CAVITATION AND PIPE FRICTION

Cavitation is a hydraulic condition which can exist in any type of pump. It is primarily a situation in which the pump is discharging less liquid than its rated capacity due to a reduction or lack of liquid supply to the pump intake. "Excessive suction lift, insufficient Npsh, or operation at too high a speed are common causes of cavitation. Pitting, vibration, and noise are common troubles stemming from cavitation. While severe cavitation is usually accompanied by excessive noise and damage to the pump, mild cavitation may produce nothing more than a small reduction in pump efficiency and moderate wear of pump parts."[1]

Diaphragm pumps, like other pumps, "do not suck in liquids; they reduce pressure in the suction chamber, and external pressure, usually atmospheric, pushes the liquid into the pump. For any pump with a given size suction line, capacity or maximum speed is fixed by the existing net positive suction head (Npsh)."[2] A diaphragm pump can be particularly vulnerable to a "starved suction" condition because it is generally pumping a viscous, solid-laden slurry. In fact, most cases of low flow rates can be traced to starved suction conditions due to either too high a static lift, too long a suction line, or a combination of both.

It is likewise possible to experience cavitation even though the pump may have a "flooded suction." In this case it is due to trying to discharge more than can be pulled in through a suction line that is too long and/or too small in diameter. If a slurry is quite "thick" it will only be possible to pump a much smaller amount than the pump's full capacity.

Cavitation is harmful to diaphragm life because on the suction stroke the diaphragm is being pulled mechanically by the shaft connected to the pressurized diaphragm. There is an "unbalanced" pressure on the diaphragm equal to the amount of suction produced. Cavitation makes the "unbalanced" pressure on the suction stroke higher. The lower the suction lift condition imposed on the diaphragm, the less the unbalanced mechanical load, and the longer the diaphragm life. Every diaphragm has a given number of flexes before failure. If the pump is cavitating, less liquid is being pumped per flex; therefore, diaphragm cost per gallon is increased.

Cavitation can be eliminated in the Wilden air-operated double-diaphragm pump easier than with any other type of pump. Start the pump slowly by controlling the volume of compressed air to the pump by the use of a gate or globe valve. After the unit starts pumping, the throttling valve can be opened to increase capacity. The point at which further opening of the valve increases cycling rate without an increase in discharge rate will be the cavitation point, and the valve should be closed slightly. Further attempts to increase capacity should be oriented around a larger suction intake line, larger pump, reduced lift condition and/or a combination of these conditions.

Under conditions of limited flow due to cavitation, damage to the Wilden double-diaphragm pump most likely will be limited only to the diaphragms, in comparison to numerous expensive parts in other types of pumps.

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[1]Tyler G. Hicks and Theodore W. Edwards, *Pump Application Engineering,* page 87.
[2]Tyler G. Hicks and Theodore W. Edwards, *Pump Application Engineering,* page 51.

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HIGH VISCOSITY PIPE FRICTION

Viscosity is that property of a liquid which resists free flow. The most common method of expressing viscosity is in SSU (Saybolt Seconds Universal). Water has a SSU viscosity of 31.5.

Centrifugal pumps can handle viscosities up to 500 SSU. Beyond 500 SSU, a positive displacement pump must be used to move a liquid. Most pipe friction tables are based on water or at most go to liquids of up to 500 SSU. The Wilden air-operated double-diaphragm pump is capable of pumping viscous slurries. On page 3 and 4 is a Pipe Friction Chart showing line loses at viscosities up to 500,000 SSU.

NOTE: These friction tables give the loss in **Pounds per Square Inch**. The losses at the very high viscosities (100,000 SSU and up) are great.

Note also that all friction loses in these tables **must be multiplied by the specific gravity** of the slurry being pumped.

With the high friction losses observed at these high viscosities, suction conditions become **ultra critical**. At best there will only be a maximum of 14# available at sea level to push liquid into the pump.

For example, the friction loss in 100' of 2" pipe of a 100,000 SSU liquid at a flow rate of 7 gpm is 230#. (See chart.) Through 10' of 2" pipe the loss would be 23#, well above the 14# available. It would only be possible to pull approximately 3 gpm through 10' of 2" pipe due to friction alone. **No static lift would be possible.**

The fact is that no pump can exert force on a liquid **until it is in the pump**. The only force able to act on the suction side is the earth atmospheric pressure of 14.7 psi at sea level. Once the liquid is in the pump, the Wilden pump can push with as much pressure as the air supply pressure available.

Typical "in plant" air supply pressures are seldom over 100 psi. Therefore, any calculated friction loss approaching this figure calls for either a shorter pipe, a larger pipe size, or a reduction in the amount of elbows. This will reduce the amount of friction loss.

CONSIDERATIONS FOR SPECIFYING A WILDEN AIR-OPERATED DOUBLE-DIAPHRAGM PUMP

- **Gallons per minute (GPM):** Required flow rate or output.
- **Specific Gravity:** The ratio of a fluid's density to that of water. Water equals 1.0.
- **Viscosity:** A measure of a fluid's tendency to resist a shearing force. Viscosity is not a constant, fixed property of a fluid, it varies with the conditions of the fluid and the system.
- **Temperature:** The temperature of a fluid at the pump inlet is usually of greatest concern.
- **Vapor Pressure:** The absolute pressure (at a given temperature) at which a liquid will change to vapor.
- **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 Discharge Head:** Static discharge head plus friction head.
- **Pipe Diameter, Pipe Length and the number of Elbows** are needed to calculate friction head.

ENGINEERING DATA: PIPE FRICTION — VISCOUS LIQUIDS

LOSS IN POUNDS PER SQUARE INCH PER 100 FEET OF NEW STEEL PIPE BASED ON SPECIFIC GRAVITY 1.0

GPM	SIZE PIPE	VISCOSITY — SAYBOLT SECONDS UNIVERSAL																	
		100	200	300	400	500	1000	1500	2000	2500	3000	4000	5000	6000	7000	8000	9000	10,000	15,000
3	½	11.0	23	35	48	60	120	182	240	300	365	475	600	720	840	960	-	-	-
	¾	3.7	7.7	11.8	15.8	19.5	39	59	78	96	117	160	195	237	273	312	351	390	585
	1	1.4	3.0	4.5	6.0	7.4	15	23	30	37.5	45	60	75	90	105	120	135	150	225
5	¾	6.2	13	20	26.5	33	66	99	132	165	198	264	330	396	462	528	594	660	990
	1	2.3	5	7.4	10.0	12.5	25	38	50	62.5	74	100	125	150	175	200	225	250	375
	1¼	0.78	1.7	2.5	3.3	4.2	8.3	12.5	16.6	21	25	34	42	50	58	66	75	83	125
7	¾	8.7	18	27.5	37	46	92	137	184	225	280	370	460	552	644	736	828	920	-
	1	3.3	6.9	10.5	14	17.5	35.5	53	71	89	106	142	178	213	249	284	320	355	533
	1¼	1.1	2.3	3.5	4.7	5.8	11.5	17.5	23	29	35	47	59	70	81	93	104	115	173
10	1	5.0	10	15	20	25	51	76	102	128	153	204	255	306	357	408	459	510	765
	1¼	1.6	3.3	5.0	6.7	8.3	16.7	25	33.5	42	50	68	84	100	117	134	150	167	250
	1½	0.84	1.8	2.7	3.6	4.5	9.0	13.5	18	23	27	36	45	54	63	72	81	89	135
15	1	11.0	15	22	30	37.5	76	114	152	190	228	304	380	456	532	608	684	760	-
	1¼	2.7	4.9	7.6	10.0	12.5	25	37.5	50	63	75	100	125	150	175	200	225	250	375
	1½	1.2	2.7	4.0	5.4	6.8	13.5	20	27	34	41	54	68	81	95	108	122	135	203
20	1	20	20	30	40	50	100	150	200	250	300	400	500	600	700	800	900	-	-
	1½	2.3	3.6	5.4	7.2	9.0	18	27.5	36	46	54	72	90	108	126	144	162	180	270
	2	0.64	1.3	2.0	2.7	3.3	6.7	10	13.5	17	20	27	34	41	47	55	60	67	100
25	1½	3.5	4.5	6.7	9.0	11.5	23	34	46	57	68	90	115	138	161	184	207	230	345
	2	1.0	1.7	2.5	3.3	4.2	8.4	12.5	16.5	21.5	25	33	42	51	59	68	76	84	126
	2½	0.42	0.8	1.2	1.6	2.0	4.0	6.0	8.0	10	12	16	20	24	28	32	36	40	60
30	1½	5.0	5.4	8.0	11.0	13.5	27	41	54	69	81	108	135	162	189	216	243	270	405
	2	1.4	2.0	3.0	4.0	5.0	10	15	20	25	30	40	50	60	70	80	90	100	150
	2½	0.60	0.95	1.5	1.9	2.4	4.8	7.2	9.8	12	14.5	19	24	29	34	38	43	48	72
40	1½	9.0	9.0	11.0	14.5	18	37	55	73	92	111	148	185	222	259	296	333	370	555
	2	2.6	2.7	3.9	5.3	6.7	13.5	20	27	34	40	54	68	82	95	108	122	135	203
	2½	1.1	1.3	2.0	2.6	3.3	6.5	9.7	13	16.5	19	25.5	32	38	45	52	59	65	98
50	1½	14.0	14.0	14.0	18.0	23	46	68	90	115	138	184	230	276	322	368	414	460	690
	2	3.8	4.0	5.0	6.7	8.4	17	25.5	34	43	51	68	85	102	119	136	153	170	255
	2½	1.6	1.7	2.4	3.2	4.0	8.0	12	16	20	24	32	40	48	56	64	72	80	120
60	2	5.3	5.8	5.9	8.0	10.0	20	30	41	52	61	80	100	120	140	160	180	200	300
	2½	2.3	2.4	2.9	3.8	4.8	9.6	14.5	19.5	24	29	38	49	58	67	77	86	96	144
	3	0.8	0.8	1.2	1.7	2.1	4.1	6.1	8.3	10	12.5	16.5	20.5	24.5	28	33	37	41	62
70	2½	2.9	3.2	3.4	4.5	5.7	11	17	23	28	34	44	55	66	77	88	99	110	165
	3	1.0	1.1	1.4	1.9	2.4	4.8	7.1	9.7	12	14.5	19	24	29	34	38	43	48	72
	4	0.27	0.32	0.48	0.65	0.80	1.6	2.4	3.2	4.1	4.9	6.6	8.1	10	11.2	13	14.4	16	24
80	2½	3.7	4.3	4.3	5.2	6.5	13	19.5	26	33	39	52	65	78	91	104	117	130	195
	3	1.3	1.4	1.7	2.2	2.8	5.5	8.2	11	13.5	17	22	27.5	33	38.5	44	50	55	83
	4	0.36	0.36	0.54	0.74	0.92	1.8	2.7	3.7	4.7	5.6	7.5	9.3	11.5	12.6	14.4	16.2	18	27
100	2½	5.5	6.7	6.7	6.7	8.0	16.5	24.5	32.5	41	48	64	80	96	112	128	144	160	240
	3	1.9	2.2	2.2	2.8	3.5	6.8	10	14	17	21	27.5	34	41	48	54	61	68	102
	4	0.53	0.57	0.68	0.92	1.2	2.3	3.4	4.5	5.9	7.0	9.3	11.5	14	16.1	18.5	20.7	23	34

MULTIPLY VALUES IN THIS TABLE BY SPECIFIC GRAVITY OF LIQUID

Example — 30 GPM. Viscosity 1000 SSU. Specific Gravity 0.90 200 Feet of 2" pipe Loss = 10 x 0.90 x 2= 18 Lb./Sq. in.
Caution — Since viscosity increases greatly with a little reduction in temperature, it is wise to be liberal in estimating pipe friction.

IF VISCOSITY IS GIVEN IN CENTIPOISES: CONVERT TO SSU BY MULTIPLYING BY 4.6.

ENGINEERING DATA: PIPE FRICTION — VISCOUS LIQUIDS

LOSS IN POUNDS PER SQUARE INCH PER 100 FEET OF NEW STEEL PIPE
BASED ON SPECIFIC GRAVITY 1.0

GPM	SIZE PIPE	VISCOSITY — SAYBOLT SECONDS UNIVERSAL														
		20,000	25,000	30.000	40,000	50,000	60,000	70,000	80,000	90,000	100,000	125,000	150,000	175,000	200,000	500,000
3	2	20	25	30	40	50	60	70	80	90	100	125	150	175	200	500
	2½	9.7	12.1	14.6	19.4	24.3	29.1	34.0	38.8	43.7	48.5	60.7	72.8	84.8	97.0	243
	3	4	5	6	8	10	12	14	16	18	20	25	30	35	40	100
5	2	33	42	50	66.3	83	99.5	116	133	150	166	208	249	290	332	829
	2½	16.2	20.3	24.3	32.4	40.5	48.6	56.7	64.8	72.9	81.1	101	122	142	162	405
	3	6.8	8.5	10.2	13.6	17.0	20.4	23.8	27.2	30.6	34.0	42.5	51.0	59.5	68.0	170
7	2	46	58	70	92	115	138	161	184	207	230	288	345	403	460	-
	2½	20.3	25.4	30.5	40.6	50.8	60.9	71.0	81.2	91.3	102	127	152	178	203	507
	3	9.5	11.9	14.3	19.0	23.8	28.5	33.2	38.0	42.7	47.5	59.4	71.2	83.1	95.0	237
10	2½	32	40	48	64	80	96	112	128	144	160	200	240	280	320	800
	3	13.6	17.0	20.4	27.2	34.0	40.8	47.6	54.4	61.2	68	85	109	119	136	340
	4	4.5	5.7	7.0	9.2	11.5	13.8	16.1	18.4	20.7	23.0	28.8	34.5	40.2	46.0	115
15	2½	48	60	72	96	120	144	168	192	216	240	300	360	420	480	-
	3	20	25	30	40	50	60	70	80	90	100	125	150	175	200	500
	4	6.7	8.6	10.5	13.7	17.0	20.4	23.8	27.2	30.6	34.0	42.5	51.0	59.5	68	170
20	3	27.0	33.7	40.5	54.0	67.5	81.0	94.5	108	122	135	169	202	236	270	675
	4	9.0	11.5	14.0	18.3	23.0	27.6	32.2	36.8	41.4	46.0	57.5	69.0	80.5	92.0	230
	6	1.8	2.3	2.7	3.6	4.6	5.5	6.4	7.3	8.2	9.1	11.4	13.7	15.9	18.2	45.5
25	3	34	42.5	51	68	85	102	119	136	153	170	213	255	297	340	850
	4	11.3	14.5	17.5	23	28.8	34.5	40.3	46.1	51.8	57.6	72	86.4	101	115	288
	6	2.2	2.8	3.3	4.4	5.5	6.6	7.7	8.8	9.9	11.0	13.8	16.5	19.3	22	55
30	3	40	50	60	80	100	120	140	160	180	200	250	300	350	400	-
	4	13.5	17	21	28	34.4	41.3	48.2	55.1	62	68.8	86	103	121	138	413
	6	2.6	3.3	3.9	5.2	6.5	7.8	9.1	10.4	11.7	13.0	16.3	19.5	22.8	26	65
40	3	54	67.5	81	108	135	162	189	216	243	270	337	405	472	540	-
	4	18	23	28	37	46	55.2	64.4	73.6	82.8	92	155	138	161	184	460
	6	3.5	4.5	5.3	7.0	8.8	10.5	12.3	14.0	15.7	17.5	21.9	26.2	30.6	35.0	87.5
50	4	22.5	29	35	46	57.5	69	80.5	92	104	115	144	173	201	230	575
	6	4.4	5.6	6.6	8.8	11.0	13.2	15.4	17.6	19.8	22	27.5	33	38.5	44	110
	8	1.5	1.9	2.3	3.0	3.7	4.5	5.3	6.0	6.8	7.5	9.4	11.3	13.1	15.0	37.5
60	4	27	34	42	54.8	68.5	82.2	95.9	110	123	137	171	206	240	274	685
	6	5.3	6.7	8.0	10.6	13.3	16.0	18.6	21.3	23.9	26.6	33.2	39.9	46.5	53.2	133
	8	1.8	2.3	2.8	3.6	4.5	5.5	6.4	7.4	8.3	9.2	11.5	13.8	16.1	18.4	46.0
70	4	32	40	49	64	80	96	112	128	144	160	200	240	280	320	800
	6	6.1	7.8	9.3	12.4	15.5	18.6	21.7	24.8	27.9	31.0	38.8	46.5	54.2	62	155
	8	2.1	2.7	3.2	4.2	5.3	6.4	7.4	8.5	9.5	10.6	13.3	15.9	18.6	21.2	53
80	6	7.0	9.0	10.7	14.2	17.8	21.3	24.9	28.4	31.9	35.5	44.4	53.3	62.1	71	178
	8	2.4	3.0	3.6	4.8	6.0	7.2	8.4	9.6	10.8	12	15	18	21	24	60
	10	0.99	1.2	1.5	1.9	2.4	3.0	3.5	4.0	4.5	5.0	6.3	7.5	8.8	10	25
90	6	7.9	9.9	11.8	15.8	19.7	23.7	27.6	31.6	35.5	39.5	49.4	59.3	69.1	79.0	197
	8	2.7	3.4	4.1	5.4	6.8	8.2	9.6	11.0	12.3	13.7	17.1	20.6	24.0	27.4	68.5
	10	1.1	1.4	1.7	2.2	2.7	3.3	3.9	4.4	5.0	5.5	6.9	8.3	9.6	11.0	27.5
100	6	8.8	11.0	13.2	17.6	22.0	26.4	30.8	35.2	39.6	44	55	66	77	88	220
	8	3.0	3.8	4.5	5.9	7.5	9.0	10.5	12.0	13.5	15.0	18.8	22.5	26.3	30.0	75
	10	1.2	1.5	1.8	2.4	3.0	3.7	4.2	4.8	5.4	6.0	7.5	9.0	10.5	12.0	30

MULTIPLY VALUES IN THIS TABLE BY SPECIFIC GRAVITY OF LIQUID

Example — 50 GPM. Viscosity 100,000 SSU. Specific Gravity 1.1 300 Feet of 6" pipe Loss = 22 x 1.1 x 3 = 72.6 Lb./Sq. in.
Caution — Since viscosity increases greatly with a little reduction in temperature, it is wise to be liberal in estimating pipe friction.

IF VISCOSITY IS GIVEN IN CENTIPOISES: CONVERT TO SSU BY MULTIPLYING BY 4.6.