Pumping System

- A major ancillary item

Considerations

1. *Type of fluid*: chemical and physical characteristics of the fluid to be pumped.
2. *System-head curve*: may be obtained from the manufacturer.
3. *Potential system modifications*
4. *Operational mode*: degree of flow, head fluctuation, and mode of operation (continuous or intermittent)
5. *Required margins*: 15~20% over the design points

Pumping System - continued

6. *Pump selection*: based on the fluid characteristics, turn-down ratio, discharge pressure and system requirements, availability of space, lay-out, energy and pump costs, code requirements, and the materials used in the construction.

- Reciprocating pumps (plunger or diaphragm type) for liquid chemical metering and injection applications (small capacity)
- Centrifugal pumps - for wide variety of hydraulic head and over a wide range of capacity requirements, for low to medium capacity with medium to high pressure.

Pumping System - continued

- Axial flow pumps: for low hydraulic head and high flow conditions
- Vertical turbine pumps: require much less space and self-priming but more head room.

7. *Drive selection*: electric motor, internal combustion engine, or steam; constant or variable speed drives; the majority of pumps are driven by squirrel-cage induction motors due to their versatility and availability

   Synchronous: requiring large horse power

   Wound rotor: requiring variable speed drives

   Reduced voltage starting and low in-rush current

Pumping System - continued

8. *Number of pumps and standby generators*: A three pump system employing identical electric motor driven pumps, each having a capacity that is 50% of the max. demand is commonly selected; for frequent power outrages, an engine driven pump or standby diesel generator should be incorporated; for a standby generator, the system will require reduced voltage starting.

Pump Specifications

- Related to pump construction and performance
- Selection of the appropriate type of metal

  e.g., for anaerobic sludge or deep well water or pumping out the bottom portion of deep lakes, type 301 or 304 stainless steel rather than type 316 should be specified.
- Request for bidding: technical specifications and general information (commercial term).
- Performance testing: agree on the method of testing and whether the testing of the pump should be witnessed.

Special Considerations

1. *Pump starting conditions*

   Centrifugal pumps: close the discharge valve during startup to prevent hydraulic surges.

   Propeller type pumps: require very high horse power at start-up.

2. *High-speed versus low-speed pumps*

   • a small sized impeller with a high-speed motor

   • a larger impeller with a slower speed motor

3. *Hydraulic surge control*

   During pump start-up: install a surge control valve

   Water hammer: install a surge tank

Special Considerations - continued

4. *Design of the pump suction well*

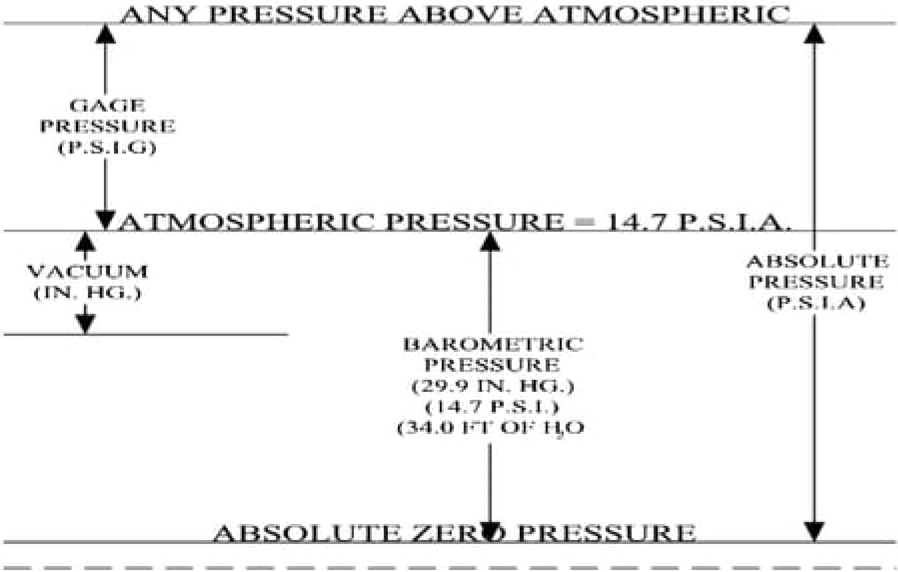
   The pump impeller requires a particular type of flow condition to exist.

5. *Sludge pumps*

- Positive displacement type - plunger (seldom used) and progressive cavity (Moyno) pumps
- Centrifugal type - screw feed, bladeless
- Torque flow type - the Wemco pump, effective but very low pump efficiency

The sludge piping should be $<$ 6 in. in diameter and the velocity should be 5 ~ 6 ft/sec.

Types of Pressure



Gage pressure is usually the one we mean when we talk about pump pressure in pounds per square inch (P.S.I.)

Head in ft

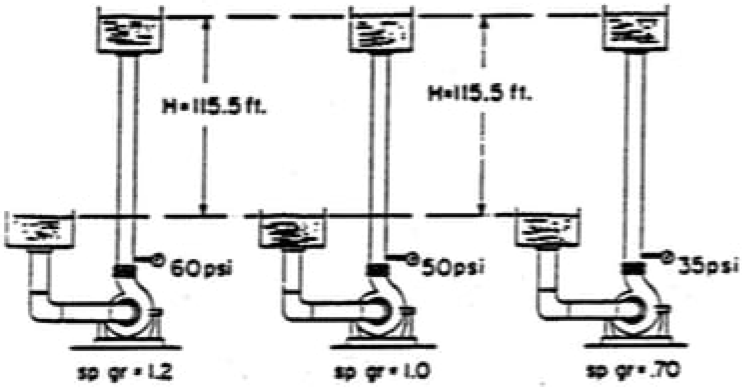
Column of Liquid which exerts a pressure

- Head in feet = 2.31 × psi/Liquid Sp. Gr.
  - For most cases water Sp. Gr. = 1.0
  - Lighter than water like oil Sp. Gr. = 0.85
  - Heavier than water like brine Sp. Gr. = 1.15
- Specific gravities for various liquids and for water at various temperatures can be found in pump handbooks such as:
  - Hydraulic institute engineering data book
  - Cameron hydraulic Data.
  - Hydraulic handbook (colt industries)

Head vs. Pressure

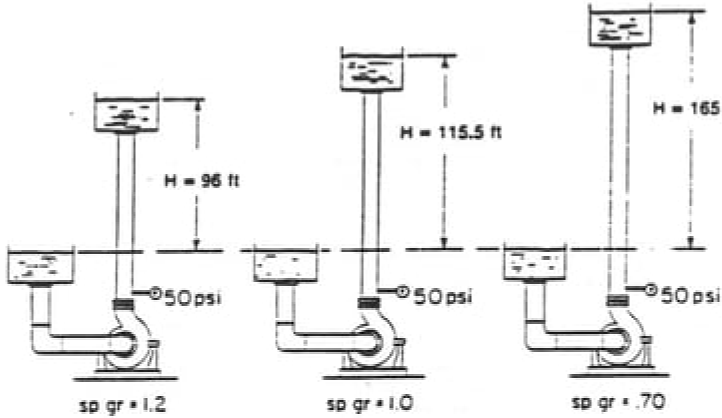
The figure are to illustrate the relationship between head and pressure with a centrifugal pump handling liquids of varying specific gravity

Head vs. Pressure - continued



Three identical pump, each designed to develop 115.5 ft. of head (water Sp. Gr. 1.0) when liquids of other Sp. Gr. are handled, the head (in feet) will remain the same, but the pressure will very proportional to the specific gravity

Head vs. Pressure - continued



Three pumps designed for same pressure will develop heads (ft. of liquid) inversely proportional to the specific gravity.

Capacity

- Quality of liquid to be pumped in a time period
  - ✓ Usually expressed as gallons per minute (gpm)
  - ✓ Sometimes expressed as gallons per hour (gph)
  - ✓ Other examples

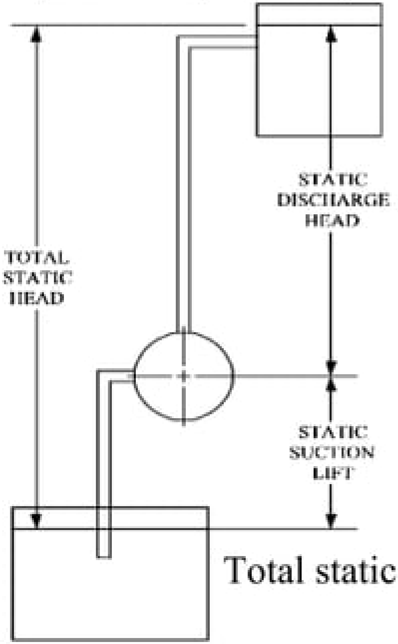
Flow Equivalents

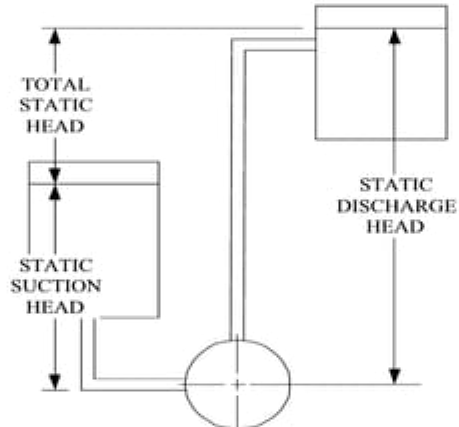
Example: 100 U S gal/min × 0.0631 = 6.31 liters/sec

Convert from \ Convert to	U S gal/min	Imp gal/min	U S million gal/day	Cu ft per sec (sec-ft)	Cu meters per hour	Liters per sec	Barrels (42 gal) per min	Barrels (42 gal) per day
U S gal/min	1	0.8327	0.00144	0.00223	0.2271	0.0631	0.0238	34.286
Imp gal/min	1.201	1	0.00173	0.002676	0.2727	0.0758	0.02859	41.176
U S million gal/day	694.4	578.25	1	1.547	157.7	43.8	16.53	23810
Cu ft/sec	448.83	373.7	0.646	1	101.9	28.32	10.686	15388
Cu m/sec	15852	13200	22.83	35.35	3600	1000	377.4	......
Cu m/min	264.2	220	0.3804	0.5886	60.0	16.667	6.290	9058
Cu m/hr	4.403	3.67	0.00634	0.00982	1	0.2778	0.1048	151
Liters/sec	15.85	13.20	0.0228	0.0353	3.60	1	0.3773	543.3
Liters/min	0.2642	0.220	0.000380	0.000589	0.060	0.0167	0.00629	9.058
Barrels (42 gal)/min	42	34.97	0.0605	0.0937	9.538	2.65	1	1440
Barrels (42 gal)/day	0.0292	0.0243	0.000042	0.000065	0.00662	0.00184	0.00069	1

Total Static Head

(Liquid at rest, no flow)





Total static head = static discharge head – static suction head

Total static head = static discharge head + static suction lift

Friction Loss or Friction Head

- Measured in feet of liquid, equivalent head to overcome resistance to liquid flow in pipes, valves and fittings in the piping system.
- Values can be located in most hydraulic handbooks. (see examples on following pages)

Fluid flow
Friction loss – Water

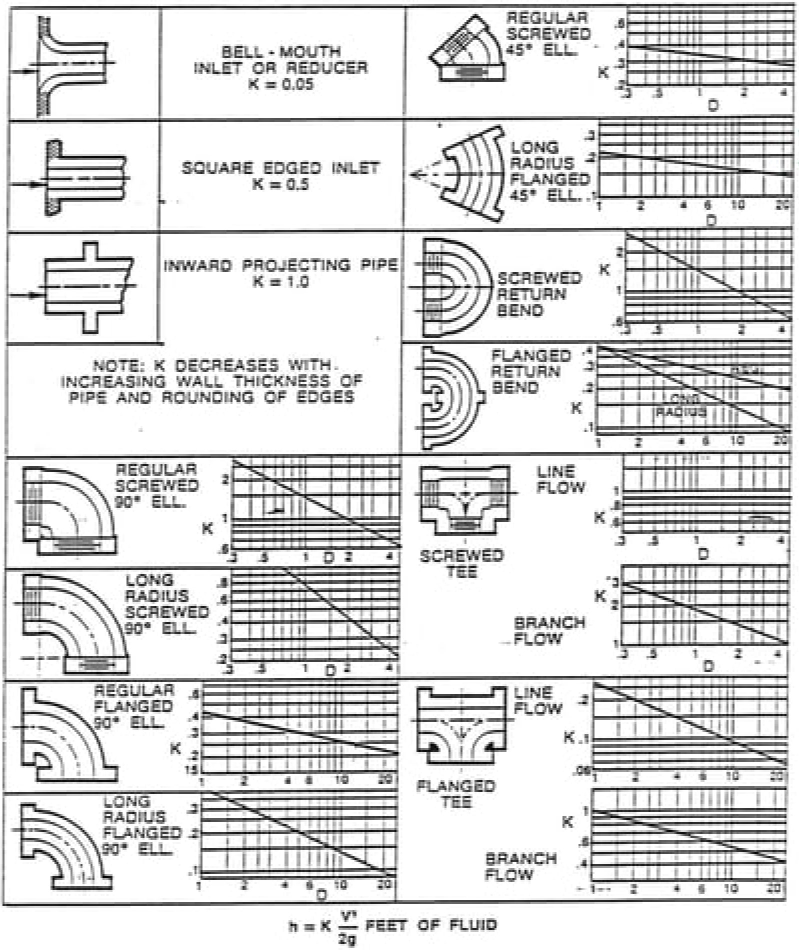
Friction loss for water in ft per 100 ft of pipe

3 INCH NOMINAL		STEEL SCHEDULE 40, ID = 3.068 INCHES, ϵ/D = 0.000587			ASPHALT-DIPPED CAST IRON, ID = 3.00 INCHES, ϵ/D = 0.00160		
DISCHARGE CFS	DISCHARGE GPM	V ft/sec	$V^2/2g$ feet	h_f feet per 100 feet of pipe	V ft/sec	$V^2/2g$ feet	h_f feet per 100 feet of pipe
0.0111	5	0.217	0.000732	0.0112	0.227	0.000800	0.0128
0.0223	10	0.434	0.00292	0.0372	0.454	0.00320	0.0435
0.0334	15	0.651	0.00659	0.0762	0.681	0.00720	0.0900
0.0446	20	0.868	0.0117	0.128	0.908	0.0128	0.1510
0.0557	25	1.085	0.0183	0.189	1.13	0.0200	0.2280
0.0668	30	1.30	0.0263	0.262	1.36	0.0288	0.330
0.0780	35	1.52	0.0359	0.347	1.59	0.0392	0.427
0.0891	40	1.74	0.0468	0.443	1.82	0.0512	0.549
0.100	45	1.95	0.0593	0.547	2.04	0.0648	0.683
0.111	50	2.17	0.0732	0.662	2.27	0.0800	0.830
0.123	55	2.39	0.0885	0.789	2.50	0.0968	0.993
0.134	60	2.60	0.105	0.924	2.72	0.115	1.170
0.145	65	2.82	0.124	1.07	2.95	0.135	1.36
0.156	70	3.04	0.143	1.22	3.18	0.157	1.56
0.167	75	3.25	0.165	1.39	3.40	0.180	1.78
0.178	80	3.47	0.187	1.57	3.63	0.205	2.02
0.189	85	3.69	0.211	1.76	3.86	0.231	2.28
0.201	90	3.91	0.237	1.96	4.08	0.259	2.55
0.212	95	4.12	0.264	2.17	4.31	0.289	2.82
0.223	100	4.34	0.2927	2.39	4.54	0.320	3.10
0.245	110	4.77	0.354	2.86	4.99	0.387	3.73
0.267	120	5.21	0.421	3.37	5.45	0.461	4.40
0.290	130	5.64	0.495	3.92	5.90	0.541	5.13
0.312	140	6.08	0.574	4.51	6.35	0.627	5.93
0.334	150	6.51	0.659	5.14	6.81	0.720	6.80
0.356	160	6.94	0.749	5.81	7.26	0.820	7.71
0.379	170	7.38	0.846	6.53	7.72	0.925	8.70
0.401	180	7.81	0.948	7.29	8.17	1.04	9.73
0.423	190	8.25	1.06	8.07	8.62	1.16	10.80
0.446	200	8.68	1.17	8.90	9.08	1.28	11.9
0.490	220	9.55	1.42	10.7	9.98	1.55	14.3
0.535	240	10.4	1.69	12.6	10.9	1.84	17.0
0.579	260	11.3	1.98	14.7	11.8	2.16	19.8
0.624	280	12.2	2.29	16.9	12.7	2.51	22.8
0.668	300	13.0	2.63	19.2	13.6	2.88	26.1
0.713	320	13.9	3.00	22.0	14.5	3.28	29.7
0.758	340	14.8	3.38	24.8	15.4	3.70	33.6
0.802	360	15.6	3.79	27.7	16.3	4.15	37.8
0.847	380	16.5	4.23	30.7	17.2	4.62	42.2
0.891	400	17.4	4.68	33.9	18.2	5.12	46.8
0.936	420	18.2	5.16	37.3	19.1	5.65	51.5
0.980	440	19.1	5.67	40.9	20.0	6.20	56.4
1.025	460	20.0	6.19	44.6	20.9	6.77	61.5
1.069	480	20.8	6.74	48.5	21.8	7.38	66.8
1.114	500	21.7	7.32	52.5	22.7	8.00	72.3
1.225	550	23.9	8.85	63.2	25.0	9.68	87
1.337	600	26.0	10.5	74.8	27.2	11.5	102
1.448	650	28.2	12.4	87.5	29.5	13.5	121
1.560	700	30.4	14.3	101	31.8	15.7	142
1.671	750	32.5	16.5	116	34.0	18.0	162
1.782	800	34.7	18.7	131	36.3	20.5	184
1.894	850	36.9	21.1	148	38.6	23.1	207
2.005	900	39.1	23.7	165	40.8	25.9	232
2.117	950	41.2	26.4	184	43.1	28.9	258
2.228	1 000	43.4	29.27	204	45.4	32.0	285

NOTE: No allowance has been made for age, differences in diameter, or any abnormal condition of interior surface. Any factor of safety must be estimated from the local conditions and the requirements of each particular installation.

Fluid flow
Friction loss – Water

Resistance coefficients for valves and fittings



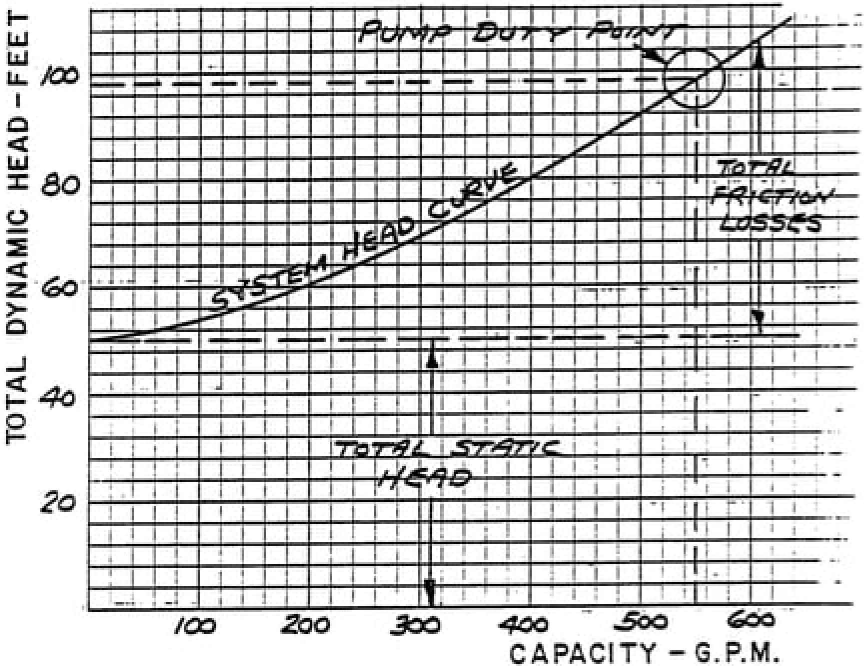
Losses and Head

- Entrance and Exit losses
  - Bell mouth opening will reduce entrance losses. Handle same way as a pipe loss. Values found in hydraulic handbooks.
- Velocity Head
  - Energy in the fluid as a result of movement. Usually a small value and can be neglected except for very accurate calculations.
    - Velocity Head = $v^2/2g$

Defining Total Head

- Combining from previous pages on static heads and friction losses.
  - Suction lift (-)
    - Dynamic suction lift = static suction lift + suction friction losses + suction entrance losses
  - Suction head (+)
    - Dynamic suction head = static suction head + suction friction losses + suction entrance losses.
  - Discharge head (+)
    - Dynamic discharge head = static discharge head + discharge friction losses + exit losses.
  - Total Head or TDH
    - Total Head = Discharge Head + Suction lift or – Suction Head.

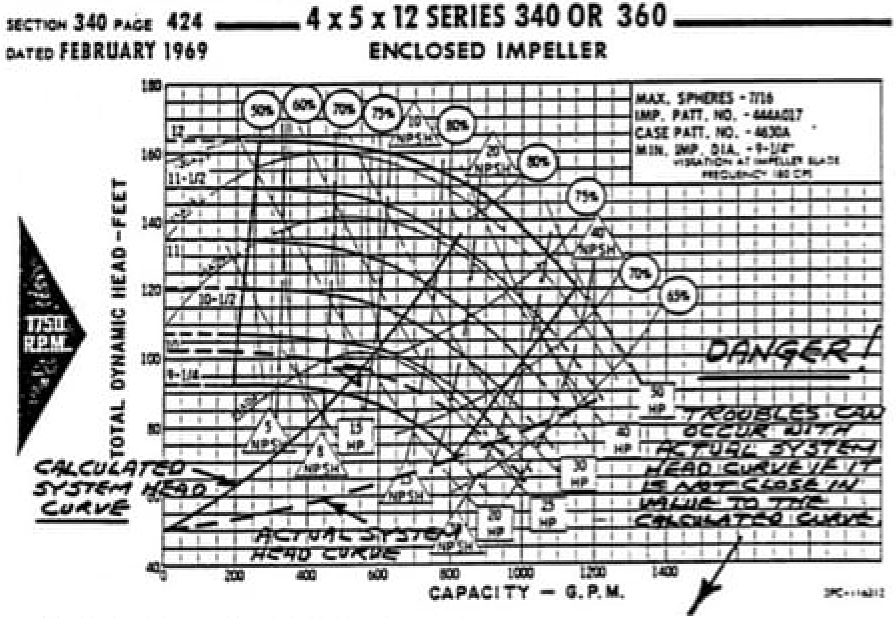
System Head Curve



Example:
If Customer needs 550 G.P.M. the pump head as selected from the system head curve will be 98 ft. T.D.H.

Selection of Pump

- Pump will operate at intersection of pump curve and system head curve. For duty point of 550 GPM@ 98 ft. T.D.H., select 4 x5 x 12 –340 pump with 20 H.P., 1750 R.P.M. motor



DO NOT!
Over calculate pump head requirement

1) Higher driver H.P. will be required.
2) Possibility of cavitation (pump noise vibration and internal damage)

Solutions

For Pumping Problems for unit over selected as result of improper system head curve

- hp requirement too high
  - Larger motor
  - Throttle discharge valve to get more head and reduce hp required. (temporary solution)
  - Cut impeller diameter for proper head and capacity requirements.
- Cavitation
  - Throttle discharge valve to get back on pump curve. (Temp. solution)
  - Cut impeller diameter to meet correct Head-Capacity requirement.

Break Horsepower

The BHP required to drive a pump at a specific duty point is:

$$BHP = \frac{\text{Head (ft)} \times \text{gpm} \times \text{Sp. Gv.}}{3{,}960 \times \text{Pump eff.}}$$

These values can be determined from the pump specification and the pump curve.

Example

- Spec. calls for 675 gpm at 95 ft. head. Performance curve shows 86%. Pump effluent liquid is ethylene glycol at Sp. Gr. of 1.08.

$$BHP = \frac{95\ \text{ft} \times 675\ \text{gpm} \times 1.08}{3{,}960 \times 86\%}$$

$$= 20.3$$

Would select a 25 hp Driver

NPSH Definition

- Hydraulic institute defines net positive suction head (NPSH) as follows:

  The net positive suction head in feet of liquid absolute determined at the suction nozzle and referred to datum less the vapor pressure of the liquid in feet absolute

  (This sounds pretty complicated,but let's try to simplify it a bit as it is very important in pump selection.)

- Also be defined as the combination of atmospheric pressure and static suction head that causes liquid to flow thru the suction piping and finally enter the eye of the impeller.
- From that it can be seen that NPSH is very important to successful operation of a pump.

Two Kinds of NPSH

Net positive suction head.

- $NPSH_R$. – required by pump at duty point, found on the pump performance curve.
- $NPSH_A$. – Available in the system and must be determined by calculation

Important !

For the pump to perform properly, the $NPSH_R$ (required), must be less than the $NPSH_A$ (available)

$NPSH_A$

$$NPSH_A = \frac{2.31(P_A - P_V)}{Sp.\,Gr.} + (H_E - H_F)$$

P_A = atmospheric pressure or pressure in tank (psia);

P_V = vapor pressure of liquid at maximum pumping temperature;

Sp. Gr. = specific gravity at pumping temperature;

H_E = elevation head (ft); and

H_F = friction loss in suction line (ft).

Refer to following pages for example calculations.

Values for vapor pressure (P_V) and atmospheric pressure (P_A) found in pump handbooks. (see attached)

Properties of Saturated Steam—Temperature Table

VAPOR PRESSURE (Pv) ↓

Temp F	Absolute pressure in Hg	Absolute pressure mm Hg	Absolute pressure lb/in²	Vacuum in Hg ref to 29.921 in bar. at 32F	Specific volume sat vap ft³/lbm v_g	Total heat or enthalpy Btu/lb water h_f	Total heat or enthalpy Btu/lb evap h_{fg}	Total heat or enthalpy Btu/lb steam h_g
180	15.290	388.42	7.5110	14.629	50.225	148.00	990.2	1138.2
181	15.635	397.12	7.679	14.287	49.194	149.00	989.6	1138.6
182	15.983	405.98	7.850	13.939	48.189	150.01	989.0	1139.0
183	16.339	415.01	8.025	13.582	47.207	151.01	988.4	1139.4
184	16.701	424.22	8.203	13.220	46.249	152.01	987.8	1139.8
185	17.070	433.58	8.384	12.851	45.313	153.02	987.1	1140.2
186	17.445	443.09	8.568	12.477	44.400	154.02	986.5	1140.5
187	17.827	452.81	8.756	12.094	43.508	155.02	985.9	1140.9
188	18.216	462.69	8.947	11.705	42.638	156.03	985.3	1141.3
189	18.611	472.72	9.141	11.310	41.787	157.03	984.7	1141.7
190	19.016	483.02	9.340	10.905	40.957	158.04	984.1	1142.1
191	19.426	493.41	9.541	10.495	40.146	159.04	983.5	1142.5
192	19.845	504.08	9.747	10.076	39.354	160.05	982.8	1142.9
193	20.271	514.87	9.956	9.651	38.580	161.05	982.2	1143.3
194	20.702	525.84	10.168	9.219	37.824	162.05	981.6	1143.7
195	21.144	537.06	10.385	8.777	37.086	163.06	981.0	1144.0
196	21.592	548.43	10.605	8.329	36.364	164.06	980.4	1144.4
197	22.050	560.07	10.830	7.871	35.659	165.07	979.7	1144.8
198	22.514	571.86	11.058	7.407	34.970	166.08	979.1	1145.2
199	22.987	583.86	11.290	6.935	34.297	167.08	978.5	1145.6
200	23.467	596.08	11.526	6.454	33.639	168.09	977.9	1146.0
201	23.956	608.46	11.768	5.966	32.996	169.09	977.2	1146.3
202	24.456	621.15	12.011	5.467	32.367	170.10	976.6	1146.7
203	24.960	633.97	12.259	4.962	31.752	171.10	976.0	1147.1
204	25.475	647.06	12.512	4.447	31.151	172.11	975.4	1147.5
205	26.000	660.40	12.770	3.921	30.564	173.12	974.7	1147.9
206	26.531	673.89	13.031	3.390	29.989	174.12	974.1	1148.2
207	27.073	687.65	13.297	2.848	29.428	175.13	973.5	1148.6
208	27.625	701.67	13.568	2.297	28.878	176.14	972.8	1149.0
209	28.185	715.89	13.843	1.737	28.341	177.14	972.2	1149.4
210	28.755	730.37	14.123	1.167	27.816	178.15	971.6	1149.7
211	29.333	745.06	14.407	0.588	27.302	179.16	970.9	1150.1
212	29.921	760.00	14.696	0.000	26.799	180.17	970.3	1150.5

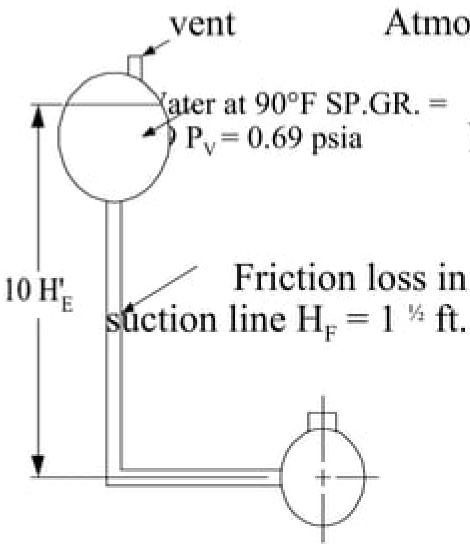
Absolute pressures in inches Hg, millimeters Hg, and vacuum in inches Hg calculated by Ingersoll-Rand.

Approximate Atmospheric Pressures and Barometer Readings at Different Altitudes

Altitude		Barometer		Atmospheric pressure lb/in²	Equivalent head of water (75°F) Feet	Boiling point of water	
Feet	Meters	Inches of mercury	Mm of mercury			°F	°C
-1000	-304.8	31.02	787.9	15.2	35.2	213.8	101.0
-500	-152.4	30.47	773.9	15.0	34.7	212.9	100.5
0	0	29.921	760.0	14.7	34.0	212.0	100.0
500	152.4	29.38	746.3	14.4	33.4	211.1	99.5
1000	304.8	28.86	733.1	14.2	32.8	210.2	99.0
1500	457.2	28.33	719.6	13.9	32.2	209.3	98.5
2000	609.6	27.82	706.6	13.7	31.6	208.4	98.0
2500	762.0	27.31	693.7	13.4	31.0	207.4	97.4
3000	914.4	26.81	681.0	13.2	30.5	206.5	96.9
3500	1066.8	26.32	668.5	12.9	29.9	205.6	96.4
4000	1219.2	25.84	656.3	12.7	29.4	204.7	95.9
4500	1371.6	25.36	644.1	12.4	28.8	203.8	95.4
5000	1524.0	24.89	632.2	12.2	28.3	202.9	94.9
5500	1676.4	24.43	620.5	12.0	27.8	201.9	94.4
6000	1828.8	23.98	609.1	11.8	27.3	201.0	93.9
6500	1981.2	23.53	597.7	11.5	26.7	200.1	93.4
7000	2133.6	23.09	586.5	11.3	26.2	199.2	92.9
7500	2286.0	22.65	575.3	11.1	25.7	198.3	92.4
8000	2438.4	22.22	564.4	10.9	25.2	197.4	91.9
8500	2590.8	21.80	553.7	10.7	24.8	196.5	91.4
9000	2743.2	21.38	543.1	10.5	24.3	195.5	90.8
9500	2895.6	20.98	532.9	10.3	23.8	194.6	90.3
10000	3048.0	20.58	522.7	10.1	23.4	193.7	89.8
15000	4572.0	16.88	428.8	8.3	19.1	184	84.4
20000	6096	13.75	349.3	6.7	15.2	—	
30000	9144	8.88	225.6	4.4	10.2	—	
40000	12192	5.54	140.7	2.7	6.3	—	
50000	15240	3.44	87.4	1.7	3.9	—	

$NPSH_A$ Example #1

Atmospheric pressure (P_A) = 14.7 psia



$$NPSH_A = \frac{2.31\,(P_A - P_V)}{SP.GR.} + (H_E - H_F)$$

$$= \frac{2.31\,(14.7 - 0.69)}{0.99} + (10 - 1.5)$$

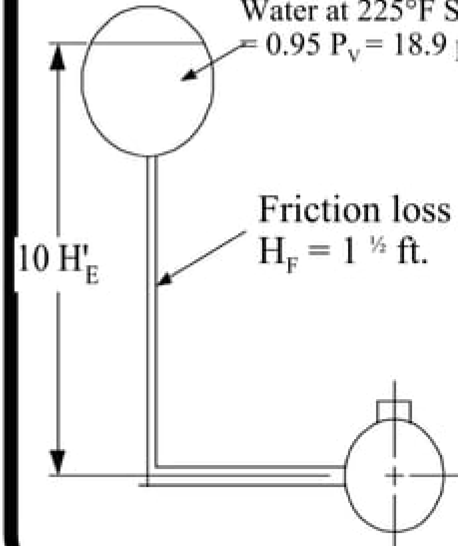
$$= 32.7 + 10 - 1.5$$

$$= 41.2 \text{ ft } NPSH_A$$

GOOD !

Should be no problem to select a pump to perform satisfactorily.

NPSH$_A$ Example #2



Deaerator system

Tank pressure (P_A) = 18.9 psia

$$NPSH_A = \frac{2.31\,(P_A - P_V)}{SP.GR.} + (H_E - H_F)$$

$$= \frac{2.31\,(18.9 - 18.9)}{0.953} + (10 - 1.5)$$

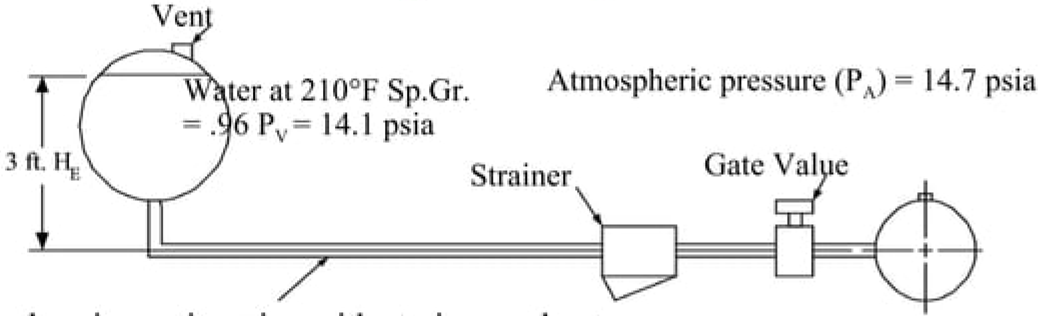
$$= 0 + 10 - 1.5$$

$$= 8.5 \text{ ft } NPSH_A$$

Fair !

Select a pump that requires less than 8.5’ NPSH$_A$ a duty point

NPSA$_A$ Example #3



Friction loss in suction pipe with strainer and gate valve $H_F = 1\frac{1}{2}$ ft.

$$NPSH_A = \frac{2.31(P_A - P_V)}{Sp.Gr.} + (H_E - H_F)$$

$$= \frac{2.31(14.7 - 14.1)}{0.96} + (3 - 2.5)$$

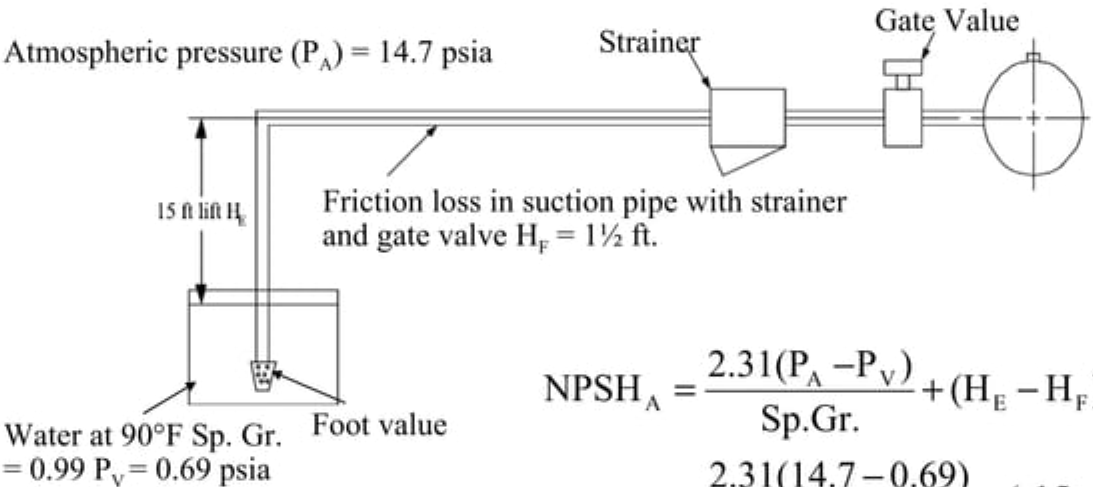
$$= 1.9 \text{ ft } NPSH_A$$

$NPSH_A$ Example #3 - continued

Bad !

It will be difficult to select a pump for satisfactory operation the $NPSH_A$ could be increased by raising the tank (H_E). If the pump requires 7 ft. $NPSH_R$, tank should be raised approximately 6 ft. add to give 7.9 ft $NPSH_A$ even more if possible

$NPSH_A$ Example #4



$$NPSH_A = \frac{2.31(P_A - P_V)}{Sp.Gr.} + (H_E - H_F)$$

$$= \frac{2.31(14.7 - 0.69)}{0.99} + (-15 - 2.5)$$

$$= 32.7 - 17.5$$

$$= 15.2 \text{ ft } NPSH_A$$

In selection the pump it would be necessary to see that the $NPSH_R$ required did not exceed 13 to 14 ft at the duty point, otherwise noise and cavitation would occur at the pump

Final Note on NPSH

Although a good working knowledge of NPSH is required to select pumps for hot water service, an estimation chart is often helpful to get you in the right area

The following chart shows approximate NPSH available at various water temperatures along with various static suction heads up to 15 feet. Note that the chart is based on water at sea level and also that no friction losses in the suction pipe are accounted for.

<u>Example of chart use:</u>

Given: Vented tank with water level at 8 feet above pump suction and water at 204°F

NPSH available = 13.1 feet

Available NPSH table for water

Temp °F	Vapor press. P.S.I.A	Equiv. Ft. of water	NPSH (ft) available at various static suction heads. (ft)											
			0	1	2	3	4	5	6	7	8	9	10	15
212	14.7	34.0	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	15
210	14.1	32.6	1.4	2.4	3.4	4.4	5.4	6.4	7.4	8.4	9.4	10.4	11.4	16.4
208	13.7	31.4	2.6	3.6	4.6	5.6	6.6	7.6	8.6	9.6	10.6	11.6	12.6	17.6
206	13.0	30.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	19.0
204	12.5	28.9	5.1	6.1	7.1	8.1	9.1	10.1	11.1	12.1	13.1	14.1	15.1	20.1
202	12.0	27.7	6.3	7.3	8.3	9.3	10.3	11.3	12.3	13.3	14.3	15.3	16.3	21.3
200	11.5	26.6	7.4	8.4	9.4	10.4	11.4	12.4	13.4	14.4	15.4	16.4	17.4	22.4
190	9.3	21.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5	27.5
160	4.7	10.9	23.1	24.1	25.1	26.1	27.1	28.1	29.1	30.1	31.1	32.1	33.1	38.1
120	1.7	3.9	30.1	31.1	32.1	33.1	34.1	35.1	36.1	37.1	38.1	39.1	40.1	45.1
80	0.5	1.5	32.5	33.5	34.5	35.5	36.5	37.5	38.5	39.5	40.5	41.5	42.5	47.5
40	0.1	0.2	33.8	34.8	35.8	36.8	37.8	38.8	39.8	40.8	41.8	42.8	43.8	48.8

Notes:

2. This chart does not take into account head losses due to friction in the pump suction piping which must be deducted from the available NPSH for the specific application
3. Values given are for water at sea level. For each 1000 feet above sea level, deduct one (1) foot from the available NPSH

Affinity Laws

On occasion you may find it necessary to determine the performance of a pump at a different operating speed the affinity laws are used in making these calculations.

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$$

$$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2$$

$$\frac{BHP_1}{BHP_2} = \left(\frac{N_1}{N_2}\right)^3$$

Q_1 = capacity

H_1 = Head (feet) at N_1 – rpm

Q_2 = capacity

H_2 = Head (feet) at N_2 – rpm

Example

Given pump at 600 gpm, 80 ft head, 15.1 BHP at 1750 rpm, what is comparable point at 1550 rpm?

$Q_1 = 600$ $H_1 = 80$ $BHP_1 = 15.1$ $N_1 = 1750$

$Q_2 = ?$ $H_2 = ?$ $BHP_2 = ?$ $N_2 = 1550$

$$Q_2 = \frac{Q_1 \times N_2}{N_1} = \frac{600 \times 1{,}550}{1{,}750} = 531\,\text{gpm}$$

$$H_2 = H_1 \times (N_2/N_1)^2 = 80\ (1550/1750)^2 = 62.8\ \text{ft.}$$

$$BHP_2 = BHP_1(N_2/N_1)^3 = 15.1\ (1550/1750)^3 = 10.5\ \text{BHP}$$

Example - continued

Other points from the 1750 rpm curve can be converted in a similar manner to plot an expected curve at the new rpm.

There are also similar equations to determine expected performance when changing the impeller diameter with rpm remaining constant. These can be shown by replacing N_1 and N_2 with D_1 and D_2 in the above equations. The use with different diameters would be the same as above