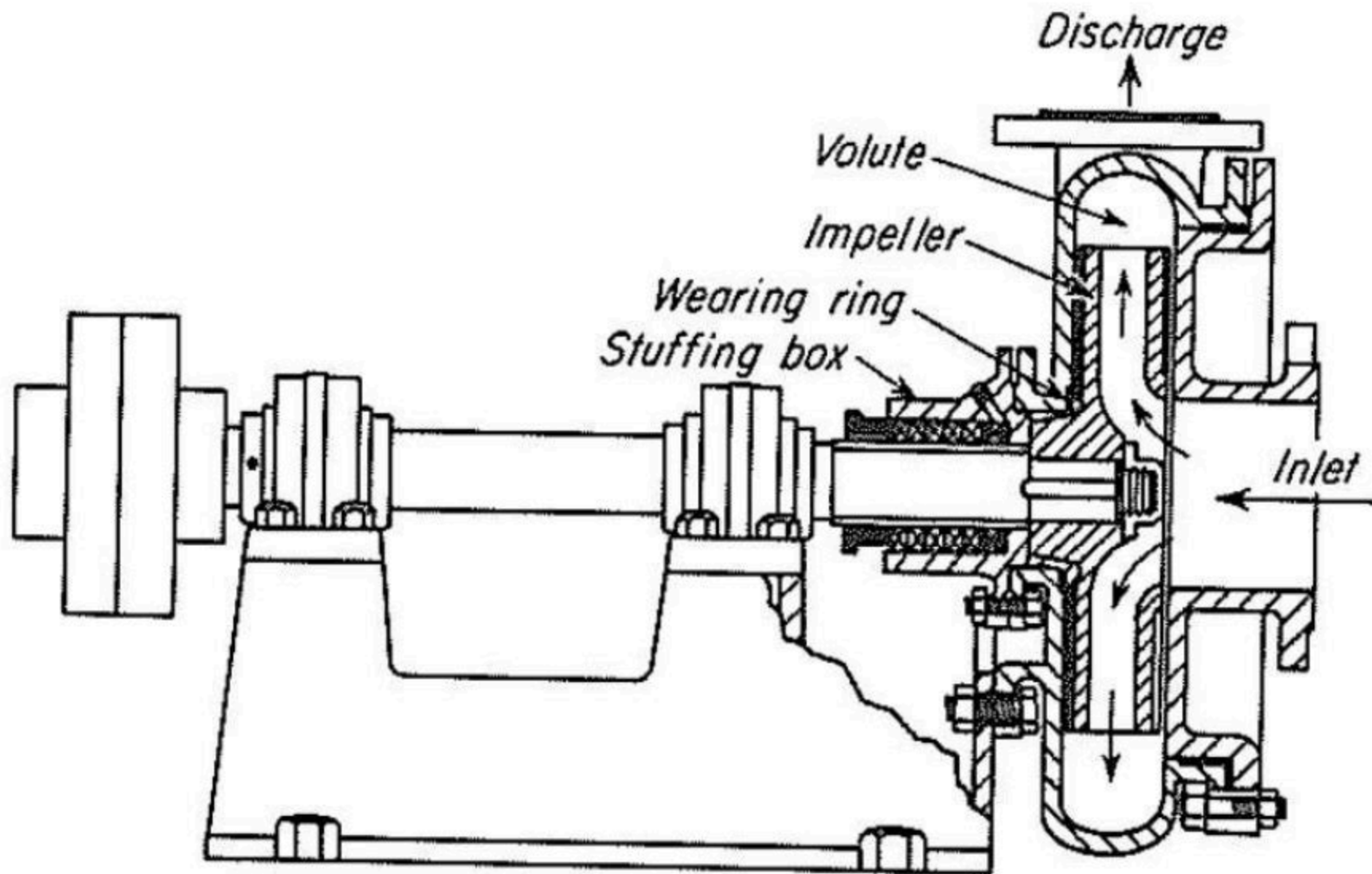
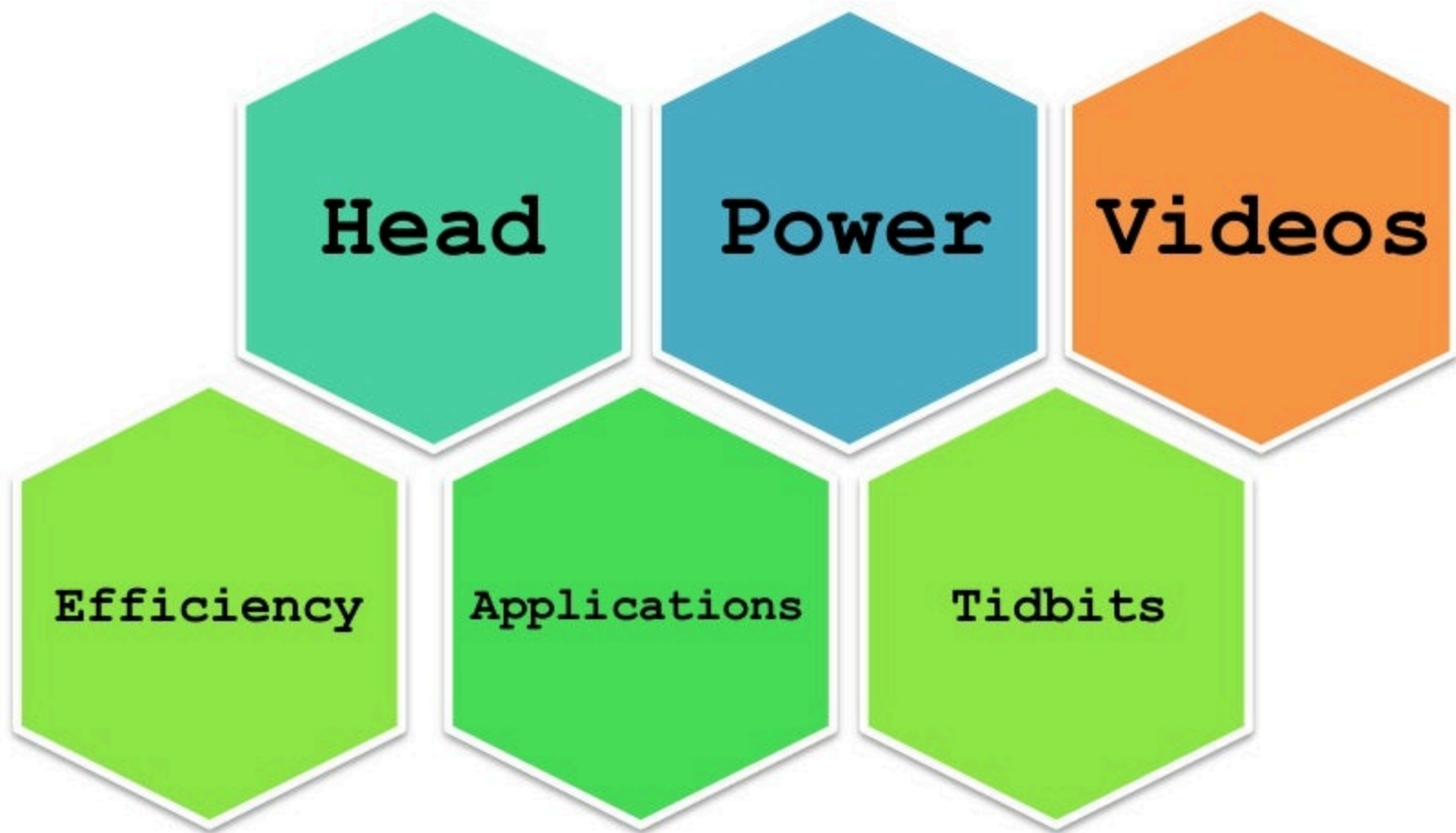


Centrifugal Pumps

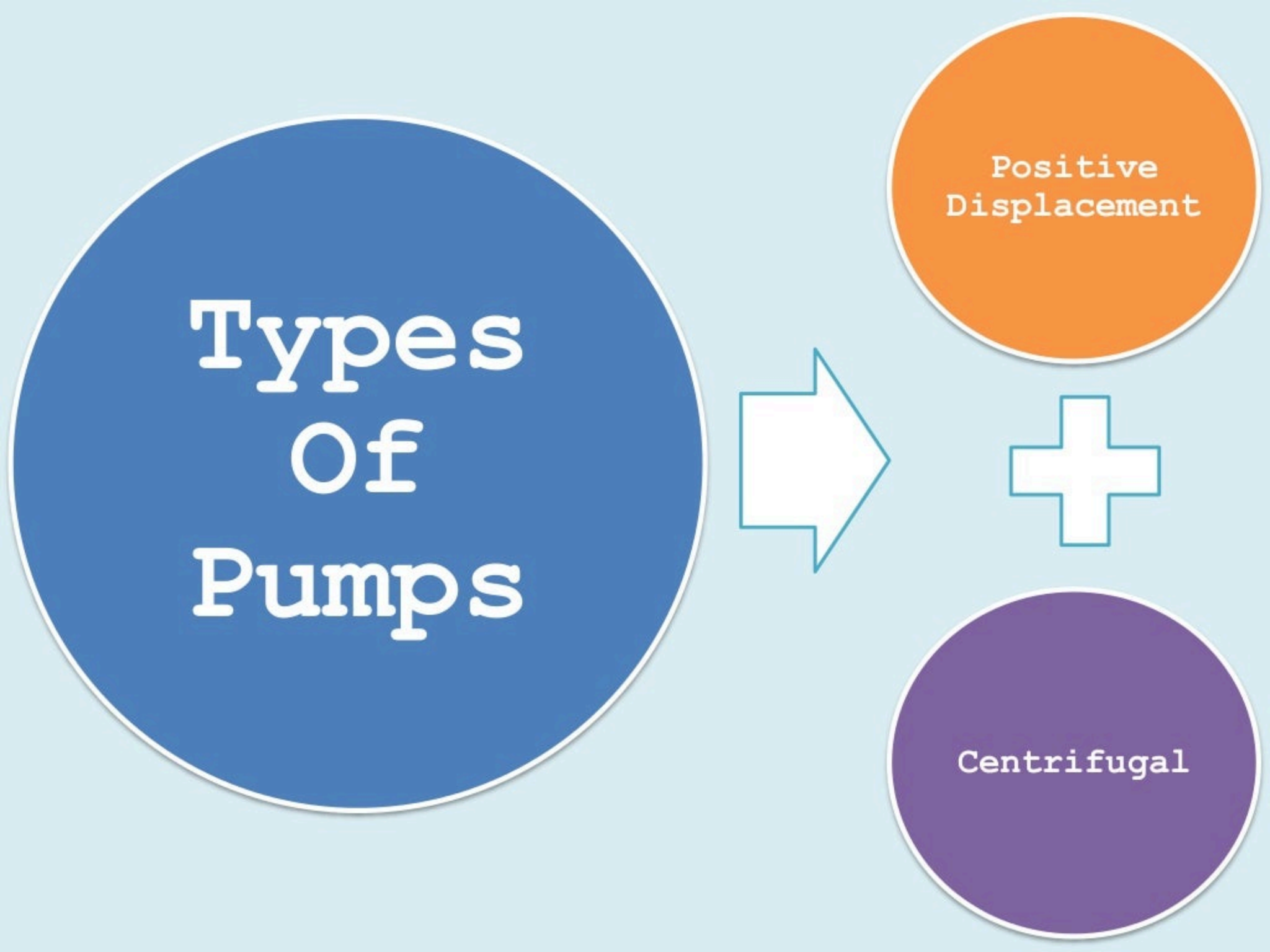


(a)

What To Expect?



Types Of Pumps



```
graph LR; A((Types Of Pumps)) --> B((Positive Displacement)); A --> C((Centrifugal));
```

The diagram illustrates the classification of pumps. A large blue circle on the left contains the text 'Types Of Pumps'. A white arrow with a blue outline points from this circle to the right. On the right side, there are two circles: an orange one at the top labeled 'Positive Displacement' and a purple one at the bottom labeled 'Centrifugal'. A white plus sign with a blue outline is positioned between these two circles, indicating that these are the two types of pumps.

Positive
Displacement

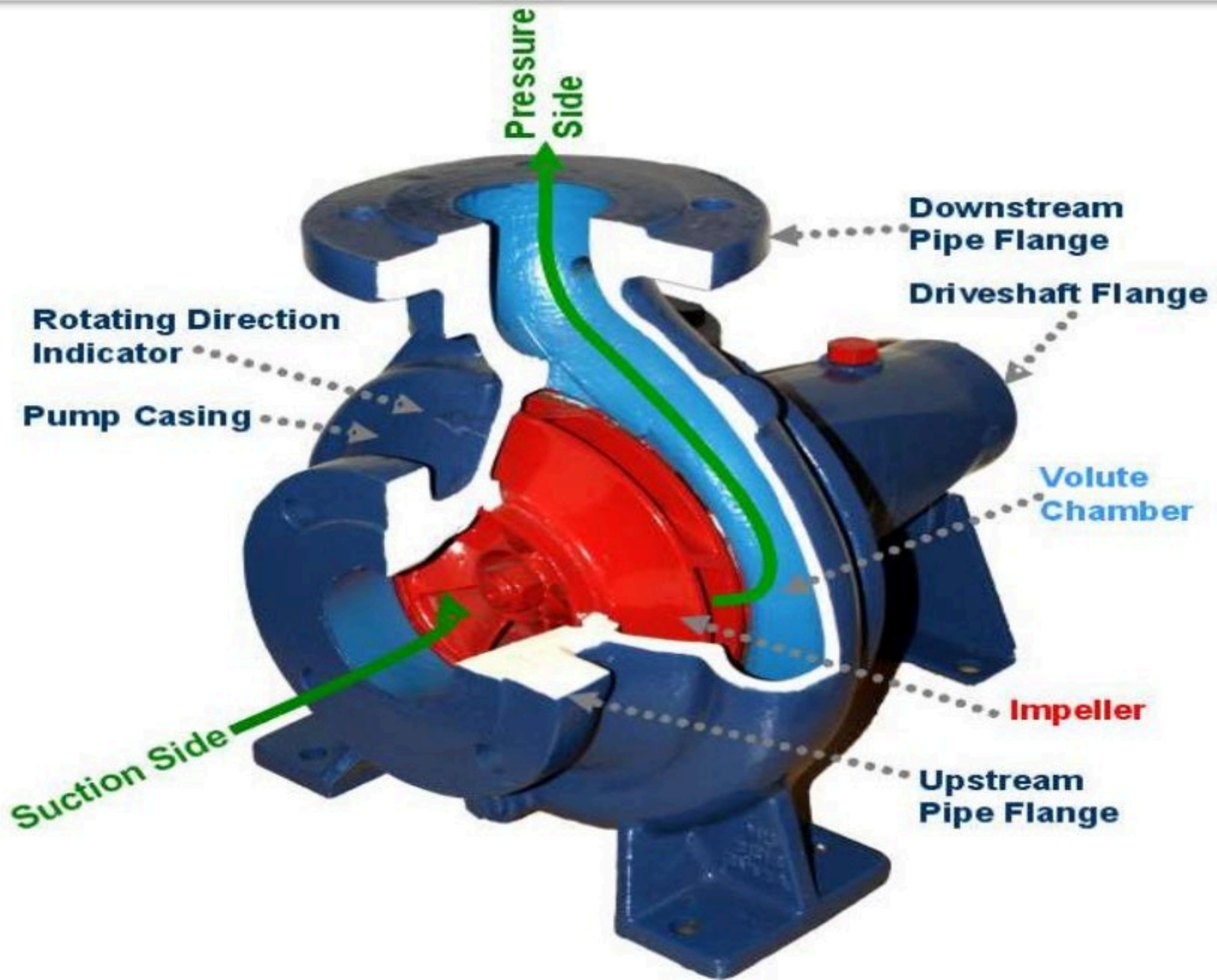


Centrifugal

- Centrifugal Pump Working

- Liquid enters through a suction connection concentric with the axis of a high speed rotary element called the impeller, which carries radial vanes integrally cast in it. Liquid flows outward, and leaves the impeller at a considerably greater with respect to the ground than at the entrance to the impeller.
- Power is applied to the fluid by the impeller and is transmitted to the impeller by the torque of the drive shaft which usually is driven by a direct connected motor at constant revolutions commonly at 1750 r/min.

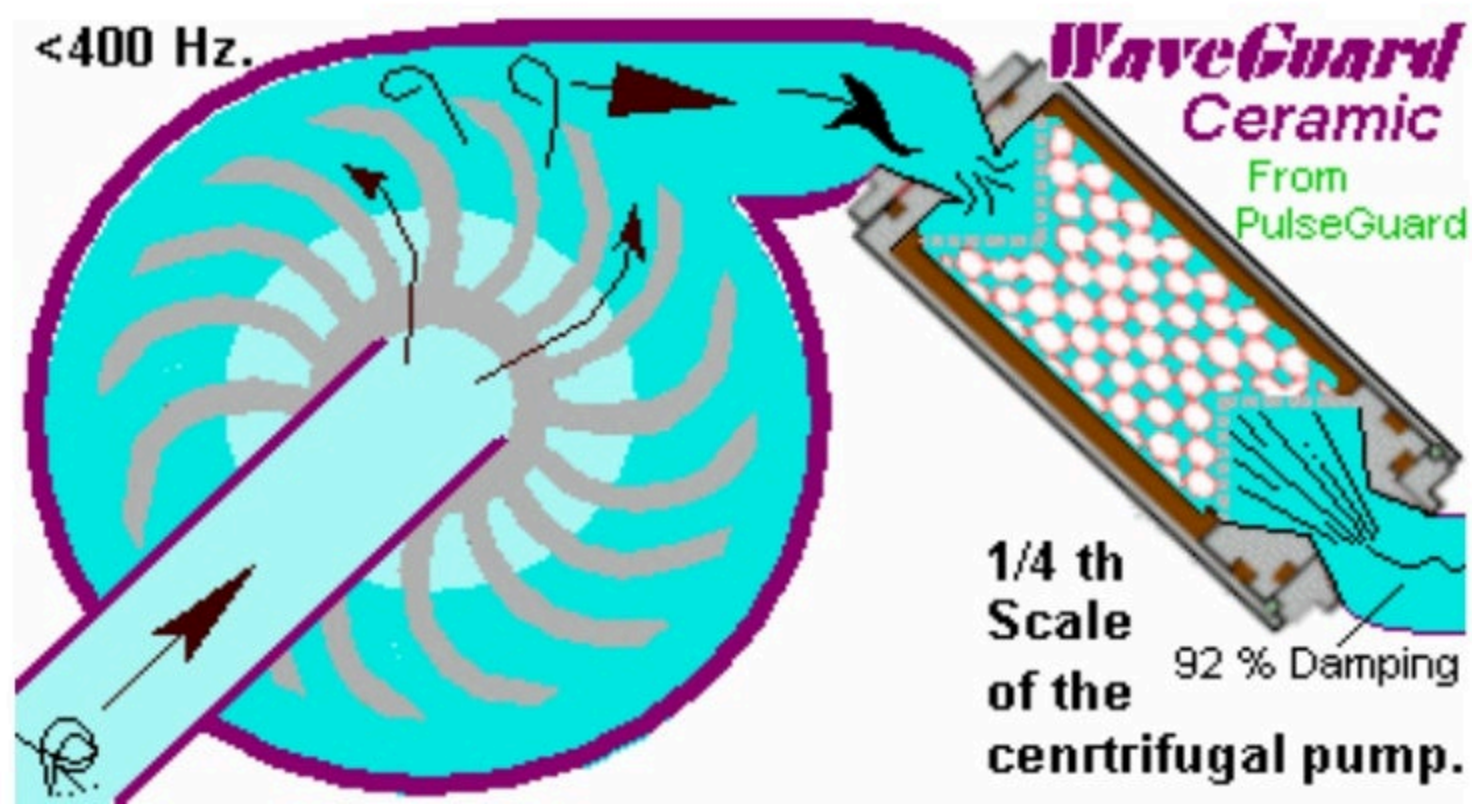
A Centrifugal Pump



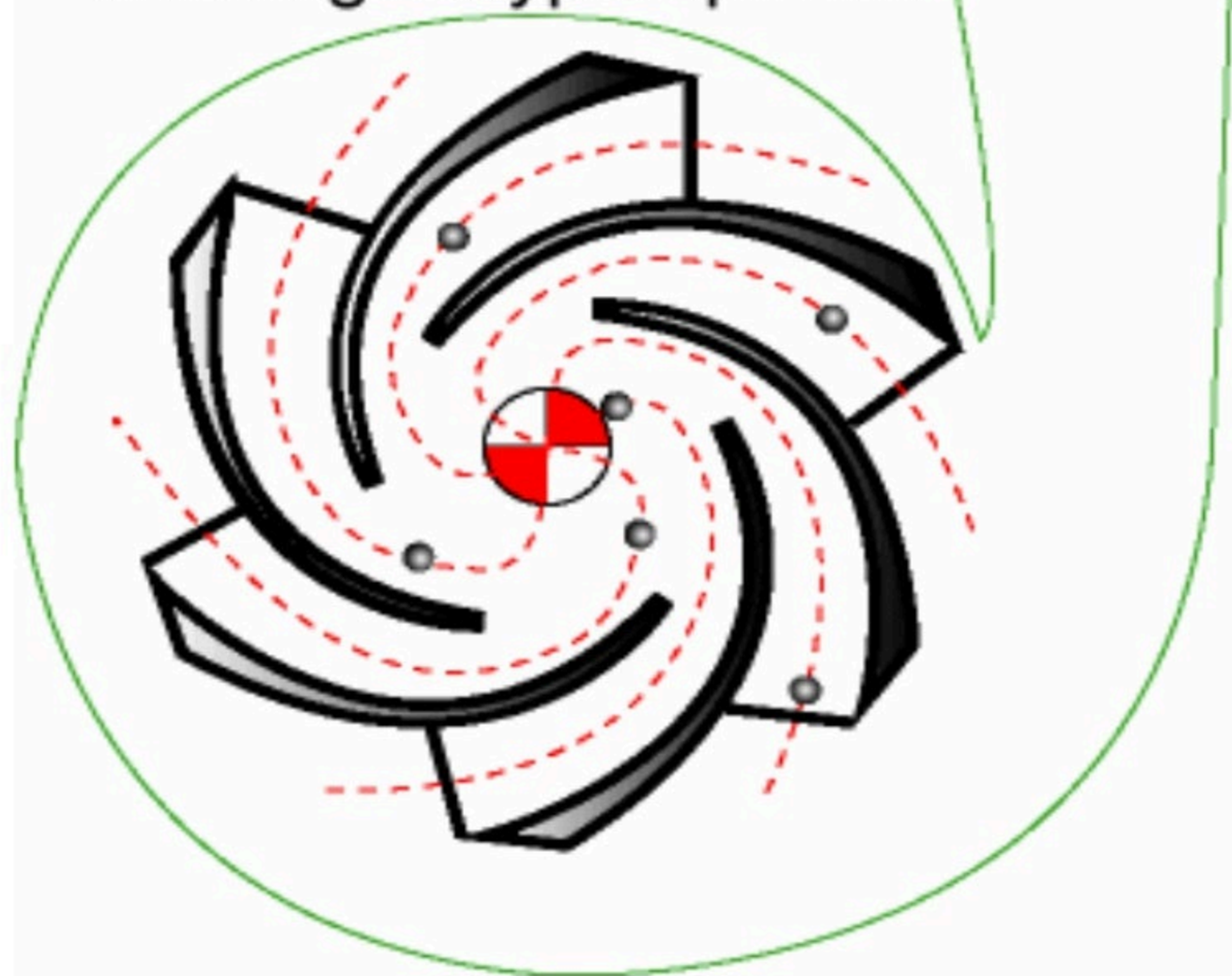


Centrifugal Pumps

- Increase of mechanical energy, pressure by centrifugal force...
- Most commonly used in the industry...
- The impellers are curved backward...



www.lightmypump.com



Most Suited Blade for Industrial Use

The big question is that out of these blade profiles, which one is the most suited for industrial use ?. To get answer for this question let's see how power consumption varies with discharge for each of these cases. For backward curved blades as energy head decreases with discharge power consumption stabilizes with flow. In radial blades since head does not have any connection with flow rate, power consumption increases linearly. In forward curved blades since energy head increases with flow power consumption increases exponentially. This will make the operation unstable and will eventually lead to burnout of motor.

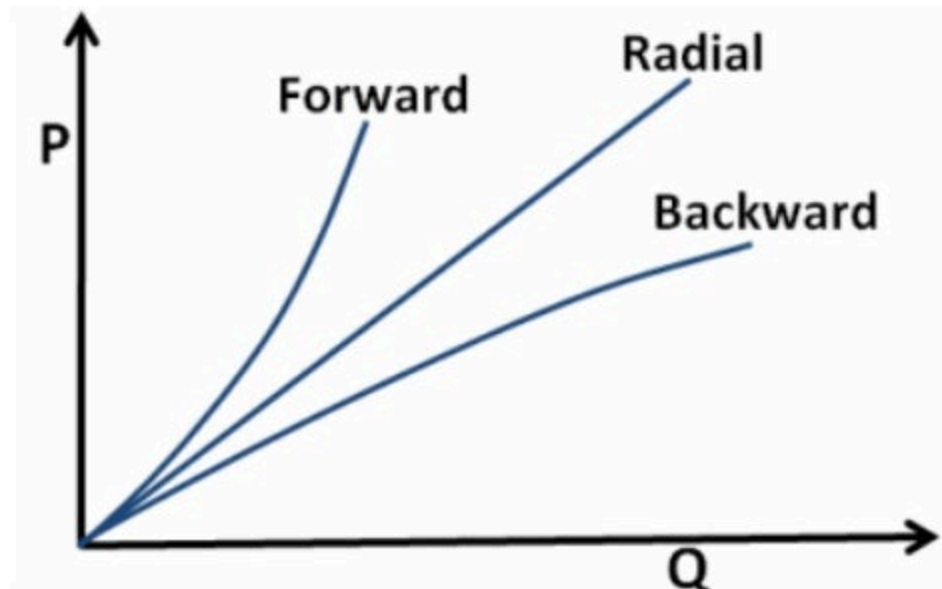


Fig.9 Power consumption in different blade geometries

Let's Start!



Head

Between two definite points in the tube, say stations a and b , Eq. (4.24) can be integrated, since ρ is constant, to give

$$\frac{p_a}{\rho} + \frac{gZ_a}{g_c} + \frac{u_a^2}{2g_c} = \frac{p_b}{\rho} + \frac{gZ_b}{g_c} + \frac{u_b^2}{2g_c} \quad (4.25)$$

Equation (4.25) is known as the Bernoulli equation without friction.

$$\frac{p_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a \bar{V}_a^2}{2g_c} = \frac{p_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b \bar{V}_b^2}{2g_c} + h_f \quad (4.29)$$

The mechanical energy delivered to the fluid is, then, ηW_p , where $\eta < 1$. Equation (4.29) corrected for pump work is

$$\frac{p_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a \bar{V}_a^2}{2g_c} + \eta W_p = \frac{p_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b \bar{V}_b^2}{2g_c} + h_f \quad (4.32)$$

Equation (4.32) is a final working equation for problems on the flow of incompressible fluids.

$$\eta W_p = \left(\frac{p_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b \bar{V}_b^2}{2g_c} \right) - \left(\frac{p_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a \bar{V}_a^2}{2g_c} \right) \quad (8.1)$$

The quantities in the parentheses are called *total heads* and are denoted by H , or

$$H = \frac{p}{\rho} + \frac{gZ}{g_c} + \frac{\alpha \bar{V}^2}{2g_c} \quad (8.2)$$

$$P_f = \dot{m} \Delta H \quad (8.5)$$

Shut Off Head

50 feet

Reservoir

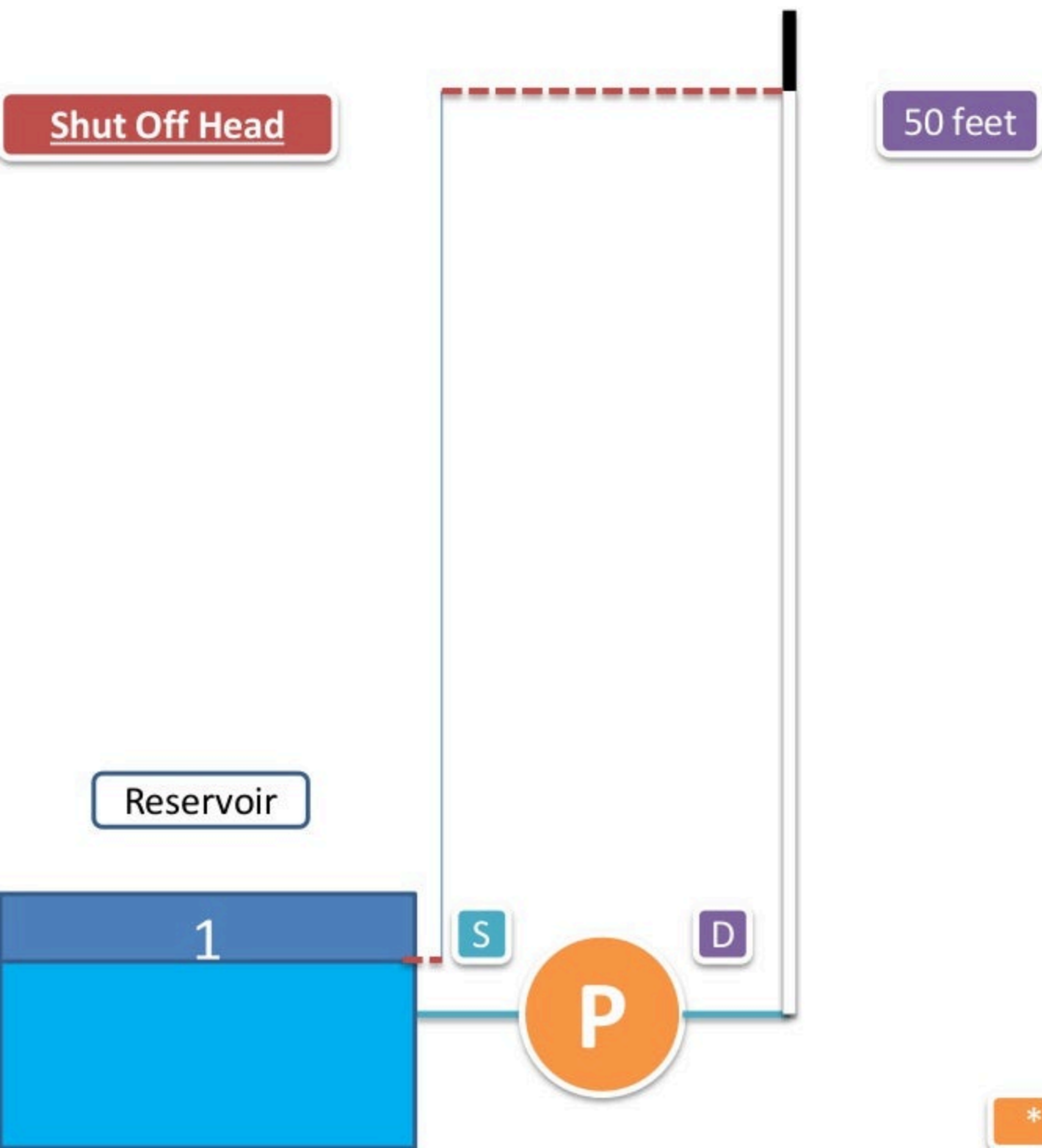
1

S

D

P

*In accordance with pump curves



In certain systems (admittedly unusual), the pump discharge line may have to run at a much higher elevation than the final discharge point. The fluid must first reach the higher elevation in the system. If the shut-off head is smaller than the static head corresponding to the high point, then flow will not be established in the system.

During start-up and checkout of the pump, a quick way to determine if the pump has the potential capacity to deliver the head and flow required, is to measure the shut-off head. This value can be compared to the shut-off head predicted by the performance curve of the pump.

Total Head is proportional to the difference in pressure at the discharge vs. the suction of the pump.

To obtain a higher head, the rotational speed or the impeller diameter can be increased.

- So to calculate your head you need the following...
1. Flow rate in GPM or m³/hour...
 2. Friction losses...

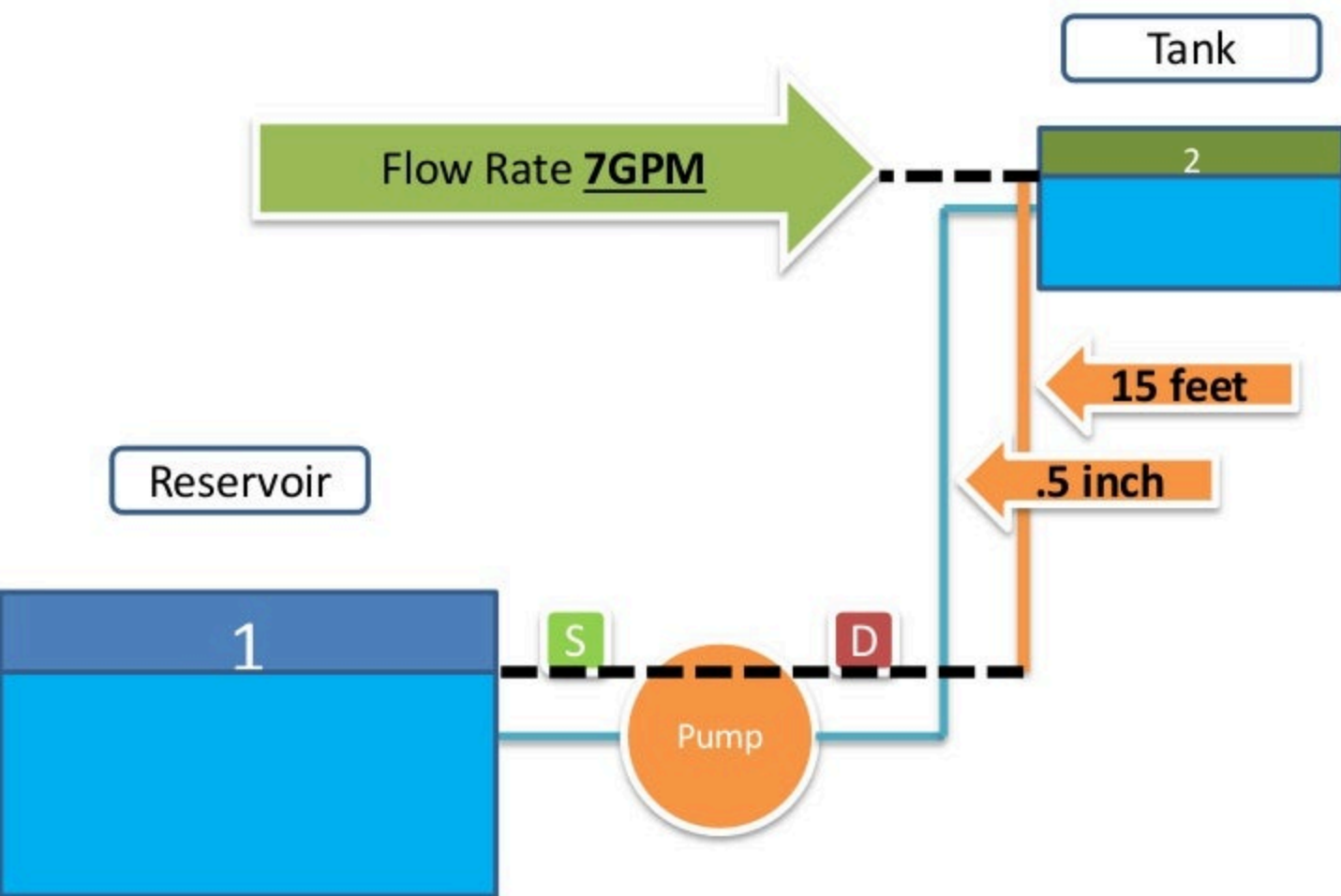
$$[P_D - P_S / \rho] = \text{height}(2-1) + \text{Friction Losses}(2-1)$$


Head

We are going to be using the flowrate of 20 GPM with 50 feet of total NOT VERTICAL pipe.

• How To Choose A Pump

- Usually we choose a pump on the basis of it's head which is basically a generic term given to the total mechanical energy content of a fluid at a given point in a piping system. So once we have established the no. of feet and flow rate that we want we can go to the manufacturer.



Friction of Water **N₁**
(Based on Darcy's Formula)
½ Inch

Flow U S gal per min	Standard wt steel—sch 40					
	0.364" inside dia					
	Velocity ft per sec	Velocity head-ft	Head loss ft per 100 ft			
0.4	1.23	0.024	3.7	1.79	0.05	9.18
0.6	1.85	0.053	7.6	2.69	0.11	19.0
0.8	2.47	0.095	12.7	3.59	0.20	32.3
1.0	3.08	0.148	19.1	4.48	0.31	48.8
1.2	3.70	0.213	26.7	5.38	0.45	68.6
1.4	4.32	0.290	35.6	6.27	0.61	91.7
1.6	4.93	0.378	45.6	7.17	0.80	118.1
1.8	5.55	0.479	56.9	8.07	1.01	147.7
2.0	6.17	0.591	69.4	8.96	1.25	180.7
2.4	7.40	0.850	98.1	10.75	1.79	256
2.8	8.63	1.157	132	12.54	2.44	345

(Based on Darcy's Formula)
½ Inch

¾ Inch

Flow U S gal per min	Standard wt steel—sch 40			Extra strong steel—sch 80		
	0.493" inside dia			0.423" inside dia		
	Velocity ft per sec	Velocity head-ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head-ft	Head loss ft per 100 ft
0.5	0.84	0.011	1.26	1.14	0.02	2.63
1.0	1.68	0.044	4.26	2.28	0.08	9.05
1.5	2.52	0.099	8.85	3.43	0.18	19.0
2.0	3.36	0.176	15.0	4.57	0.32	32.4
2.5	4.20	0.274	22.7	5.71	0.51	49.3
3.0	5.04	0.395	32.0	6.85	0.73	69.6
3.5	5.88	0.538	42.7	8.00	0.99	93.3
4.0	6.72	0.702	55.0	9.14	1.30	120
5.0	8.40	1.097	84.2	11.4	2.0	185
6.0	10.08	1.58	119	13.7	2.9	263

Calculations on pages 3-12 to 3-34 are by Ingersoll-Rand Co.

Note: No allowance has been made for age, difference 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. It is recommended that for most commercial design purposes a safety factor of 15 to 20% be added to the values in the tables—see page 3-5.

Friction of Water **New Steel Pipe (Continued)**
(Based on Darcy's Formula)
½ Inch

Standard wt steel—sch 40			Extra strong steel—sch 80			Schedule 160		
.622" inside dia			.546" inside dia			.464" inside dia		
Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
0.7	0.739	.008	0.74	.96	.01	1.39		
1.0	1.056	.017	1.06	1.37	.03	2.58	1.90	.056
1.5	1.58	.039	1.59	2.06	.07	5.34	2.65	.136

Standard wt steel—sch 40			
.622" inside dia			
Flow U S gal per min	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
5.5	5.81	.524	30.9
6.0	6.34	.624	38.4
6.5	6.86	.732	42.4
7.0	7.39	.849	48.8
7.5	7.92	.975	55.6

7	4.21	.276	11.7	5.20	.42	19.9	7.84	.905	53.0
8	4.81	.360	15.1	5.94	.55	25.6	8.73	1.18	68.4
9	5.42	.456	18.8	6.69	.69	32.1	9.82	1.50	85.8
10	6.02	.563	22.0	7.42	.86	39.2	10.91	1.85	105
11	6.62	.681	27.6	8.17	1.04	47.0	12.00	2.23	126
12	7.22	.722	32.5	8.91	1.23	55.5	13.09	2.66	149
13	7.82	.951	37.9	9.63	1.44	64.8	14.18	3.13	175
14	8.42	1.103	43.7	10.4	1.7	74.7	15.27	3.62	202
16	9.63	1.44	56.4	11.9	2.2	96.7	17.45	4.73	261
18	10.8	1.82	70.8	13.4	2.8	121			
20	12.0	2.25	86.8	14.8	3.4	149			

Note: No allowance has been made for age, difference 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. It is recommended that for most commercial design purposes a safety factor of 15 to 20% be added to the values in the tables—see page 3-5.

- The table does not know how many feet of pipe you have so therefore it lists pressure loss for a 100 feet of pipe.

48.8 feet of head loss

100 feet of pipe

We have 50 feet of pipe

=24 feet

Friction of Water New Steel Pipe (Continued)
(Based on Darcy's Formula)
2 Inch

Flow U S gal per min	Standard wt steel—sch 40			Extra strong steel—sch 80			Schedule 160—steel		
	2.067" inside dia			1.939" inside dia			1.587" inside dia		
	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
5	.478	.004	.074	.54	.00	.101	.718	.008	.197
6	.574	.005	.102	.65	.01	.139	.861	.012	.271
7	.669	.007	.134	.76	.01	.182	1.01	.016	.357
8	.765	.009	.170	.87	.01	.231	1.15	.020	.452
9	.860	.012	.209	.98	.01	.285	1.29	.026	.559
10	.956	.014	.252	1.09	.02	.343	1.44	.032	.675
12	1.15	.021	.349	1.30	.03	.476	1.72	.046	.938
14	1.34	.028	.481	1.52	.04	.629	2.01	.063	1.20
16	1.53	.036	.659	1.74	.05	.809	2.30	.082	1.53
18	1.72	.046	.875	1.96	.06	.991	2.58	.104	1.90
20	1.91	.057	.878	2.17	.07	1.16	2.87	.128	2.31
22	2.10	.069	1.05	2.39	.09	1.38	3.16	.155	2.76
24	2.29	.082	1.18	2.61	.11	1.62	3.45	.184	3.25
26	2.49	.096	1.37	2.83	.12	1.88	3.73	.216	3.77
28	2.68	.111	1.57	3.04	.14	2.16	4.02	.251	4.33
30	2.87	.128	1.82	3.26	.17	2.46	4.31	.288	4.93
35	3.35	.174	2.38	3.80	.22	3.28	5.02	.392	6.59
40	3.82	.227	3.06	4.35	.29	4.21	5.74	.512	8.49
45	4.30	.288	3.82	4.89	.37	5.26	6.48	.648	10.6
50	4.78	.355	4.66	5.43	.46	6.42	7.18	.799	13.0
55	5.26	.430	5.58	5.98	.56	7.70	7.89	.967	15.6
60	5.74	.511	6.58	6.52	.66	9.09	8.61	1.15	18.4
65	6.21	.600	7.66	7.06	.77	10.59	9.33	1.35	21.5
70	6.69	.696	8.82	7.61	.90	12.2	10.05	1.57	24.8
75	7.17	.799	10.1	8.15	1.03	13.9	10.77	1.80	28.3
80	7.65	.909	11.4	8.69	1.17	15.8	11.48	2.05	32.1
85	8.13	1.03	12.8	9.03	1.27	17.7	12.20	2.31	36.1
90	8.60	1.15	14.3	9.78	1.49	19.8	12.92	2.59	40.3
95	9.08	1.28	15.8	10.3	1.6	22.0	13.64	2.89	44.8
100	9.56	1.42	17.5	10.9	1.8	24.3	14.35	3.20	49.5
110	10.52	1.72	21.0	12.0	2.2	29.2	15.79	3.87	58.8
120	11.5	2.05	24.9	13.0	2.6	34.5	17.22	4.61	70.8
130	12.4	2.40	29.1	14.1	3.1	40.3	18.66	5.40	82.6
140	13.4	2.78	33.6	15.2	3.6	46.8	20.10	6.27	95.3
150	14.3	3.20	38.4	16.3	4.1	53.3	21.53	7.20	109
160	15.3	3.64	43.5	17.4	4.7	60.5	22.97	8.19	124
170	16.3	4.11	49.0	18.5	5.3	68.1	24.40	9.24	140
180	17.2	4.60	54.8	19.6	6.0	76.1	25.84	10.36	158
190	18.2	5.13	60.9	20.6	6.6	84.6	27.27	11.54	174
200	19.1	5.66	67.3	21.7	7.3	93.6	28.71	12.79	192
220	21.0	6.88	81.1	23.9	8.9	113			
240	22.9	8.18	96.2	26.9	10.6	134			
260	24.9	9.60	113	29.3	12.4	157			
280	26.8	11.14	130	30.4	14.4	181			
300	28.7	12.8	149	32.6	16.5	208			

Note: No allowance has been made for age, difference 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. It is recommended that for most commercial design purposes a safety factor of 15 to 20% be added to the values in the tables—see page 3-5.

Friction of Water New Steel Pipe (Continued)
(Based on Darcy's Formula)
2½ Inch

Flow U S gal per min	Standard wt steel—sch 40			Extra strong steel—sch 80			Schedule 160—steel		
	2.469" inside dia			2.323" inside dia			2.125" inside dia		
	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft	Velocity ft per sec	Velocity head ft	Head loss ft per 100 ft
8	.536	.005	.072	.61	.01	.097	.724	.008	.148
10	.670	.007	.107	.76	.01	.144	.905	.013	.221
12	.804	.010	.148	.91	.01	.199	1.09	.018	.305
14	.938	.014	.195	1.06	.02	.261	1.27	.025	.403
16	1.07	.018	.247	1.21	.02	.332	1.45	.033	.512
18	1.21	.023	.305	1.36	.03	.411	1.63	.041	.634
20	1.34	.028	.369	1.51	.04	.487	1.81	.051	.767
22	1.47	.034	.436	1.67	.04	.590	1.99	.061	.912
24	1.61	.040	.513	1.82	.05	.681	2.17	.073	1.03
26	1.74	.047	.593	1.97	.06	.800	2.35	.086	1.20
28	1.88	.055	.679	2.12	.07	.915	2.53	.100	1.37
30	2.01	.063	.770	2.27	.08	1.00	2.71	.114	1.56
35	2.36	.086	.999	2.65	.11	1.33	3.17	.156	2.08
40	2.68	.112	1.28	3.03	.14	1.71	3.62	.203	2.66
45	3.02	.141	1.57	3.41	.18	2.13	4.07	.257	3.32
50	3.35	.174	1.91	3.79	.22	2.58	4.52	.318	4.05
55	3.69	.211	2.28	4.16	.27	3.10	4.98	.384	4.85
60	4.02	.251	2.69	4.54	.32	3.65	5.43	.457	5.72
65	4.36	.295	3.13	4.92	.38	4.25	5.88	.537	6.66
70	4.69	.342	3.60	5.30	.44	4.88	6.33	.622	7.67
75	5.03	.393	4.10	5.68	.50	5.58	6.79	.714	8.75
80	5.36	.447	4.64	6.05	.57	6.31	7.24	.813	9.90
85	5.70	.504	5.20	6.43	.64	7.06	7.69	.918	11.1
90	6.03	.565	5.80	6.81	.72	7.89	8.14	1.03	12.4
95	6.37	.630	6.43	7.19	.80	8.76	8.59	1.15	13.8
100	6.70	.696	7.09	7.57	.89	9.66	9.05	1.27	15.2
110	7.37	.844	8.51	8.33	1.08	11.6	9.95	1.54	18.3
120	8.04	1.00	10.1	9.08	1.28	13.7	10.66	1.83	21.6
130	8.71	1.16	11.7	9.84	1.50	16.0	11.76	2.15	25.2
140	9.38	1.37	13.5	10.6	1.7	18.5	12.67	2.49	29.1
150	10.05	1.57	15.5	11.3	2.0	21.1	13.57	2.86	33.3
160	10.7	1.79	17.5	12.1	2.3	23.9	14.47	3.25	37.8
170	11.4	2.02	19.7	12.9	2.6	26.9	15.36	3.67	42.5
180	12.1	2.26	22.0	13.6	2.9	30.1	16.28	4.12	47.5
190	12.7	2.52	24.4	14.4	3.2	33.4	17.19	4.59	52.8
200	13.4	2.79	27.0	15.1	3.5	36.9	18.09	5.08	58.4
220	14.7	3.28	32.5	16.7	4.3	44.4	19.90	6.15	70.3
240	16.1	4.02	38.5	18.2	5.1	52.7	21.71	7.32	83.4
260	17.4	4.72	45.0	19.7	6.0	61.6	23.52	8.59	97.6
280	18.8	5.47	52.3	21.2	7.0	71.2	25.33	9.96	113
300	20.1	6.28	59.8	22.7	8.0	81.6	27.14	11.43	129
350	23.5	8.55	80.6	26.5	10.9	110	31.66	15.56	175
400	26.8	11.2	105	30.3	14.3	144	36.19	20.32	226
450	30.2	14.1	132	34.1	18.1	181	40.71	25.72	286
500	33.5	17.4	163	37.9	22.3	223	45.23	31.75	354

Note: No allowance has been made for age, difference 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. It is recommended that for most commercial design purposes a safety factor of 15 to 20% be added to the values in the tables—see page 3-5.

Height from point 1 to point 2, in our case it is 15ft...

1. You also need to account for the head you're going to be losing because of the friction and you need to accommodate that, you can calculate the lost head due to friction by the use of tables, here you need to know the nominal diameter of your pipe and flow rate in gal/min..... Now all you have to do is add them up...
- Also you ought to add a factor of 15-20 % for a commercial design to the values of the table...

$$(\text{Head}) = 15\text{ft} + 24\text{ft} = 39\text{ft}$$

Characteristic Curves

- The performance of a given pump is commonly illustrated by plots of actual head, power consumption, and efficiency versus volumetric flow rate. These plots are called characteristic curves
- ΔH is head capacity
- P is power of the pump
- η is the pump efficiency
- NPSHR

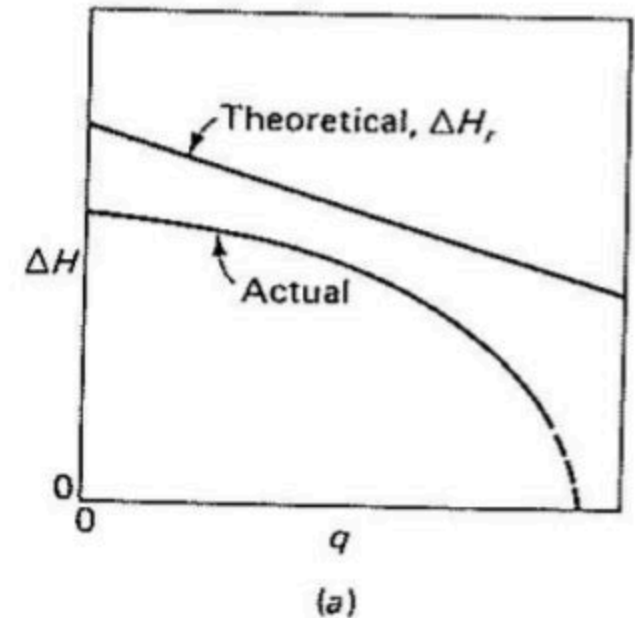


FIGURE 8.12
Characteristic curves of a centrifugal pump.

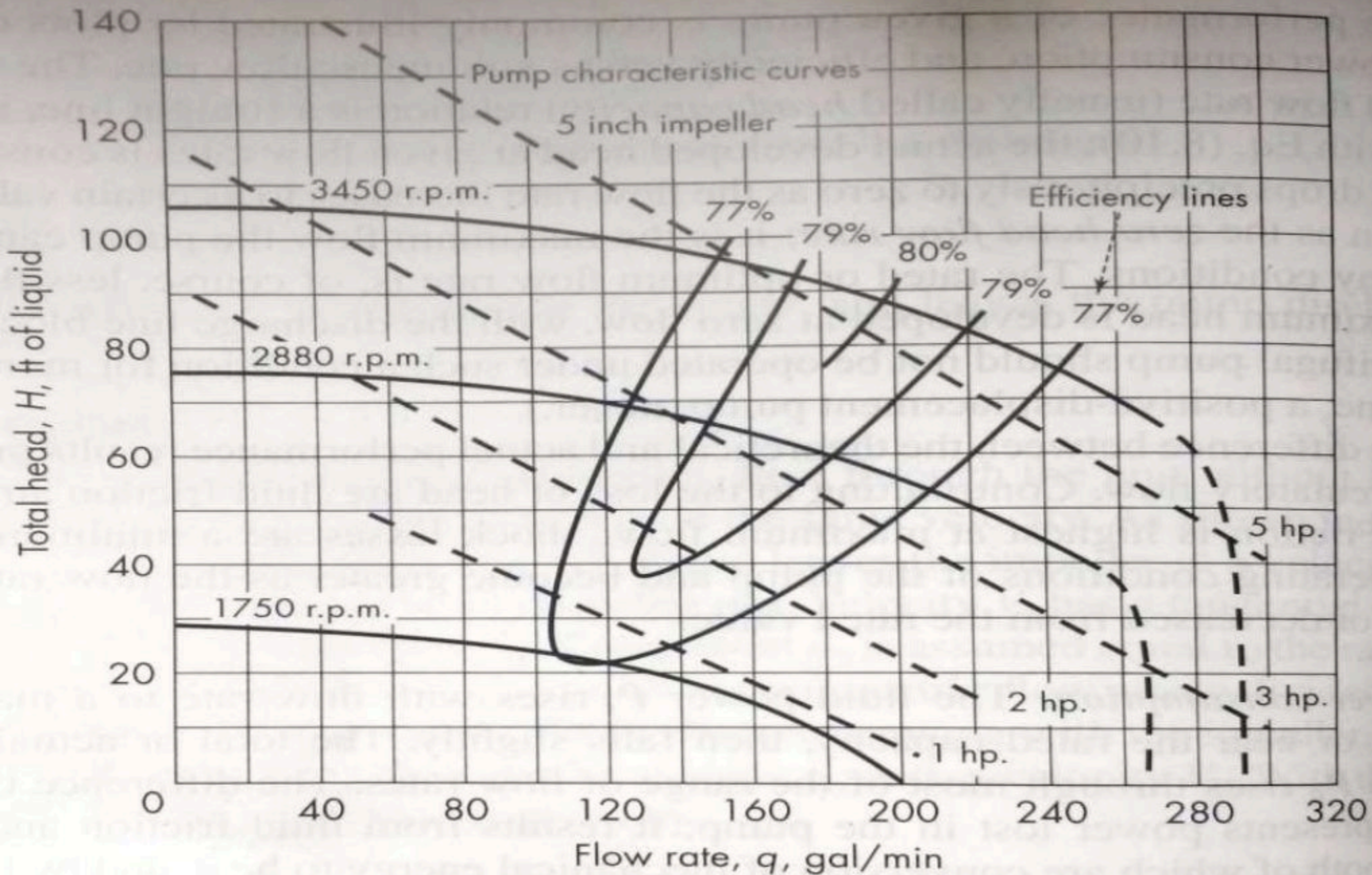


FIGURE 8.10
Characteristic curves of a centrifugal pump operating at various speeds. (By permission from Perry's Chemical Engineers' Handbook,

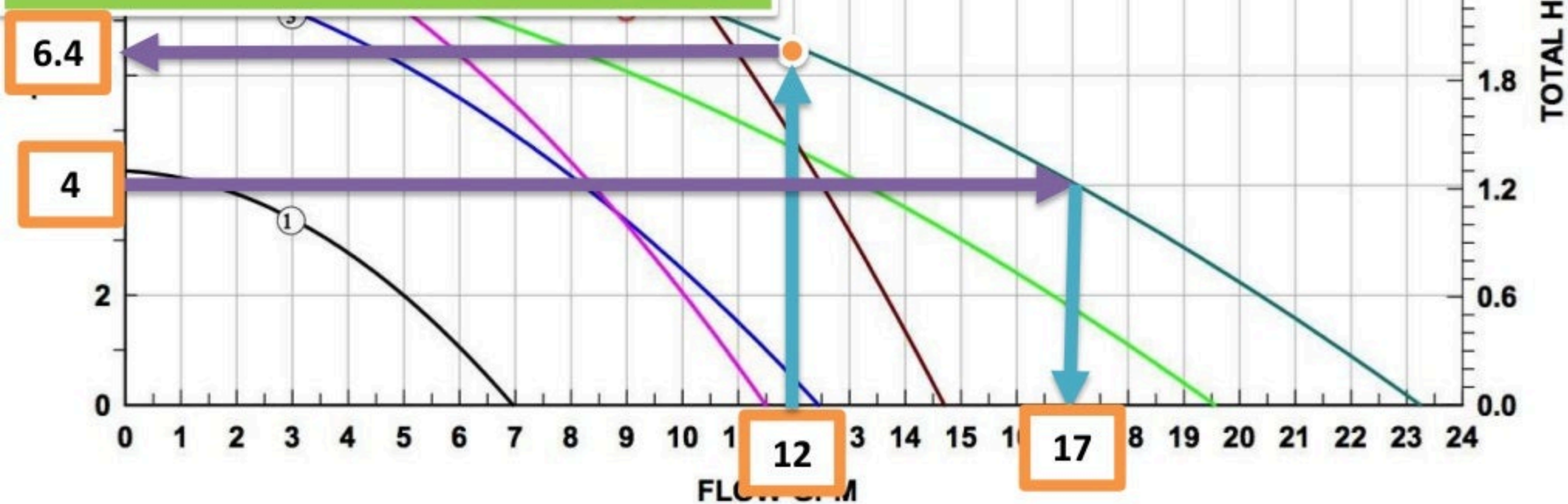
1. Technically if the head and the flow rate operating point for your system is located above on or below a performance curve then that pump will be sufficient to do it's job (but do remember the economics!)...
2. A fixed speed circulator forces the system to work on it's curve, a variable speed circulator adjusts its curve to meet the needs of the system.

Pump Curves

FLOW-M3/H

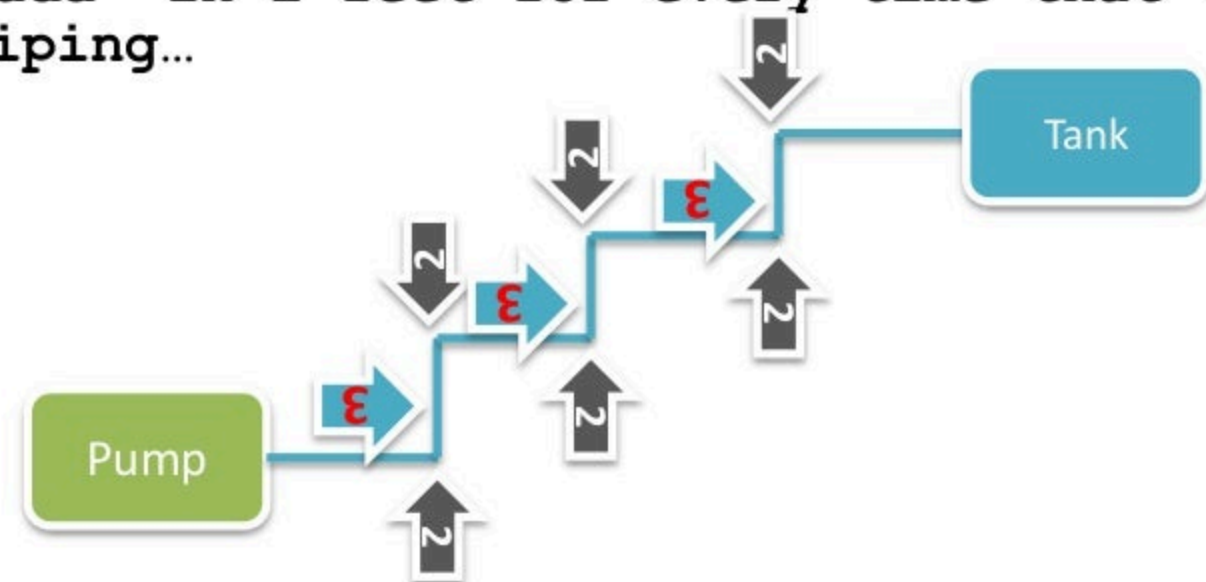
Product
Name

This Means that at flow of 12 GPM in the product 007-(5) the pump will create a head of 6.4 ft. Or at 4 feet of head the pump will generate a flowrate of 17 GPM.



• Pump Head Compensation

- From an industrial point of view pump head is very important, for every elbow/bend in pipe you have to add in a certain no. of head usually in feet in order to accommodate the losses... i.e. 1elbow=2feet then you'd have to add in 2 feet for every time that elbow appears in the piping...



- So, you can see here the elbows are causing us 2 feet loss in head every time they appear so we have to add that in order to compensate the losses... We also have 3 ft. loss in head due to the vertical piping, we don't count in horizontal piping...
- So, Total Head = 9ft. + 12ft. + some excess feet to be safe...

• Cavitations And NPSH

- If the suction pressure is only slightly greater than the vapor pressure some liquid may flash to vapor inside the pump a process called as cavitations which greatly reduces the pump capacity and causes severe erosion. If the suction pressure is actually less than the vapor pressure there will be vaporization in the suction line and no liquid can be drawn into the pump.
- To avoid the cavitations the pressure at pump inlet must exceed the vapor pressure by a certain value called as the net positive suction head. The required value of NPSH is about 2 to 3 m (5 to 10 ft) for small centrifugal pumps but It increases to 15m (50 ft) are recommended for larger pumps.



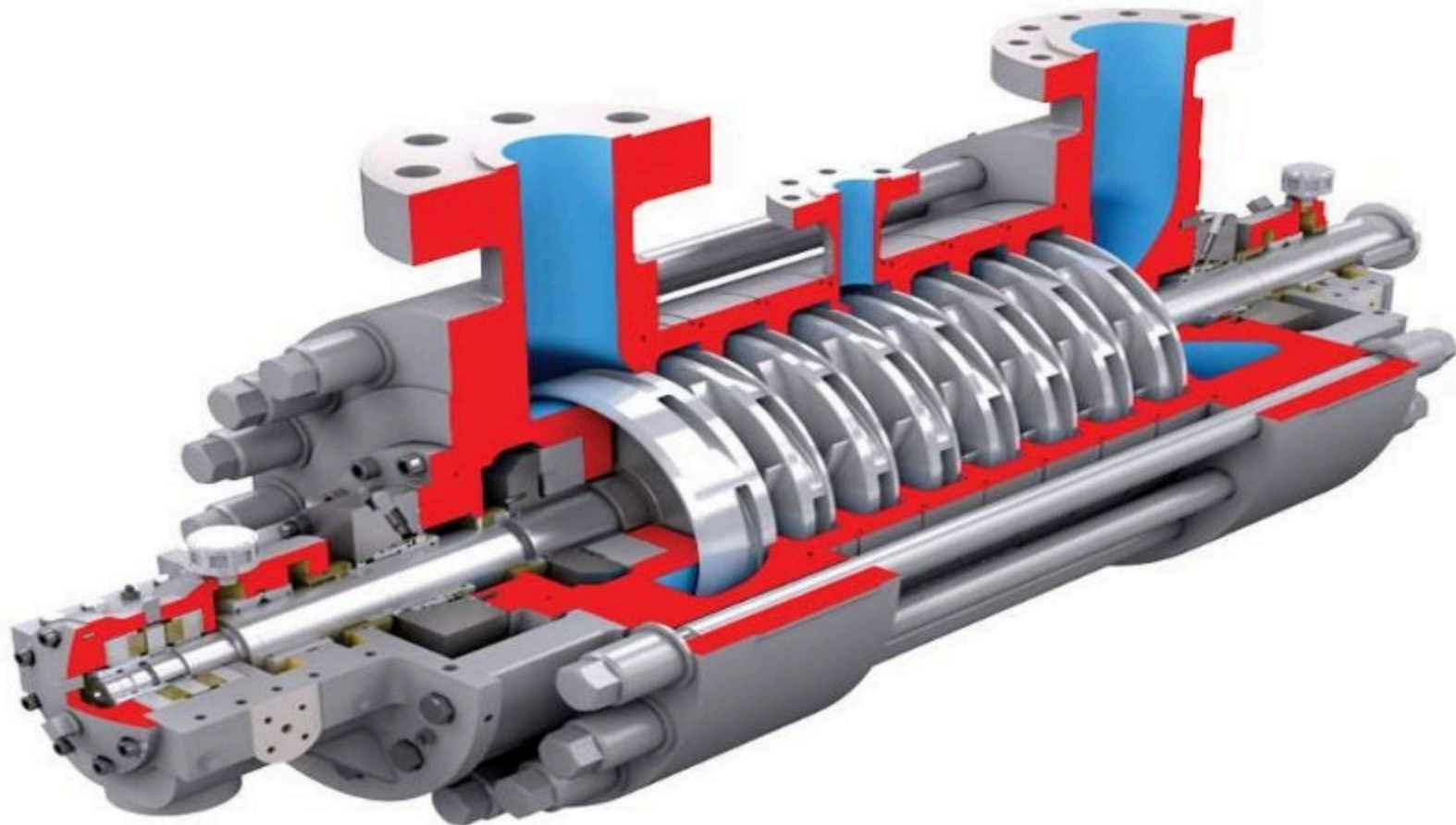
A blue hexagon with a white border, centered on a white background.

Tid Bits

Rotary Pumps

Multi Stage Centrifugal Pumps

- High energy centrifugal can generate a head of 200 m only.
- To increase the head (>200 m), multistage centrifugal pumps is used where multiple impeller is installed on a single shaft.



PEERLESS PROCESS PUMPS

MODEL
8196MT

RPM
1750

SIZE
4 x 6-10

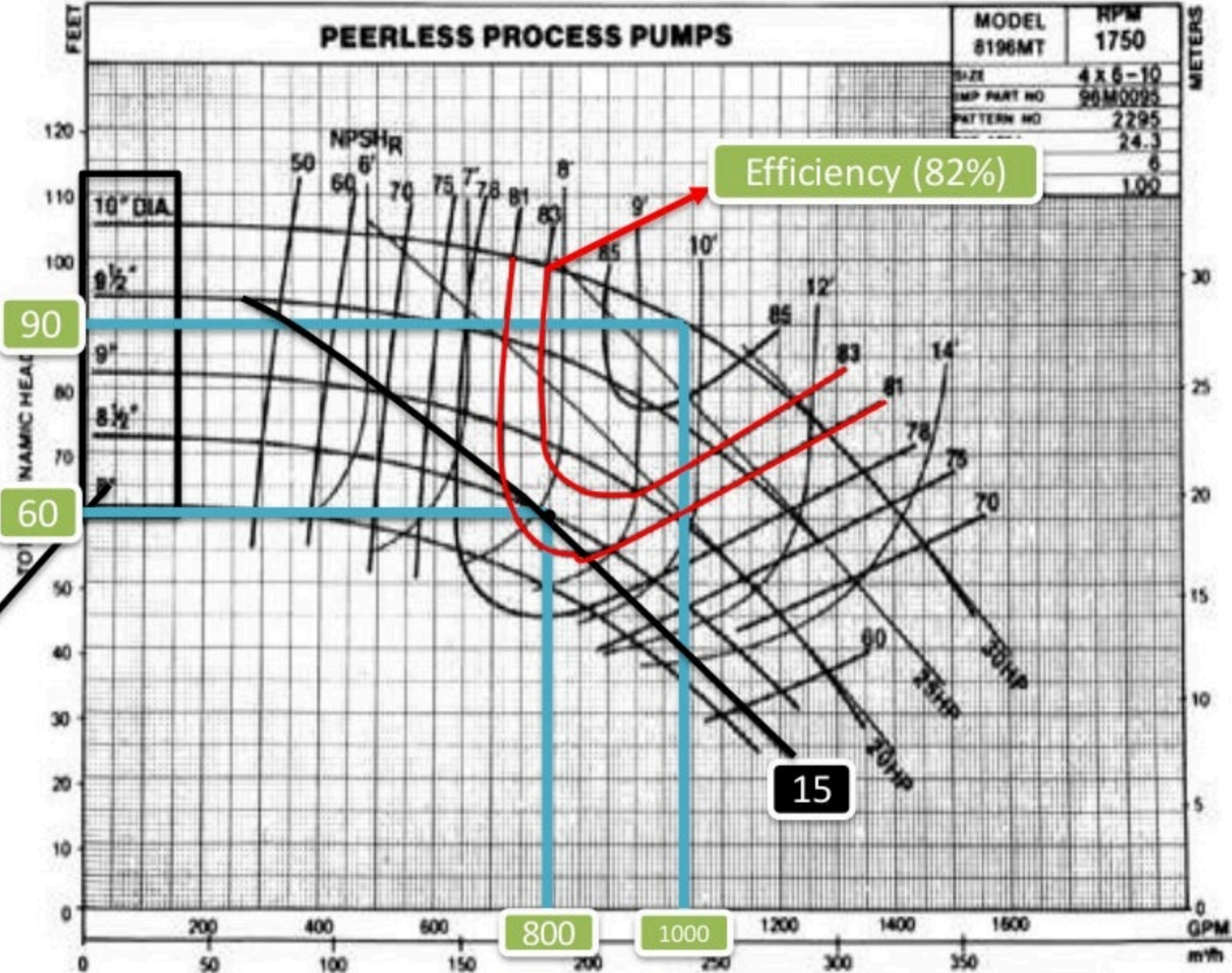
IMP PART NO
90M0025

PATTERN NO
2295

24.3

6

1.00



Efficiency (82%)

90

60

15

800

1000

Imp. Dia.

Pump Priming

- What is it?
- To remove the entrapped air inside the pump is called pump priming
- When we do it?
 1. First start up after a long time
 2. First start up after maintenance
 3. First start up for a new pump
- How we do it?
- If there is any air entrapped in the suction line, we need to replace this air with liquid.
- Air can be displaced by pouring liquid from any tank into the suction line and submerge the pump impeller...

Positive displacement pump can compress the gas to a required discharge pressure, that's why they are known to self priming...

Pump Priming

Priming of a pump is very essential step in start up of a centrifugal pump.

Fact is that centrifugal pump are not capable of pumping air or vapors.

Priming is the process in which the impeller of a centrifugal pump will get fully sub merged in liquid without any air trap inside. This is especially required when there is a first start up. But it is advisable to start the pump only after priming.

Liquid and slurry pumps can lose prime and this will require the pump to be primed by adding liquid to the pump and inlet pipes to get the pump started. Loss of "prime" is usually due to ingestion of air into the pump. The clearances and displacement ratios in pumps used for liquids and other more viscous fluids cannot displace the air due to its lower density.

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Pump Safety

A note about centrifugal pump is that it doesn't require a safety valve while a P.D pump must have a safety valve because at certain pressure C.F pump will stop producing any further pressure while the P.D pump will continue to increase pressure with every stroke until or unless the Safety valve blows or the discharge is opened..

Turbulence

Turbulence may be generated in other ways than by flowing fluid in a pipe.. in general however it results from either of these scenarios, one is the flowing fluid gets In contact with a solid boundary called as the wall turbulence or two fluid layers moving with varying velocities contact called as the free turbulence.. Free turbulence is especially important in mixing..