSI).

Pressure is used to raise water to a height expressed in feet. This height is also expressed as feet head.

Vacuum is measured with a vacuum gauge. The gauge can be calibrated in feet suction lift or inches vacuum.

A. 1 inch vacuum equals 1.13 feet suction.

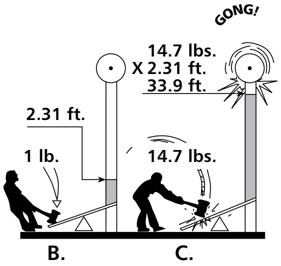


A reading of 20" on a vacuum gauge placed on a suction side of the pump would tell you that you had a vacuum or suction lift of 22.6 ft.

20" x 1.13' = 22.6 ft.

B. 1 pound pressure equals 2.31 feet head.

C. Atmospheric pressure of 14.7 x 2.31 = 33.9ft. head, which is the maximum possible lift at sea level.



NOTE: You lose approximately one foot of suction lift per 1000 ft. of elevation.

Example: Denver, CO is approximately 5000 ft. above sea level. The total suction lift would only be 28.9 ft. not 33.9 ft. like at sea level.

SUMMING THIS UP:
When the atmospheric pressure is 14.7 lbs. per sq. inch a perfect vacuum should be 30 inches and this would lift water by suction to a height of 33.9 ft.

Most shallow well or suction pumps are capable of developing a near perfect vacuum, and at sea level they can lift water about thirty feet. However, suction lifts of more than 25 ft. at sea level are not recommended. Shallow well jet pumps deliver inadequate capacity on lifts over 25 ft.

Suction conditions, or total suction lift must include all resistances to the flow of the water through the suction pipe up to the pump. Height or vertical lift is one resistance. Friction between the water and the pipe walls is the other resistance.

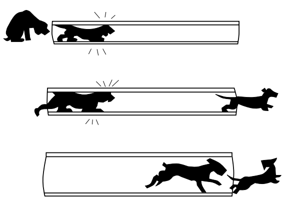
FRICTION LOSS
When water flows through pipe, the inner wall of the pipe resists the flow of the water. This resistance is called pipe friction. Pipe friction means extra work for the pump or system and presents a total loss. Therefore, it is desirable to keep friction loss as low as is practicable in order to waste the least possible amount of work. Keep in mind that all work being done on the suction side of the pump is actually performed by the pressure of atmosphere. Since in common practice we consider this pressure is sufficient to overcome only 25 ft., the 25 ft. must always include any losses due to friction.

We don’t have to be too concerned with how or why friction loss is incurred, but it is essential that we accept it as occurring always when water flows through pipes. It is, also, most essential that we understand how it is measured.

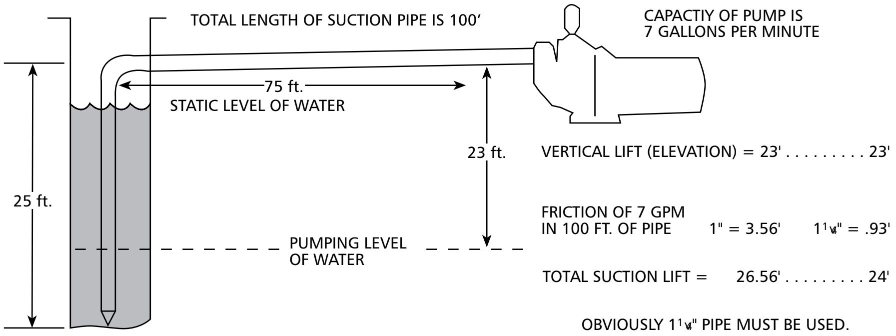
In our discussion of suction lift, atmospheric pressure and the height this pressure will raise water, we established the fact that 14.7 lb. pressure will raise water to a height of 33.9 ft. Although there is no relation between atmospheric pressure and friction loss, the relation between pounds pressure and feet elevation or head as we call it, is the same whether the pressure is coming from atmosphere or any other source. So, as stated before, 14.7 lbs. pressure from any source will raise water 33.9 ft. and this gives us the conversion factor to change our terms from pressure to feet or the reverse of this. Therefore, 1 lb. of pressure is always equal to 2.31 ft. (33.9 divided by 14.7 equals 2.31).

Now getting back to friction loss, the amount of this loss increases as the quantity of water flowing through a given size pipe is increased. There are formulas to determine the amount of flow and any pipe size. But we don’t have to be concerned with this, since it has all been carefully calculated and set up in the friction loss table as shown below.

Example: The example at the top of the page shows that using the correct size pipe will reduce friction loss. On some jobs, a smaller pump with larger pipe will do the same work (flow) as a larger pump with smaller pipe. Larger pipe is not much more expensive but larger pumps are. Larger pumps also use more energy. Using the correct pipe size saves money in the long run. Calculating friction loss is especially important if you are not sure of the well drawdown. It is a very good rule of thumb to always use a suction pipe that is the same size or larger than the pump suction.



Friction Loss Increases
when Capacity Increases
or Pipe Length Increases



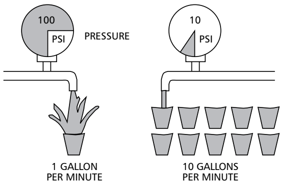
3 *Discharge Conditions*

What are the conditions under which the water system must discharge its capacity?

The capacity of the pump has already been established so we are now concerned only with the pressure required of the system.

It seems that the pressure and its use in a domestic water system are generally misunderstood, so perhaps some explanation is in order. Quite often it is stated that a particular pump is delivering sufficient capacity but fails to develop adequate pressure. In most cases this is a misstatement and the opposite condition is true. This complaint is generally made when a particular system fails to provide sufficient flow through several outlets at the same time. This is caused in most cases by the demand in rate of flow being greater than the capacity of the system. If the system has sufficient capacity to supply the maximum number of outlets which are likely to be used at the same time, our only concern with pressure is that we have sufficient pressure to overcome the resistance to flow which will be encountered. If you have any doubts about this, consider your answer to this question:

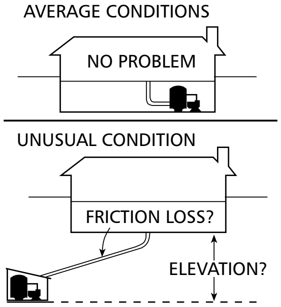
Would you rather have at a faucet one gallon per minute at a hundred pounds pressure or ten gallons per minute at ten pounds pressure? Which will fill a tub quicker?

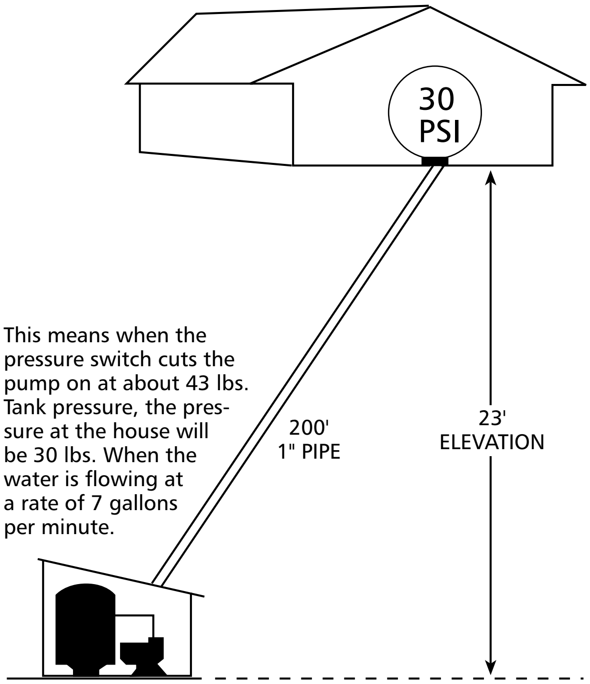


Now as to the resistance to flow which will be encountered, there are three causes. These are (1) the resistance by the outlet itself such as a partially rusted shower head, (2) friction loss in pipe lines, and (3) that resistance due to difference in elevations.

Actually none of these will have to be computed in most applications because usually the pump is installed at the house, and the standard pressure range of the system is sufficient to overcome these resistances and deliver its capacity to the various outlets. An example in which these computations must be made is when the pump or system is located at considerable distance from the point of use and on a lower elevation.

In such a case the difference in elevation must be determined (1 lb. Pressure is necessary to overcome each 2.3 ft. elevation); the friction loss in feet calculated and changed to pounds pressure (again the same relation, 1 lb. Pressure equals 2.3 ft. or this can be read directly from the table in lbs.); the service pressure or pressure required at the faucet must be decided; the total of these three will be the discharge conditions or operating pressure required of the pump.





This means when the pressure switch cuts the pump on at about 43 lbs. Tank pressure, the pressure at the house will be 30 lbs. When the water is flowing at a rate of 7 gallons per minute.

Example

Service pressure desired – 30 lbs. minimum	30 lbs.
Elevation 23 ft. 1 lb. = 2.3 ft. 23 ft. / 2.3 ft. = 10 lbs.	10 lbs.
Friction: Pump capacity is 7 GPM This flow through 200 ft. of 1" pipe gives a friction loss of 3.06 lbs.	3 lbs.
	43 lbs.

Pressure switch setting at the pump would be (43-63 lbs.)

Summary

Now let's summarize briefly the points we've covered. We have shown that in a water system application, there are three factors to consider:

1. Water Needed or Determination of Capacity
2. Suction Conditions, and
3. Discharge Conditions.

We have concluded that capacity required is determined by the maximum number of outlets which will be in continuous use at the same time with a minimum flow of three gallons per minute per outlet.

We have shown that all jet pumps, whether shallow well or deep well, have a water end in which there is a suction chamber; that the suction chamber is actually a closed container in which a partial vacuum is created. This allows atmospheric pressure to force in the water. The suction chamber must be located within about 25 feet vertical distance above the pumping level of the water.

The main difference between shallow well and deep well pumps is that in the former the water end is built onto the power end. The water end of deep well jet pumps is a separate part. It is installed in the water and is used to pump water from levels below a 25 feet depth. We have shown that a submersible should be used when source will allow. Since the submersible is submerged in water only discharge conditions apply. We've established three distinct forms of resistance to flow encountered as Discharge Conditions and shown that they must be considered but computed only in special cases. Also, that the pump is only part of the system necessary to provide an automatic service. Other accessories are necessary and we've established the need and function of each of these accessories.

We have mentioned 3 GPM as a minimum acceptable flow rate per outlet. But a larger flow rate is more desirable and the following table should be used as an average supply required when the source of supply will allow it.

We would like to leave you with one thought. That is, capacity and pressure are inversely related. When one goes up, the other goes down. Always check the rating chart or curve of a pump to make sure if you raise the pressure you will still receive the needed supply of water at your outlets.

Using the rating chart below, we would be getting 8 GPM from the pump at 20 lbs. pressure. If we were trying to supply two outlets at once, this would give us approximately 4 GPM at each one. If we increase the pressure to 30 lbs. pressure, we only get 6 GPM which will give us approximately 3 GPM at each outlet. By raising the pressure we have reduced the amount of water at each outlet by approximately 25%.

Always check the pump performance rating before making a change.

Performance Rating in Gallons per Minute

Pump Discharge Pressure			
Total Suction Lift	**20 PSI**	**30 PSI**	**Max. Shut-Off in Lbs.**
5 feet	8 GPM	6 GPM	51 lbs.

Seven Minute Peak Demand Period Usage

Outlets	Flow Rate GPM	Total Usage Gallons	Bathrooms In Home			
			1	1½	2-2½	3-4
Shower or Bath Tub	5	35	35	35	53	70
Lavatory	4	2	2	4	6	8
Toilet	4	5	5	10	15	20
Kitchen Sink	5	3	3	3	3	3
Automatic Washer	5	35	–	18	18	18
Dishwasher	2	14	–	–	3	3
Normal seven minute*peak demand (gallons)			45	70	98	122
Minimum sized pump required to meet peak Demand without supplemental supply			7 GPM (420)	10 GPM (600)	14 GPM (840)	17 GPM (1020)

Note: Values given are average and do not include higher or lower extremes.

*Peak demand can occur several times during morning and evening hours.

Additional Requirements: Farm, irrigation and sprinkling requirements are not shown. These values must be added to the peak demand figures if usage will occur during normal demand periods.

NOTES

NOTES

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