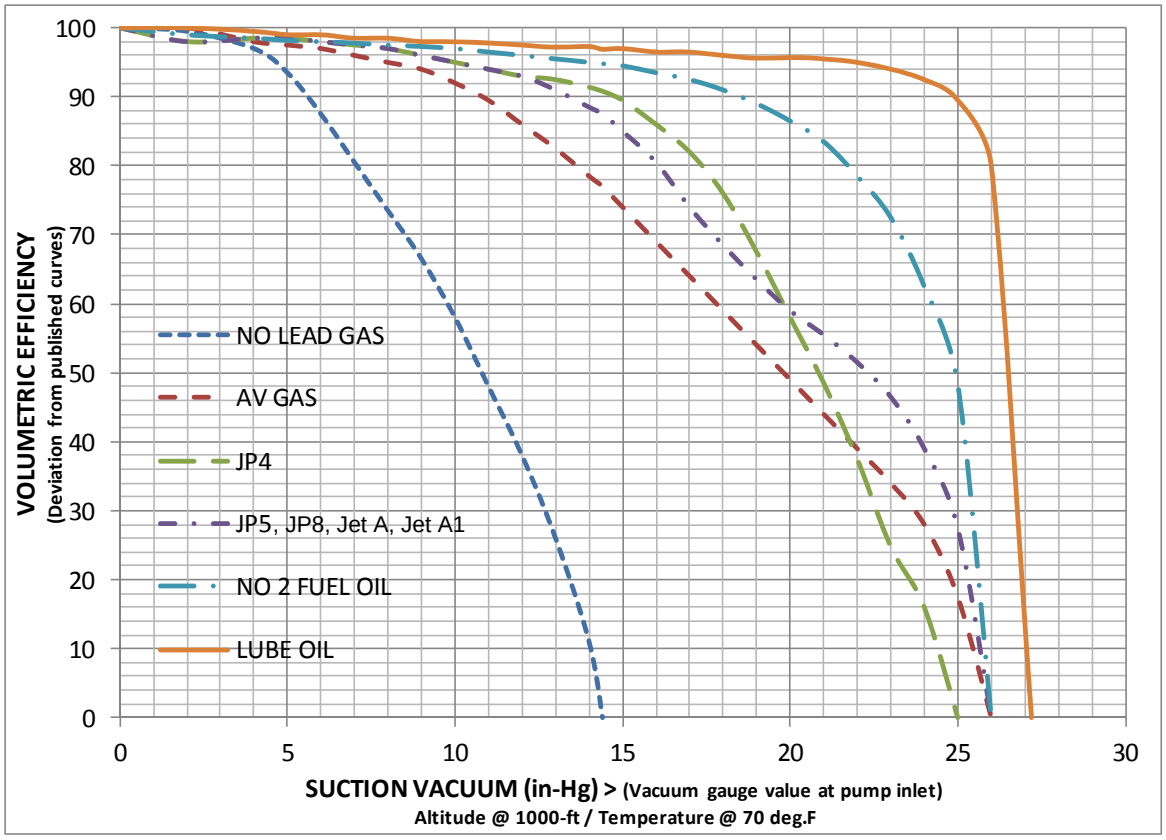
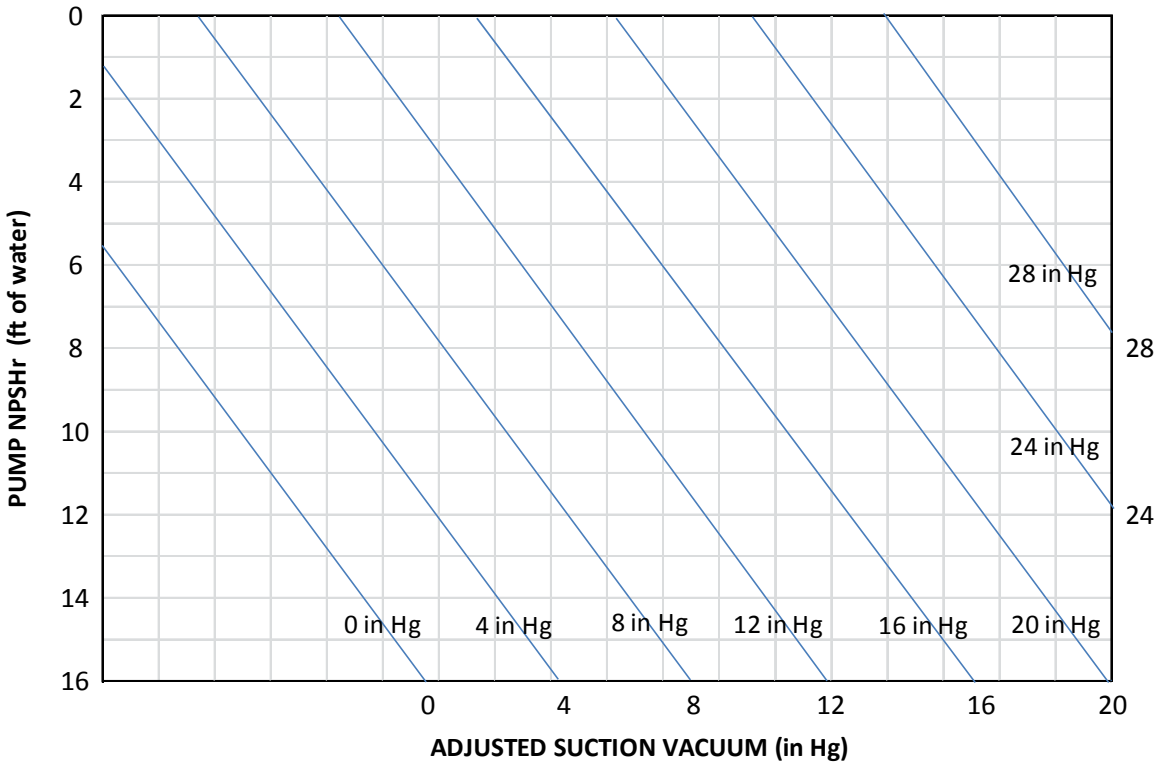

VOLUMETRIC EFFICIENCY
(Deviation from published curves)
100
90
80
70
60
50
40
30
20
10
0
NO LEAD GAS
AV GAS
JP4
JP5, JP8, Jet A, Jet A1
NO 2 FUEL OIL
LUBE OIL
0
5
10
15
20
25
30
SUCTION VACUUM (in-Hg) > (Vacuum gauge value at pump inlet)
Altitude @ 1000-ft / Temperature @ 70 deg.F


PUMP NPSHr (ft of water)
0
2
4
6
8
10
12
14
16
28 in Hg
24 in Hg
0 in Hg
4 in Hg
8 in Hg
12 in Hg
16 in Hg
20 in Hg
28
24
0
4
8
12
16
20
ADJUSTED SUCTION VACUUM (in Hg)

Overview:
Many fuels and hydrocarbon mixtures include volatile or light hydrocarbons that are dissolved in organic liquids. A typical example is gasoline which includes n-Butane has a very high vapor pressure).

COMPOSITION and INFORMATION ON INGREDIENTS - GASOLINE

Ingredient Name (CAS No.)	Concentration Percent by Weight
Gasoline (86290-81-5)	100
Benzene (71-43-2)	0.1 - 4.9 (0.1 - 1.3 reformulated gasoline)
n-Butane (106-97-8)	< 10
Ethyl Alcohol (Ethanol) (64-17-5)	0 - 10
Ethyl benzene (100-41-4)	< 3
n-Hexane (110-54-3)	0.5 to 4
Methyl-tertiary butyl ether (MTBE) (1634-04-4)	0 to 15.0
Tertiary-amyl methyl ether (TAME) (994-05-8)	0 to 17.2
Toluene (108-88-3)	1 - 25
1,2,4- Trimethylbenzene (95-63-6)	< 6
Xylene, mixed isomers (1330-20-7)	1 – 15

As gasoline, hydrocarbon mixtures, or other fuels are drawn into the pump, the lighter hydrocarbons such as n-Butane can come out of solution and vaporize in the suction line. The vapor will then be collapsed into liquid phase as the flow passes through the pump (similar effect as cavitation). The result is that the actual flow rate through the pump is reduced.

Quantitative Effects:
The reduction in flow rate from published curves (a component of pump volumetric efficiency) can be measured during laboratory testing. The volumetric efficiency is correlated to the vacuum or absolute pressure at the pump suction and the pump Net Positive Suction Head Required (NPSHr). Data has been taken for five of the most common hydrocarbon fuels and lubricating oil. Also note that adjustments must be made for liquid temperature. One additional reminder, the altitude of the installation must be considered when determining the vacuum/pressure at the pump inlet.

Note that many systems will provide adequate pressure at the pump inlet and there will be no reduction in volumetric efficiency.

Use of Graph – New Applications
The volumetric efficiency for some fuels and mixtures can be estimated utilizing the Graph.
For <u>new applications</u> you will need:

- Required flow rate
- Desired Volumetric Efficiency (usually 90% is selected)
- Pump model selection including RPM (NPSHr can then be determined)
- Liquid temperature – See chart for inlet pressure/vacuum adjustment based on temperature. Graph assumes liquids at 70 deg F.).
- Altitude – When determining the pressure/vacuum at the pump suction, adjust the atmospheric pressure based on altitude. See Altitude chart below. Or, if pumping from a closed vessel, use vapor space pressure.

Temperature Adjustment	
Liquid Temp. Deg F	Increase Vacuum by
70	0.0 inches Hg
80	0.5 inches Hg
90	1.0 inches Hg
100	1.5 inches Hg
110	2.0 inches Hg

Example: If the calculated inlet vacuum is determined to be -5 in. Hg, and temperature of liquid is 90 deg. F, adjusted inlet pressure is then -6 in Hg.

Altitude Above Sea Level	Absolute Barometer		Absolute Pressure	
	inch Hg	mm Hg	PSI	Ft of Water
0	29.9	760	14.7	34.0
500	29.4	746	14.4	33.3
1000	28.9	733	14.2	32.9
1500	28.3	720	13.9	32.2
2000	27.8	707	13.7	31.6
2500	27.3	694	13.4	31.0
3000	26.8	681	13.2	30.5
3500	26.3	669	12.9	29.9
4000	25.8	656	12.7	29.3
4500	25.4	644	12.5	28.9
5000	24.9	632	12.2	28.3
6000	24.0	609	11.8	27.3
7000	23.1	586	11.3	26.3
8000	22.2	564	10.9	25.4

The Volumetric Efficiency Graph will allow one to determine either the maximum NPSHr **or** lowest suction pressure.

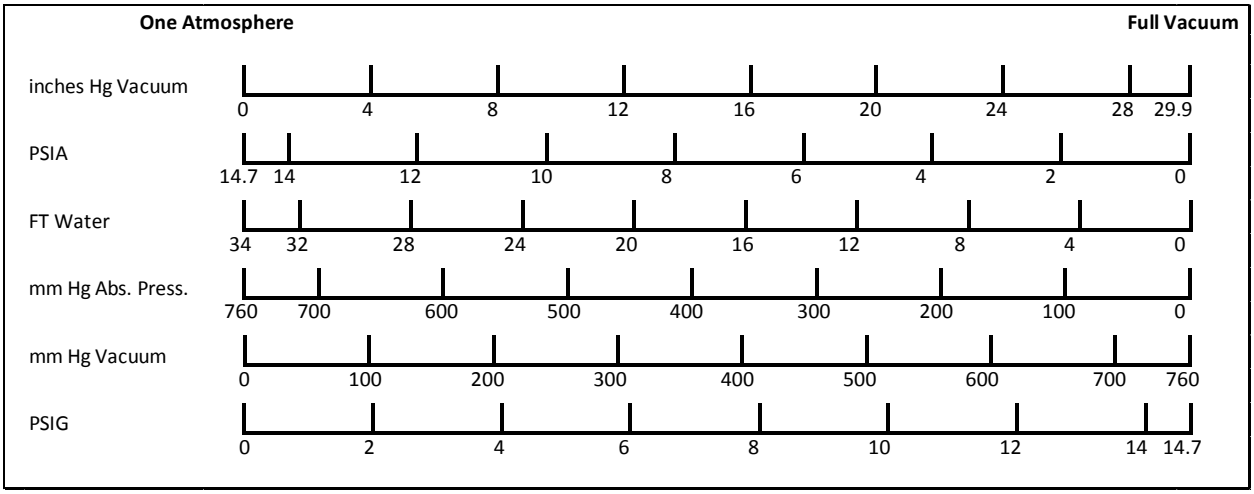
Use of Graph – Existing Applications

One can also analyze an **existing system** and estimate the volumetric efficiency. From the existing installation, determine:

- Pump RPM (and obtain NPSHr)
- Suction pressure at pump inlet utilizing a compound pressure/vacuum gauge. All Blackmer pumps have a gauge connection port at pump inlet. Remember to adjust for liquid temperature.

Chart will tell you the predicted volumetric efficiency. Multiply the calculated efficiency by the flow rate from the pump performance curve to obtain the actual flow rate.

Nomograph correlating vacuum and pressure values ranging from full vacuum and one atmosphere:



Here are two examples:

Example #1

Select a new pump for AvGas at 90 deg F. that will pass 100 GPM. Design for 90% volumetric efficiency (therefore select a pump with an operating point at 110 GPM). The vacuum at pump inlet is 9 in Hg. What is maximum NPSHr allowed to meet the 90% volumetric efficiency requirement?

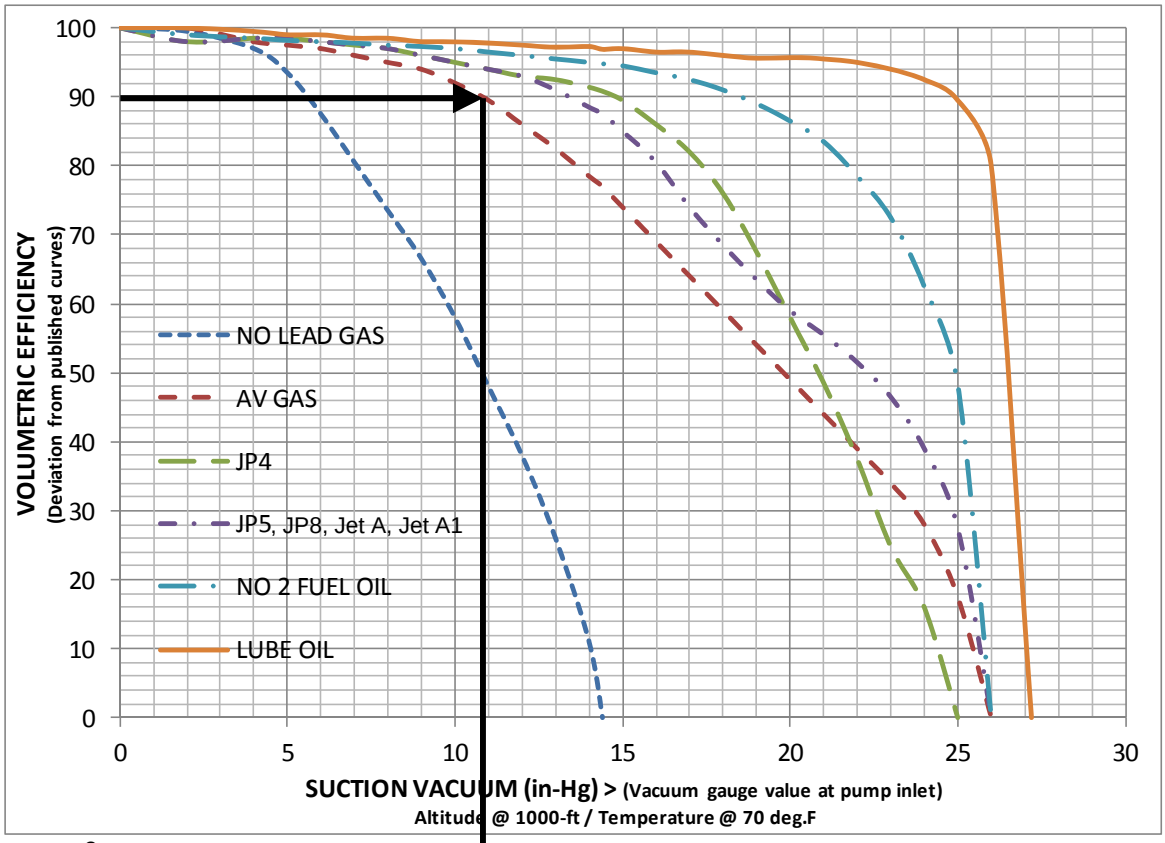
1. Adjust for temperature 9 + 1 = 10 in Hg Vacuum
2. Enter chart at 90% volumetric efficiency. Go horizontal to the AvGas curve.
3. Go vertically down to the suction pressure of 10 in Hg Vacuum
4. Then go horizontal to the axis at left. The maximum NPSHr is approximately 6.5 feet of water to achieve a 90% volumetric efficiency.

Example #2

Assume there is an existing pump for JP4 jet fuel. The system includes a Blackmer pump with NPSHr of 8' water. The suction pressure is 16 in Hg.

What is volumetric efficiency?

1. Enter the chart at NPSHr of 8'.
2. Move horizontally to 16 in Hg suction. Then go vertically up until you cross the curve for JP4 fuel.
3. Go to the left axis and read a volumetric efficiency of 72%.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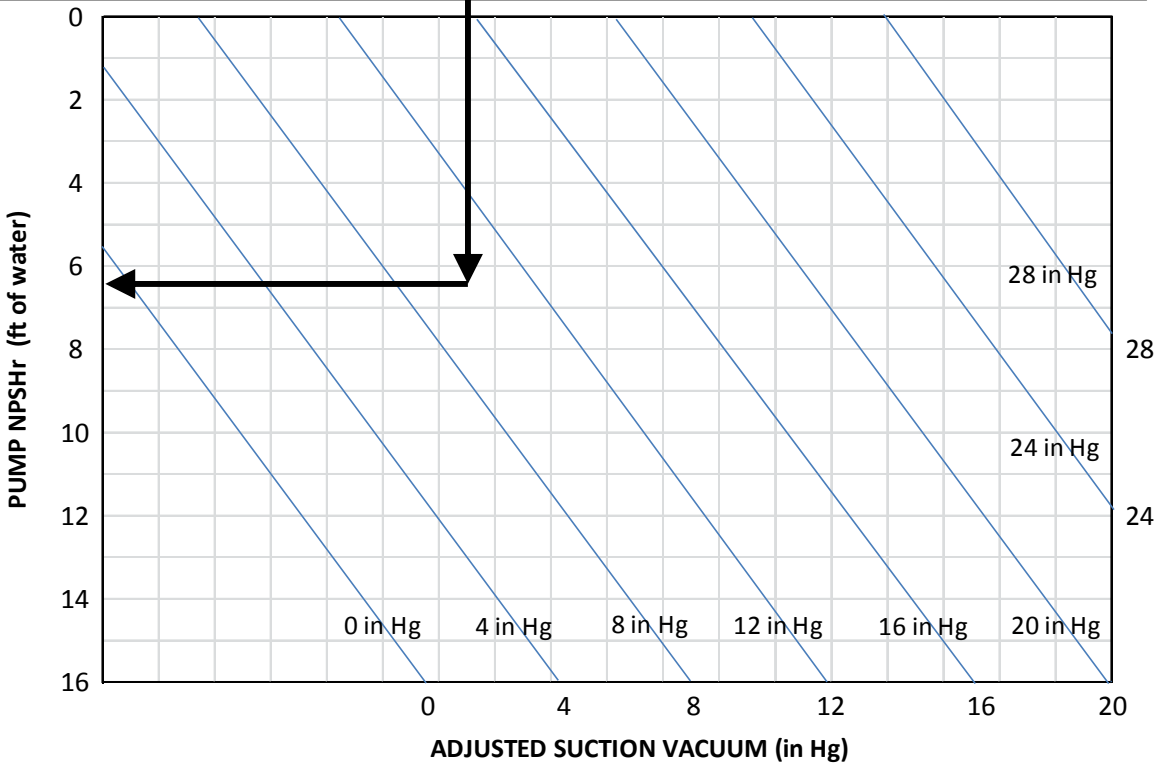
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16 in Hg
20 in Hg
0
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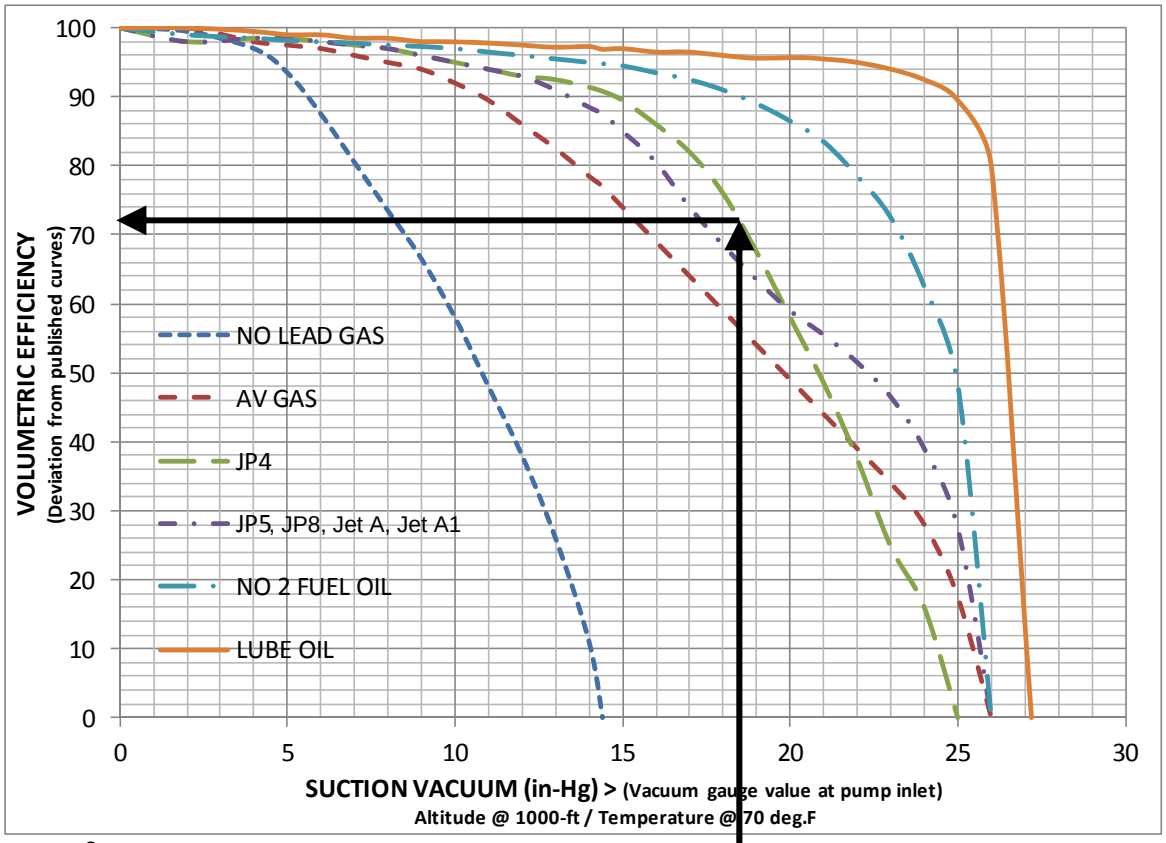
16
20
ADJUSTED SUCTION VACUUM (in Hg)

EXAMPLE #1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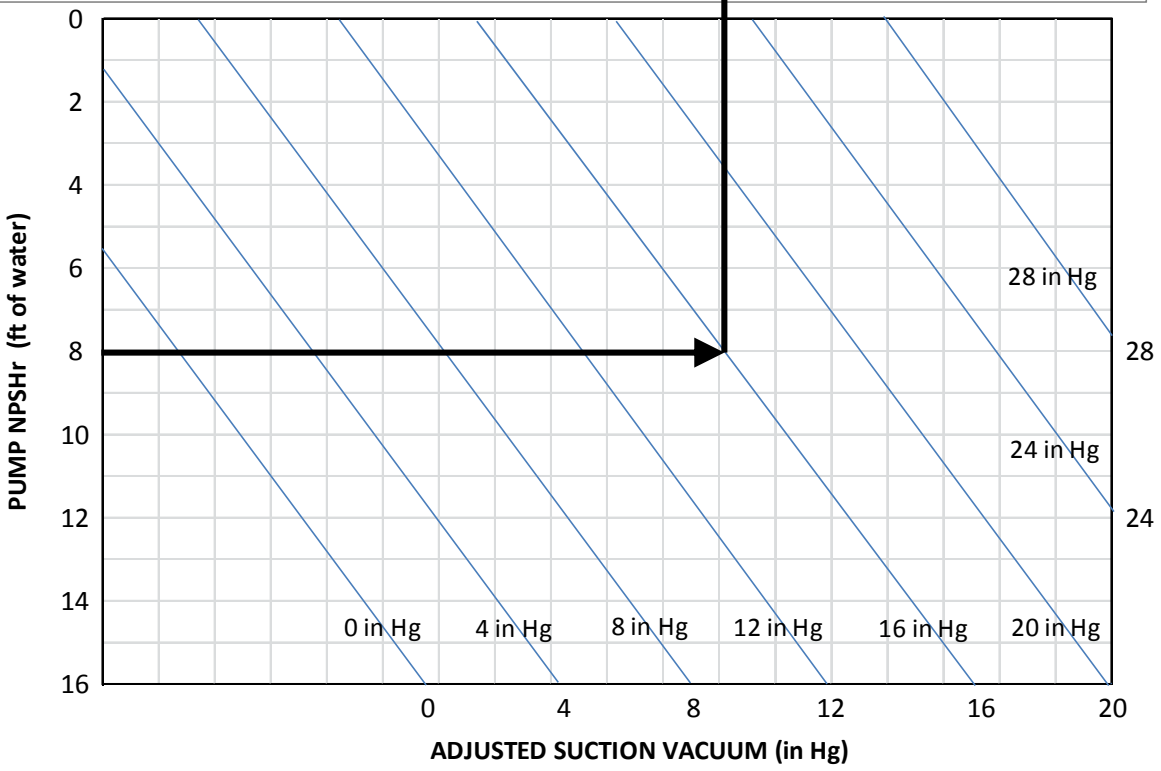
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ADJUSTED SUCTION VACUUM (in Hg)

EXAMPLE #2