Blackmer®

UNDERGROUND TANK
APPLICATION GUIDE

Practical suggestions on the design and installation of underground
piping systems for liquefied petroleum gases
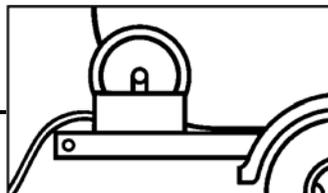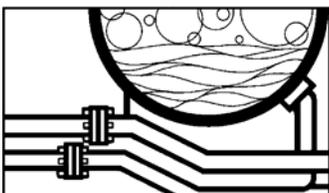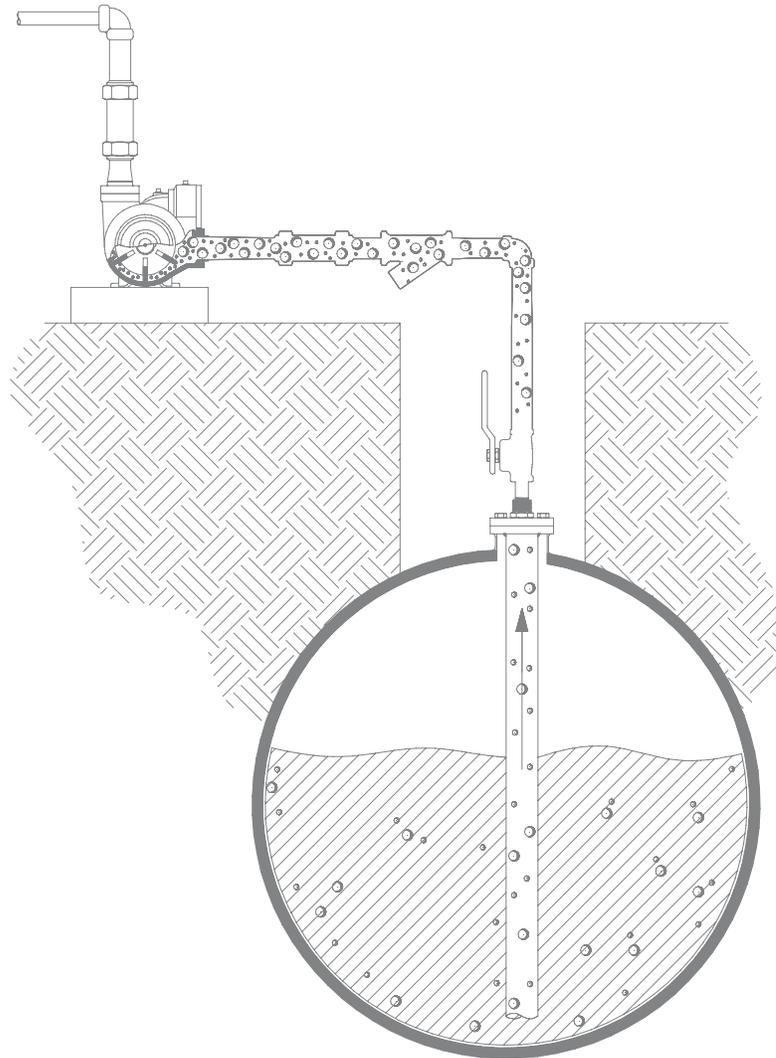
Bulletin 500-002

This GUIDE is to present practical solutions to the problem of attempting to lift LPG from underground tanks with a pump. The drawings in this guide portray only those components pertinent to the topic being discussed.

Before installing any propane equipment, review the requirements of N.F.P.A. Pamphlet No. 58 "Standard for the Storage and Handling of Liquefied Petroleum Gases."

You can obtain a copy from:
National Fire Protection Association
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web: www.nfpa.org

This pamphlet is generally accepted by regulatory authorities and is the industry guide to safety in equipment and handling procedures. In addition, check state and local laws and ordinances on the subject.

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Information for all Blackmer products, both present and past models, is available at our website. Specification Sheets, Parts Lists, Instruction Manuals and more are all available worldwide 24 hours a day.

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1 LPG Properties

1-1 *General Characteristics of Liquefied Petroleum Gas (LPG)*

LPG is a common name given to a number of fuels of which Butane and Propane are the most widely used. Butane and propane are gases when at atmospheric pressure and normal temperatures, but they are compressed into a liquid for transport and storage. When liquefied, these fluids are always at the boiling point at equilibrium conditions. The slightest drop in pressure, or the least addition of heat will cause the liquid to boil and produce vapor or gas. This characteristic becomes critical when transferring liquefied gases from one tank to another, and especially critical when pumping from an underground tank application.

1-2 *Compressing Vapor and Gas*

When a vapor or gas is compressed to a higher pressure, its temperature will rise. As the heat generated by compression is dissipated, the vapors will condense into liquid. Conversely, when the pressure is released, the temperature will drop as the gas expands and the liquid vaporizes.

1-3 *Properties of Liquefied Gases*

Refer to table 1 for properties of liquefied gases. This information is derived from commercial grade fluids and the figures provided represent <u>average</u> values. Refer to figure 1 for vapor pressure of liquefied gases.

1-4 *Effect of Vaporization*

Refer to figure 2 for an illustration of the effects of vaporization on an underground tank application. As the liquid level drops in the tank, the vapor above expands and its pressure drops. Immediately, the liquid in the tank begins to boil, creating vapor bubbles. Liquid entering the dip tube carries some of the bubbles with it. Each restriction in the pump inlet piping drops the pressure of the liquid-vapor mixture, causing the vapor bubbles to expand and causing more boiling and more vapor bubbles to form. In addition, a significant pressure reduction for lifting applications is due merely to the change in elevation from the tank fluid level to the pump inlet. All the vapor bubbles entering the pump are rapidly collapsed back into liquid when they move to the discharge side of the pump. LPG vapor occupies much more space when vaporized than in the liquid form. Therefore, a significant volume reduction occurs whenever a vapor bubble is collapsed on the discharge side of the pump. This explains why a pumping system never delivers as much actual liquid as the pump flow rating would indicate.

1-5 *Effects of Temperature and Fluid Mixture*

Vaporization of fluid at the pump inlet will cause reduced flow. Temperature and propane/butane mixture ratios will also affect delivery rates. Reducing the temperature of the fluid or increasing the percentage of butane in the fluid will reduce the vapor pressure in the storage tank. Lower vapor pressure results larger vapor bubble formation since gas volume is inversely proportional to pressure. Refer to figure 1.

Blackmer pumps are typically rated for 100% propane at 80º F (27° C) when properly installed below the supply tank. The delivery rate of propane at 32º F (0° C) will only be about 80% of the rated capacity at 80º F (27° C). The delivery rate of butane will be about 60% to 70% of the rated capacity, and will be as low as 35% to 45% at 32º F (0º C). Pumps withdrawing LPG from an underground tank will have lower flows than pumps withdrawing liquid from the bottom of an above ground tank. Propane/butane mixture ratios, fluid temperature and inlet piping all affect a pump's delivery rates

Table 1. Properties of Liquefied Gases[1] - (English Units)

	Propane	Butane
Formula	C_3H_8	C_4H_{10}
Initial Boiling Point at 14.7 PSIA, ºF	-44°	31°
Vapor Pressure (PSIG) at:		
70 ºF	109	17
100 ºF	172	37
105 ºF	185	41
130 ºF	257	67
Specific Gravity of Vapor (Air = 1.00) @ atmosphere and 60 ºF	1.52	2.01
Specific Gravity of Liquid at 60 ºF	0.508	0.584
Weight per Gallon of Liquid at 60 ºF, Lbs	4.23	4.86
Cubic Feet of Vapor at 60 ºF/Gallon of Liquid at 60 oF	36.45	31.28
Cubic Feet of Vapor/Lb of Liquid at 60 oF	8.62	6.54
Cubic Feet of Vapor/Cubic Feet of Liquid at 60 oF	272	238
Latent Heat of Vaporization at Boiling Point		
BTU per Gallon	774	797
BTU per Pound	183	166
Combustion Data		
Cubic Feet of Air required to burn 1 Cubic Foot of Vapor	23.87	31.03
Ignition Temperature in Air, ºF	950 to 1,080°	890 to 1020°
Maximum Flame Temperature in Air, ºF	3,497°	3,447°
Total Heating Values after Vaporization:		
BTU per Cubic Foot of Vapor at 60 oF	2521	3267
BTU per Pound	21690	21340
BTU per Gallon	91300	103000
Limits of Inflammability, Percentage of Vapor in Air Mixture:		
At Lower Limit - %	2.0-2.4	1.5-1.9
At Upper Limit - %	7.0-9.5	5.7-8.5

[1] From Handbook Butane-Propane Gases, Third Edition, Copyright 1951, Jenkins Publications

Table 1. Properties of Liquefied Gases – (Contd.)
(Metric Units)

	Propane	Butane
Formula	C_3H_8	C_4H_{10}
Initial Boiling Point at 1.00 Atm. Pressure, C	-42°	-1°
Vapor Pressure (bar) at:		
20 °C	7.5	1
40 °C	11.9	2.5
45 °C	12.8	2.8
55 °C	17.7	4.6
Specific Gravity of Vapor (Air = 1.00)	1.50	2.01
Specific Gravity of Liquid at 16 C	0.504	0.582
Weight per Cubic Meter of Liquid at 16 C, kg	507	582
Cubic Meter of Vapor at 16 C/Liter of Liquid at 16 C	0.271	0.233
Cubic Meter of Vapor/Kilogram of Liquid at 16 C	0.536	0.407
Cubic Meter of Vapor/Cubic Meter of Liquid at 16 C	272	234
Latent Heat of Vaporization at Boiling Point		
Kilojoule per Liter	216	222
Kilojoule per Kilogram	426	386
Combustion Data		
Cubic Meters of Air required to burn 1 Cubic Meter of Vapor	23.87	31.03
Ignition Temperature in Air, C	510 – 582°	477 – 549°
Maximum Flame Temperature in Air, C	1925°	1897°
Total Heating Values after Vaporization:		
Kilojoule per Cubic Meter of Vapor at 16 C	9387	12165
Kilojoule per Kilogram	50449	49635
Kilojoule per Liter	25444	28705
Limits of Inflammability, Percentage of Vapor in Air Mixture:		
At Lower Limit - %	2.0 – 2.4	1.5 – 1.9
At Upper Limit - %	7.0 – 9.5	5.7 – 8.5

Vapor Pressure of Propane and N-Butane
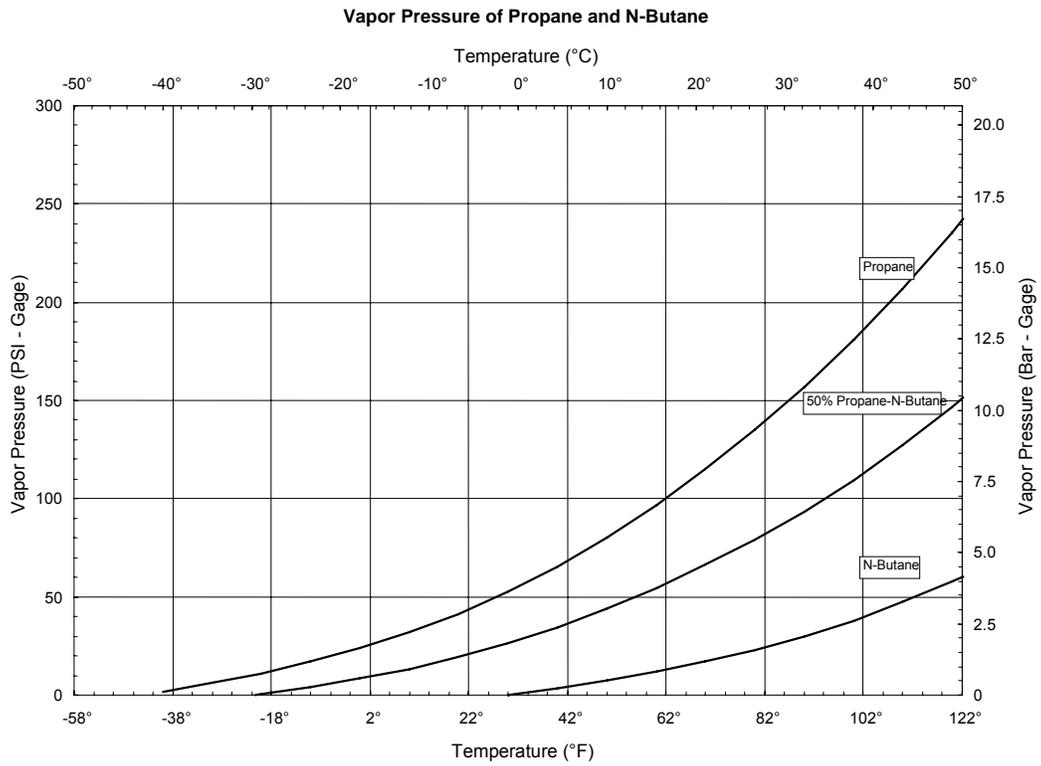
Figure 1. Vapor Pressure of Liquefied Gases
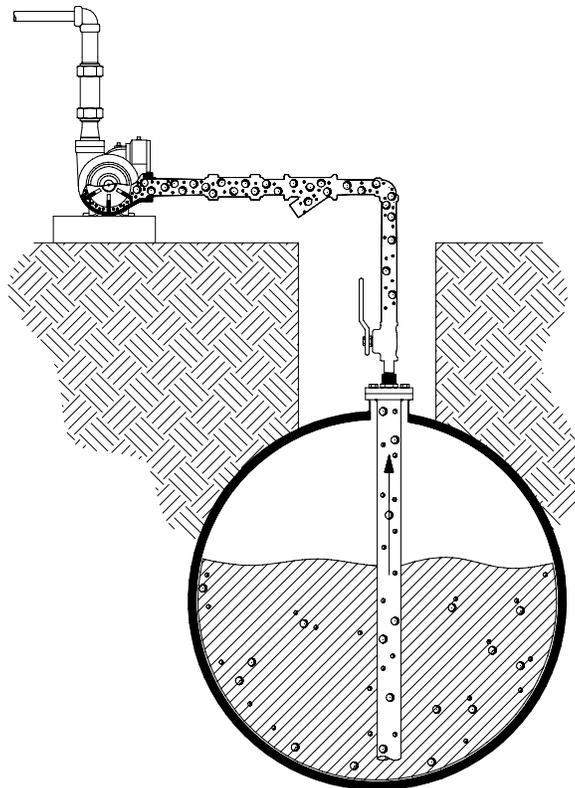
Figure 2. Vaporization in an Underground Tank and Piping

2 Guidelines for Underground Tank Installation

When pumping from an underground tank, the change in elevation from the fluid level in the tank to the inlet of the pump will cause significant vaporization of the fluid in the inlet piping. For this reason alone, it is impossible to prevent vaporization at the inlet of the pump for an underground tank installation. However, there are many things that can be done to minimize these effects. The following paragraphs are presented as a method to optimize the performance of an underground tank application. Refer to figure 3 as a guide to a typical underground tank application.

2-1   Vapor Removal During Startup

For an underground tank installation, the piping between the pump and the tank is filled with vapor when the pump is at rest. This vapor must be removed before the pump can be primed with liquid and before adequate performance can be expected. Fortunately, a sliding-vane positive-displacement pump, such as Blackmer's LGL pumps, is capable of moving vapor as well as liquid. This enables the pump to "self-prime" and rapidly establishes liquid flow. However, when a pump is operating without liquid, excessive heat and wear will result. The following paragraphs are provided as a guide to reduce the amount of vapor during startup.

2-1.1 Inlet Piping Length

Keep the inlet piping as short as possible. Install the pump directly over the tank and as close to the ground as possible. This will eliminate the overall volume of vapor that the pump must remove during startup.

2-1.2 Minimize the Number of Fittings

Every fitting, valve, and piece of straight piping causes a pressure drop. During initial startup and also during normal operation, the pressure drop caused by the inlet piping components will lead to vaporization. Use a minimum number of fittings on the inlet side of the pump. Eliminate all possible elbows in the inlet piping by moving the pump so that they will not be necessary. If possible, rotate the pump inlet so it is vertically orientated and can be piped directly to the inlet piping. Sizing the inlet piping one or two pipe sizes <u>larger</u> than the inlet of the pump will reduce the overall pressure loss of the inlet piping.

2-1.3 Strainers

Suction strainers should not normally be used on underground tank installations as they create a significant pressure drop during priming and normal operation. Contaminates in a tank should settle to the bottom. In a properly designed system, the end of the dip tube should be placed two to three inches (five to eight centimeters) above the bottom of the tank. In applications with known high levels of contaminates, install a strainer that is one or two sizes larger than the pump inlet to minimize the pressure drop.

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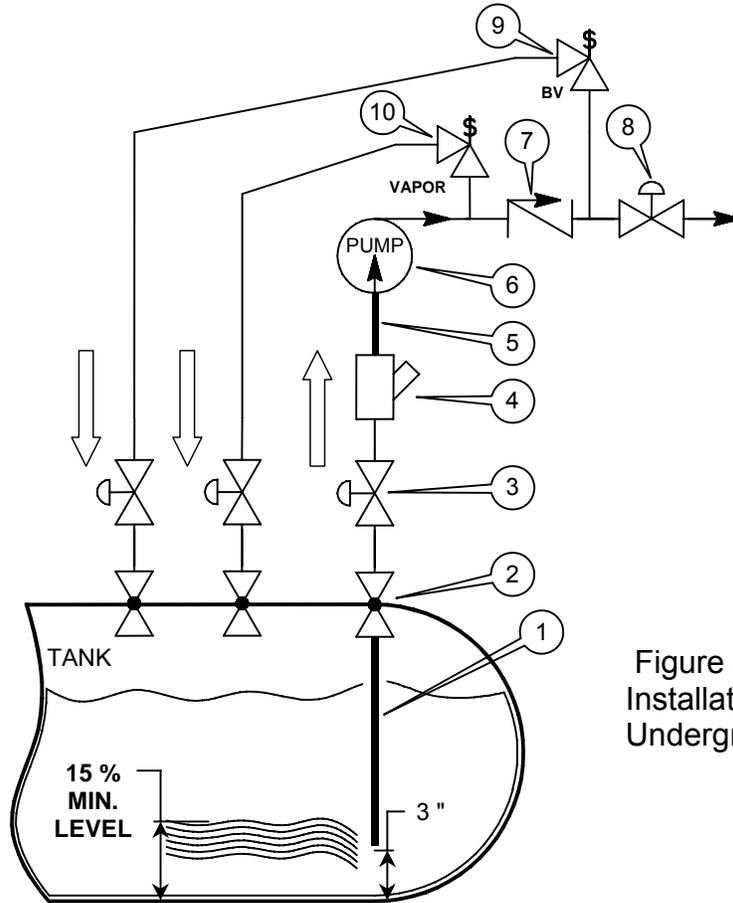
Figure 3. Typical Installation Drawing for an Underground Application

No.	Description	Size			
		LGF1(P) & LGB1(P)	LG(R)LF1.25 & LG(R)L1.25	LGL1.5 LGL158	LGL2
1	Dip Tube	1.25"	2"	2"	3"
2	Excess Flow Valve	Fisher F102, Rego 3282A, or equivalent	Fisher F190, Rego A2137A, or equivalent	Fisher F190, Rego A2137A, or equivalent	Fisher F194, Rego 2139A, or equivalent
3	Control Valve - Full Flow Ball	1.25"	1.5"	2"	3"
4	Strainer (Optional)	1.25"	1.5"	2"	3"
5	Inlet Piping	1.25"	1.5"	2"	3"
6	Pump Speeds	1750 RPM	1150, 1450, & 1750 RPM	1150, 1450, & 1750 RPM	350 & 420 RPM
7	Back Check Valve	Fisher G200-10, Rego A3187S or equivalent	Fisher G200-10, Rego A3187S or equivalvent	Fisher G200-16, Rego A7794 (sight glass) or equivalent	Fisher G200-16, Rego A7794 (sight glass) or equivalent
8	Control Valve - Full Flow Ball	1"	1.25"	1.5"	2"
9	Bypass Valve	BV1"	BV1.25"	BV1.5"	BV2"
10	Priming Valve	Fisher F138 or equivalent	Fisher F138 or equivalent	Fisher F138 or equivalent	Fisher F138 or equivalent

2-1.4 Vapor Excess Flow Valve

Install a vapor excess flow valve on the discharge side of the pump, between the soft seat back check valve and the pump. Refer to figure 4 for an illustration of an installed excess flow valve and to figure 3 for recommended valve sizes. The vapor excess flow valve provides a path to return the vapors to the tank during startup. When a flow of approximately three GPM is established, the vapor excess flow valve will close. When piping the return line from the vapor excess flow valve to the tank, ensure that there are no low spots where liquid can collect. If liquid is present in the vapor return line, excessive pressure will be required to push vapors out of the pump. Pipe the vapor return line to the vapor space in the tank, NOT to the liquid space of the tank or to the inlet of the pump.

2-1.5 Soft Seat Back Check Valve

Install a soft seat back check valve on the discharge side of the pump. A swing valve is preferred. Refer to figure 4. Place the valve as close as possible to the pump. The soft seat back check valve isolates the pump from high vapor pressure that can develop in the discharge piping due to fluid heating and vaporization after pump shutdown. This is especially true with long discharge lines and days when the ambient temperature is greater than the temperature of the fluid in the tank. The soft seat back check valve will close whenever the pressure down stream of the valve is greater than the pressure in the pump. During priming, this can greatly reduce the amount of vapor and the pressure against which the pump must prime.
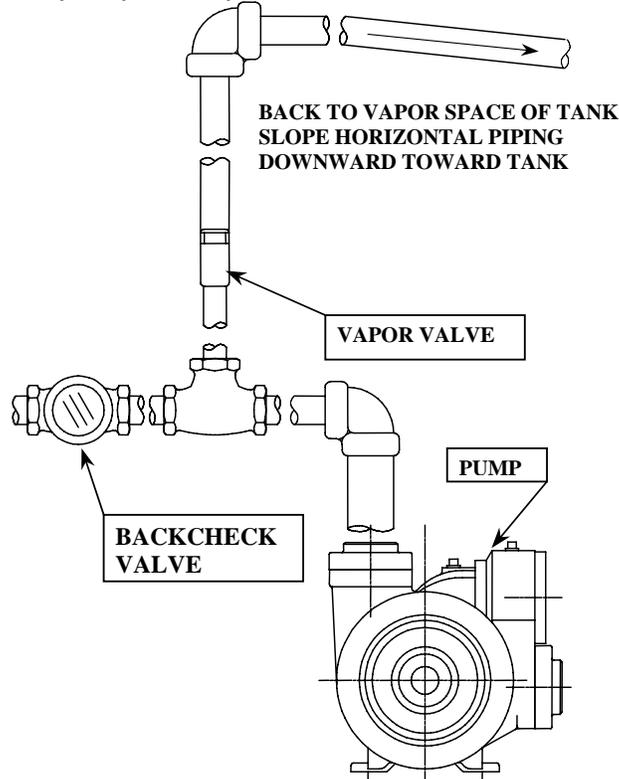
Figure 4. Vapor Excess Flow Valve and Soft Seat Back Check Valve Installation

2-2   Reducing Vapor Formation During Operation

Many of the topics discussed for vapor removal during startup operation in the previous paragraphs also apply to reducing the formation of vapor bubbles during normal operation. Installing the pump directly over the tank and using the minimum number of fittings possible will greatly reduce the amount of vapor bubble formation during normal operation, as discussed previously. The following paragraphs outline other considerations to achieve good performance during normal operation.

2-2.1 Tank Size

The size of the supply tank has a significant effect on overall system performance. As soon as liquid is removed from a supply tank, the liquid in the tank will begin to vaporize. As liquid is removed, the pressure in the tank drops slightly. To maintain equilibrium, the fluid will begin to vaporize. If liquid is removed too rapidly, significant vaporization and boiling will occur. Liquid in the tank will actually cool, reducing the equilibrium temperature and increasing the vaporization rate. This vaporization imposes a rather rigid limit on the maximum delivery rate that can be achieved with any size tank. This limit is about 2 ½% of the tank capacity per minute for pumps mounted below the tank, and should not exceed 2% for underground tanks. Therefore, the supply tank should be at least 50 times larger than the nominal flow-per-minute rating of the pump. For example, if a tank has a capacity of 2000 gallons (7570 liters), the pump should be rated for a maximum of 40 gallons per minute (150 liters per minute).

Under-sizing a tank can be a costly mistake. It will cause inadequate delivery rates, pump damage due to cavitation and potentially lost business if the system can not deliver product. When sizing a tank, error on the side of caution to ensure a trouble-free system.

2-2.2 Piping Size

Use inlet piping that is one or two sizes larger than the pump inlet connection. Keep the inlet velocity to a maximum of about 3 ft/sec. The following equation can be used to determine the inlet speed:

$$V = \frac{231*GPM}{180*\pi*D^2} = 0.4085*\frac{GPM}{D^2}$$

Or, for a velocity of 3 ft/sec:

$$D = \sqrt{0.1362*GPM}$$

Where:
   V = velocity in feet per second
   GPM = rated flow rate of the pump in gallons per minute
   D = actual pipe inside diameter in inches

Refer to figure 5 for a chart showing the maximum nominal flow rate for various pipe diameters.

Flow Rate Limits for Maximum Velocity of 3 Ft/Sec
Flow of Fluid vrs Nominal Pipe Diameter
Schedule 80 Pipe
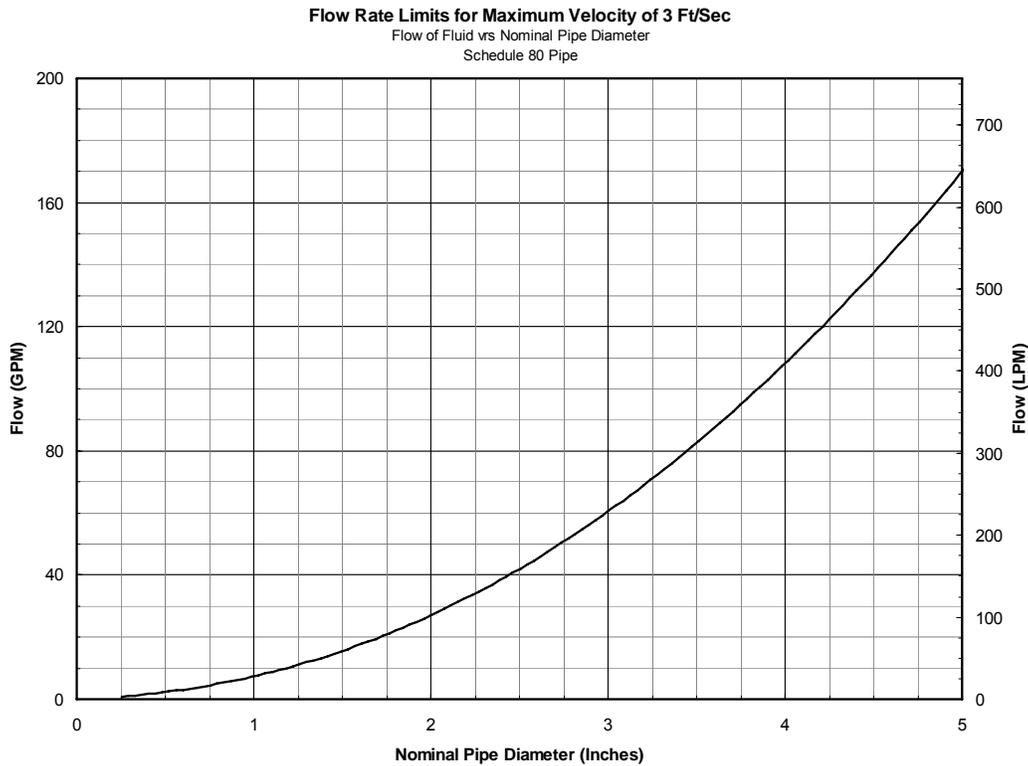
Figure 5. Flow Limits for Various Inlet Pipe Sizes for a Velocity of 3 Ft/Sec

2-2.3 *Minimize the Number of Fittings*

Although minimizing the number of fittings in the inlet piping has been discussed in previous paragraphs, its importance is worth repeating. Restrictive inlet piping not only reduces the efficiency of the pump to self-prime, it will also cause excessive vapor bubbles to form during operation.   Restrictive inlet piping between the tank and the pump can also prevent the excess flow valve and other safety devices on the tank from working properly if a break in the piping were to occur. Piping restriction is often calculated in feet of equivalent straight pipe. Fittings and valves can all be rated in equivalent feet of straight pipe friction loss. The chart in table 2 can be used to calculate the equivalent pipe lengths of various piping components. The excess flow valve should be at least 50% of the total equivalent feet of straight pipe on the inlet side of the pump. Table 3 shows the effect that increasing the piping diameter can have on total equivalent feet of straight pipe. By simply increasing the inlet piping from 1 ¼" diameter to 2" diameter reduces the overall equivalent pipe length by a factor of more than 9. This drives the need to make the inlet piping one or two sizes larger than the inlet of the pump. Figures A-1 and A-2 show the relationship between length of piping and pressure drop for various size piping and flow rate. After calculating the equivalent length of straight pipe for a system, figures A-1 and A-2 can be used to determine the expected pressure losses in the system. Refer to paragraph 3-3 for an example inlet loss calculation.

Table 2. Piping Resistance[1]

Pipe Size		1	1.25	1.5	2	2.5	3	4
Actual Dia (Schedule 80)		0.957	1.278	1.500	1.939	2.323	2.900	3.826
Friction Factor		0.023	0.022	0.021	0.019	0.018	0.018	0.016
Sharp Flush Pipe Entrance	K	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Equivalent Feet	1.7	2.4	3.0	4.3	5.4	6.7	10.0
Standard Tee - Thru Branch	K	1.4	1.3	1.3	1.1	1.1	1.1	1.0
	Equivalent Feet	4.8	6.4	7.5	9.7	11.6	14.5	20.3
Standard Tee - Thru Flow	K	0.5	0.4	0.4	0.4	0.4	0.4	0.3
	Equivalent Feet	1.6	2.1	2.5	3.2	3.9	4.8	6.8
Full-Port Ball Valve	K	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Equivalent Feet	0.2	0.3	0.4	0.5	0.5	0.7	1.0
Globe Valve	K	7.8	7.5	7.1	6.5	6.1	6.1	5.8
	Equivalent Feet	27.0	36.3	42.3	55.3	65.6	81.9	115.6
Angle Valve	K	3.5	3.3	3.2	2.9	2.7	2.7	2.6
	Equivalent Feet	12.0	16.0	18.8	24.2	29.0	36.3	50.8
Excess Flow Valve	K							
	Equivalent Feet	65 to 70	65 to 70	65 to 70	65 to 70	65 to 70	65 to 70	65 to 70
90 Elbow	K	0.7	0.7	0.6	0.6	0.5	0.5	0.5
	Equivalent Feet	2.4	3.2	3.8	4.8	5.8	7.3	10.2
45 Elbow	K	0.4	0.4	0.3	0.3	0.3	0.3	0.3
	Equivalent Feet	1.3	1.7	2.0	2.6	3.1	3.9	5.4

Equivalent Length = Dia" x K/(12 x Friction Factor)

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[1] K-factors from Cameron Hydraulic Data, Copyright 1998 by Ingersoll-Dresser Pump Co.

Table 2. Piping Resistance[1] – Contd.

	Nominal Small Size	Nominal Large Size	1.25	1.5	2	2.5	3	4
Bushing - Reducing	1	K	0.2	0.3	0.4	0.4	0.4	0.5
		Equivalent Feet of Large Size	1.1	1.8	3.2	4.5	6.0	9.3
	1.25	K	---	0.1	0.3	0.3	0.4	0.4
		Equivalent Feet of Large Size		1.8	3.2	4.5	6.0	9.3
	1.5	K	---	---	0.2	0.3	0.4	0.4
		Equivalent Feet of Large Size			3.2	4.5	6.0	9.3
	2	K	---	---	---	0.2	0.3	0.4
		Equivalent Feet of Large Size				4.5	6.0	9.3
	2.5	K	---	---	---	---	0.2	0.3
		Equivalent Feet of Large Size					6.0	9.3
	3	K	---	---	---	---	---	0.2
		Equivalent Feet of Large Size						9.3
Bushing - Enlarging	1	K	0.2	0.4	0.6	0.7	0.8	0.9
		Equivalent Feet of Large Size	0.9	2.1	4.9	7.4	10.7	17.5
	1.25	K	---	0.1	0.3	0.5	0.6	0.8
		Equivalent Feet of Large Size		0.4	2.7	5.2	8.7	15.7
	1.5	K	---	---	0.2	0.3	0.5	0.7
		Equivalent Feet of Large Size			1.4	3.7	7.2	14.3
	2	K	---	---	---	0.1	0.3	0.6
		Equivalent Feet of Large Size				1.0	4.1	11.0
	2.5	K	---	---	---	---	0.1	0.4
		Equivalent Feet of Large Size					1.7	7.9
	3	K	---	---	---	---	---	0.2
		Equivalent Feet of Large Size						3.6
Equivalent Length = Dia" x K/(12 x Friction Factor)								

[1] K-factors from Cameron Hydraulic Data, Copyright 1998 by Ingersoll-Dresser Pump Co.

Table 3. Comparison of Equivalent Lengths between Various Pipe Sizes

Pipe Dia	Actual Dia (Schedule 80)	Friction Factor	Equivalent Length of 2" Pipe	Equivalent Length of 3" Pipe
1	0.957	0.023	41.3	326.5
1.25	1.278	0.022	9.3	73.5
1.5	1.500	0.021	4.0	31.5
2	1.939	0.019	1.0	7.9
2.5	2.323	0.018	0.4	3.0
3	2.900	0.018	0.1	1.0
4	3.826	0.016	0.0	0.2

2" Pipe = (Friction Factor x 1.939^5)/((Actual Dia)^5 x .019)

3" Pipe = (Friction Factor x 2.900^5)/((Actual Dia)^5 x .018)

2-2.4 Excess Flow Valve

Like the inlet piping, the excess flow valve must be sized one or two pipe sizes larger than the pump inlet. Refer to table 2 for equivalent feet of straight pipe for excess flow valves. Select an excess flow valve with a rated closing flow at least 50% greater than the nominal flow rating of the pump. Refer to figure 3 for recommended excess flow valves for various Blackmer pump models. Many excess flow valves can be connected to two different pipe sizes on the inlet side of the valve. (This is where the tank dip tube is connected to the excess flow valve on the inside of the tank.) Use the largest diameter piping possible as the dip tube piping for the selected valve. Refer to figure 3.

2-2.5 Piping Location and Insulation

Proper piping location can reduce heat gain, and resultant vaporization, on the pump inlet piping. To prevent heat gain, do not bury inlet piping in the ground. During sunny, hot days, the ground near the surface will be warmer than the liquid in the tank. This will cause the piping, and the fluid in contact with the piping, to heat up. Install a shade screen over the inlet piping and the pump to prevent solar heat gain. Place insulation on the inlet piping to prevent heat gain.

3 Inlet Conditions

In all pump installations, understanding the pump inlet condition is very important and is a significant factor on pump operation. Inlet restrictions should be kept to a minimum to improve performance and life of the pump. Too much inlet restriction will cause cavitation of the fluid, reducing the pump capacity and causing damage to the pump. This is especially true for liquefied gas applications. Fluids such as propane and butane are stored under pressure to keep the fluid in a liquid state. Any reduction of pressure of a liquefied gas, stored at equilibrium conditions, will cause the fluid to vaporize. As a general rule, keep the inlet restriction of a liquefied gas pump to a maximum of 3 PSI (20.5 kPa) total for lift and piping losses.

3-1 Inlet Restrictions

Inlet restrictions for pumping systems can be organized into two basic categories; elevation pressure losses, and piping losses. Elevation losses are a function of the height from the liquid level to the pump inlet. Piping losses are a function of the type, size, and overall length of the inlet piping, and the type and number of fittings and valves.

3-1.1 Elevation Losses

Elevation losses are due to the height difference between pump inlet and the tank liquid level. Essentially, there is a vertical column between the inlet of the pump and the tank liquid level. If the liquid level is above the pump inlet, the column of fluid is adding to the overall inlet pressure at the pump. This addition is due to the weight of the column of fluid between the liquid level and the pump inlet. Conversely, if the liquid level is below the pump inlet, the vertical column of fluid subtracts from the overall inlet pressure at the pump. Refer to table 4 for the pressure loss of a column of liquefied compressed gas. Since elevation may be the largest pressure loss factor on a well-designed inlet system, it is recommended that the supply tank be filled regularly to reduce the overall elevation pressure loss. Elevation of the pump above the liquid level should be kept to a maximum of 10 feet (3.0 meters).

Table 4. Pressure Loss Factors for Lifting Liquefied Compressed Gases

Fluid	Height of 1 PSI Loss (ft)	Pressure Loss/Foot of Elevation (PSI)	Height of 1 kPa Loss (m)	Pressure Loss/Meter of Elevation (kPa)
Propane	4.58	0.22	0.20	4.94
Butane	3.96	0.25	0.18	5.71
Data at 60 °F (16 C)				

3-1.2 Piping Losses

Piping losses are caused by the resistance to flow of each piping component in a piping system. Each elbow, valve, coupling, and straight pipe section causes friction loss when flow passes through. This friction loss results in head loss in the system, which can be measured in feet of liquid head loss or pressure loss.

Typically, friction loss is measured in feet of fluid. The Darcy-Weisbach equation, shown below, can be used to calculate the friction loss of a piping system. The equation is as follows:

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

$$h_f = \left(f \frac{L}{D} \right) \frac{V^2}{2g} \quad ; \quad K = f \frac{L}{D} \quad ; \quad L = \frac{KD}{f}$$

Where

   h_f = friction loss in feet of liquid

   V = average pipe velocity (ft/sec)

   L = pipe length in feet

   D = average inside diameter in feet

   g = gravitational constant (32.174 ft/sec)

   f = friction factor – a dimensionless number that depends on the
relative roughness of the piping, velocity of fluid in the piping,
diameter of the piping, and absolute viscosity of the fluid. For the
friction analysis in this publication, friction factors for the various
fittings and components are assumed to be in full turbulent flow and
have been determined by reference to the Moody diagram. Refer
to figure A-3 in the Appendix for the validity of this assumption.

   K = resistance coefficient

The resistance coefficient for various fittings can be used to determine the
equivalent length of pipe for each fitting, if the friction value of the system is
known, since:

$$K = f\frac{L}{D} \text{ and therefore } L = \frac{KD}{f}$$

Table 2 shows the equivalent length of pipe for various fittings. This table
assumes that the flow in the piping is turbulent. Refer to figure A-3 for an
estimation of the validity of this assumption. Except for very low flow, this
assumption will be accurate for all liquefied compressed gas systems.

3-2   Overall Piping Configurations

Figures A-4 through A-8 in the Appendix offer some additional installation
guidelines for piping a pump in an underground tank application. These figures
are simplified to illustrate specific installation guidelines and do not show all the
components, such as hydrostatic relief valves and isolation valves, that will be
necessary to safely pipe a system.

3-3   Inlet Piping Example Calculation

Refer to figure 6. An LGL1.25 pump is installed at an elevation of 8 feet (2.4
meters) above the bottom of an underground tank. This pump location requires
three 90° elbows in the inlet piping and the pump has 10 feet (3 meters) of
horizontal run from the tank outlet. Calculate the expected inlet pressure loss
due to the given inlet conditions.

The following table calculates the equivalent feet of straight pipe on the inlet of
the pump. Refer to table 2 for the restriction factor for each component. Since
the largest piping in the system is 2" piping, (dip tube and excess flow valve), the
total equivalent feet of the inlet was calculated for 2" piping. Refer to table 3 for
conversion factors between piping sizes.

Inlet Restriction Calculations					
Component	Size	Qty or (ft) **A**	Equivalent Feet for Actual Size (Table 2) **B**	Equivalent Length factor for 2" Pipe (Table 3) **C**	Equivalent Feet of 2" Restriction (**A** x **B** x **C**)
Entrance	2	1	4.3	1.0	4.3
Dip Tube	2	4.6	1.0	1.0	4.6
Excess Flow Valve	2	1	70.0	1.0	70.0
Angle Valve	1.5	1	18.8	4.0	75.2
1.5" to 1.25" Reducer	1.5	1	1.8	4.0	7.2
90° Elbow	1.5	2	3.8	4.0	30.4
90° Elbow	1.25	1	3.2	9.3	29.8
Vertical Pipe	1.5	3	1.0	4.0	12.0
Horizontal Straight Pipe	1.5	7.5	1.0	4.0	30.0
Horizontal Straight Pipe	1.25	3	1.0	9.3	27.9
Total					291.4

From this table, the calculated equivalent feet of 2" piping on the inlet of the pump is 291 feet (89 m). The LGL1.25 pump is rated at about 24 GPM (91 LPM) for 100% propane at minimum differential pressure. (Use minimum differential pressure flow rates for determining pressure loss). From figures A-1 and A-2, this would result in a pressure loss of approximately 0.30 PSI per 100 feet (.07 bar per 100 meters). With an equivalent inlet length of 291 feet (89 meters), the proposed pressure loss due to the piping would be slightly less than 0.9 PSI (or nearly .06 bar).

Next, determine the pressure loss due to elevation. The pump is located 96" (2.4m) from the bottom of the tank. Assuming the tank liquid level is always at least 25% of the tank's diameter, the elevation from the fluid level to the pump would be 81" (2.0 m) (96" – 0.25 * 60"). Multiplying the elevation by the pressure loss per the elevation factor from table 4, this would result in a loss of 1.5 PSI (0.1bar).

The total expected pressure loss for the system would be the sum of the piping losses and the elevation losses, or approximately 2.4 PSI (0.17 bar).
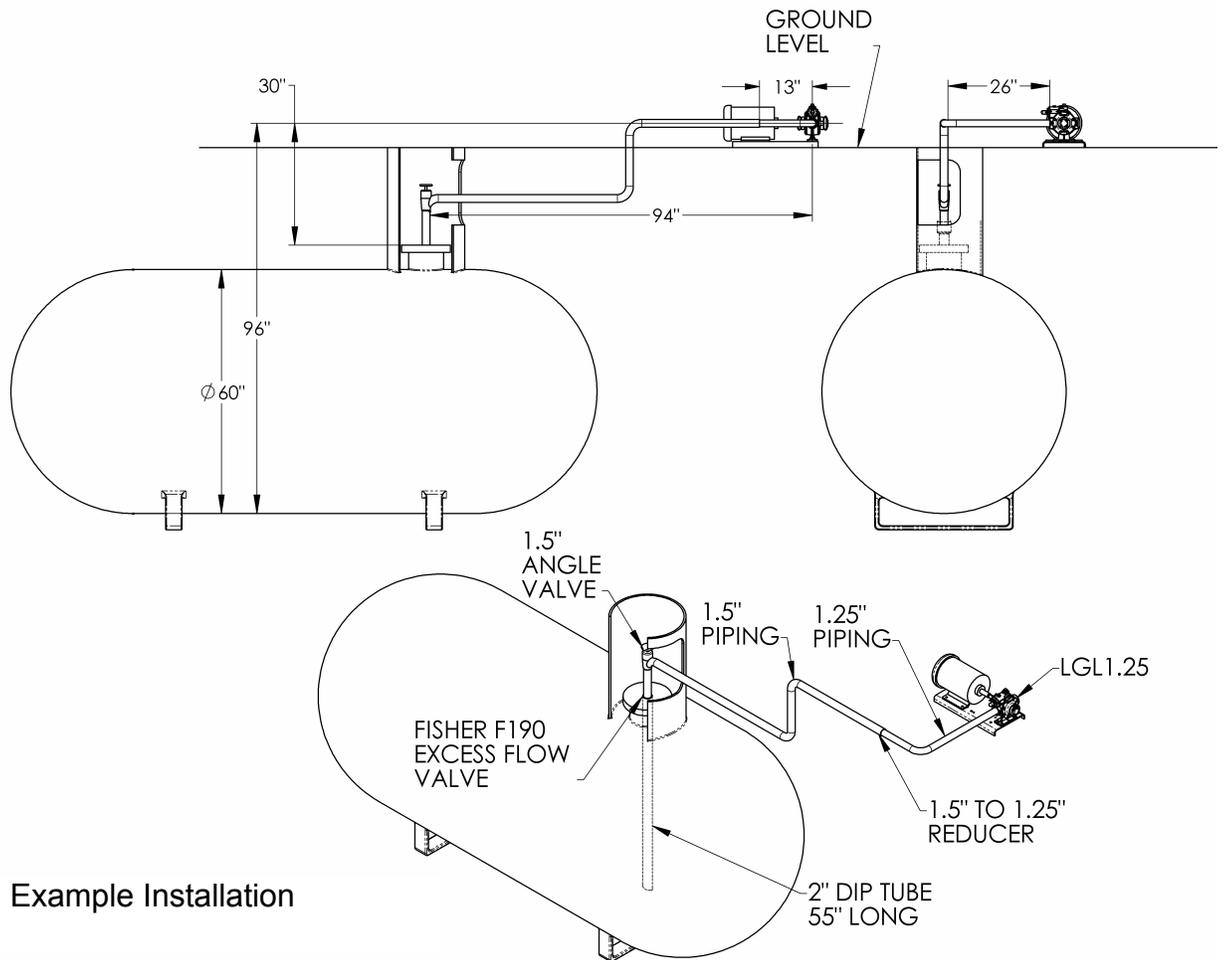
Figure 6. Example Installation

Although the above example is within the recommended maximum pressure loss of 3 PSI (0.2 bar), any improvement to the inlet conditions would be very beneficial in this application. Also, the piping has a horizontal run that is below ground level (after the angle valve) which will probably be buried in the ground during installation. This could result in excessive heat gain during operation, and may cause excessive vaporization. The most restrictive piping components in the inlet are the angle valve and the excess flow valve, but the horizontal run of piping is also significant. A better installation would be to:

- A) mount the pump closer to the tank, eliminating almost all of the horizontal straight piping and elbows
- B) replace the angle valve with full-flow ball valve
- C) upsize the 1.5 inch piping and fittings to 2.0 inch
- D) relocating the reducer closer to the pump, but still at least 10 pipe diameters from the pump inlet.
- E) lower the pump height from the tank opening in half which results in nearly 0.5 psi lower pressure loss.

The improved design is shown in figure 7 with the losses calculated in the following table.

Improved Inlet Restriction Calculations					
Component	Size	Qty or (ft) **A**	Equivalent Feet for Actual Size (Table 2) **B**	Equivalent Length factor for 2" Pipe (Table 3) **C**	Equivalent Feet of 2" Restriction (**A** x **B** x **C**)
Entrance	2	1	4.3	1.0	4.3
Dip Tube	2	4.6	1.0	1.0	4.6
Excess Flow Valve	2	1	70.0	1.0	70.0
Ball Valve	2.0	1	0.4	1.0	0.4
2.0" to 1.25" Reducer	2.0	1	3.2	1.0	3.2
90 o Elbow	2.0	1	3.8	1.0	3.8
Vertical Pipe	2.0	1.5	1.0	1.0	1.5
Horizontal Pipe	2.0	0.5	1.0	1.0	0.5
Horizontal Pipe	1.25	1	1.0	9.3	9.3
Total					97.6

From the above table, the calculated equivalent feet of 2" piping on the inlet of the pump is 97.6 feet (30 m), about a third the original. With the same flow rate of 24 GPM (91 LPM), and the same pressure loss of 0.30 PSI per 100 feet (.07 bar per 100 meters) from figures A-1 and A-2, the new pressure loss due to the piping would be about 0.30 PSI (.02 bar).

The elevation losses would be lower than previously calculated, since the elevation was shortened. The elevation losses would be 1.15 PSI (0.08 bar). The total expected pressure loss for the system would be approximately 1.4 PSI (0.1 bar). This is about 1.0 PSI (0.07 bar) less than in the first design. Also, the inlet piping will not need to be buried and can be insulated to prevent heat gain during operation.

GROUND
LEVEL

12"

12"
6"

78"

$\varnothing$ 60"

1.25" PIPING

LGL1.25

2" PIPING

2" TO 1.25"
REDUCER

2" BALL VALVE

2" DIP TUBE
55" LONG

FISHER F190
EXCESS FLOW
VALVE
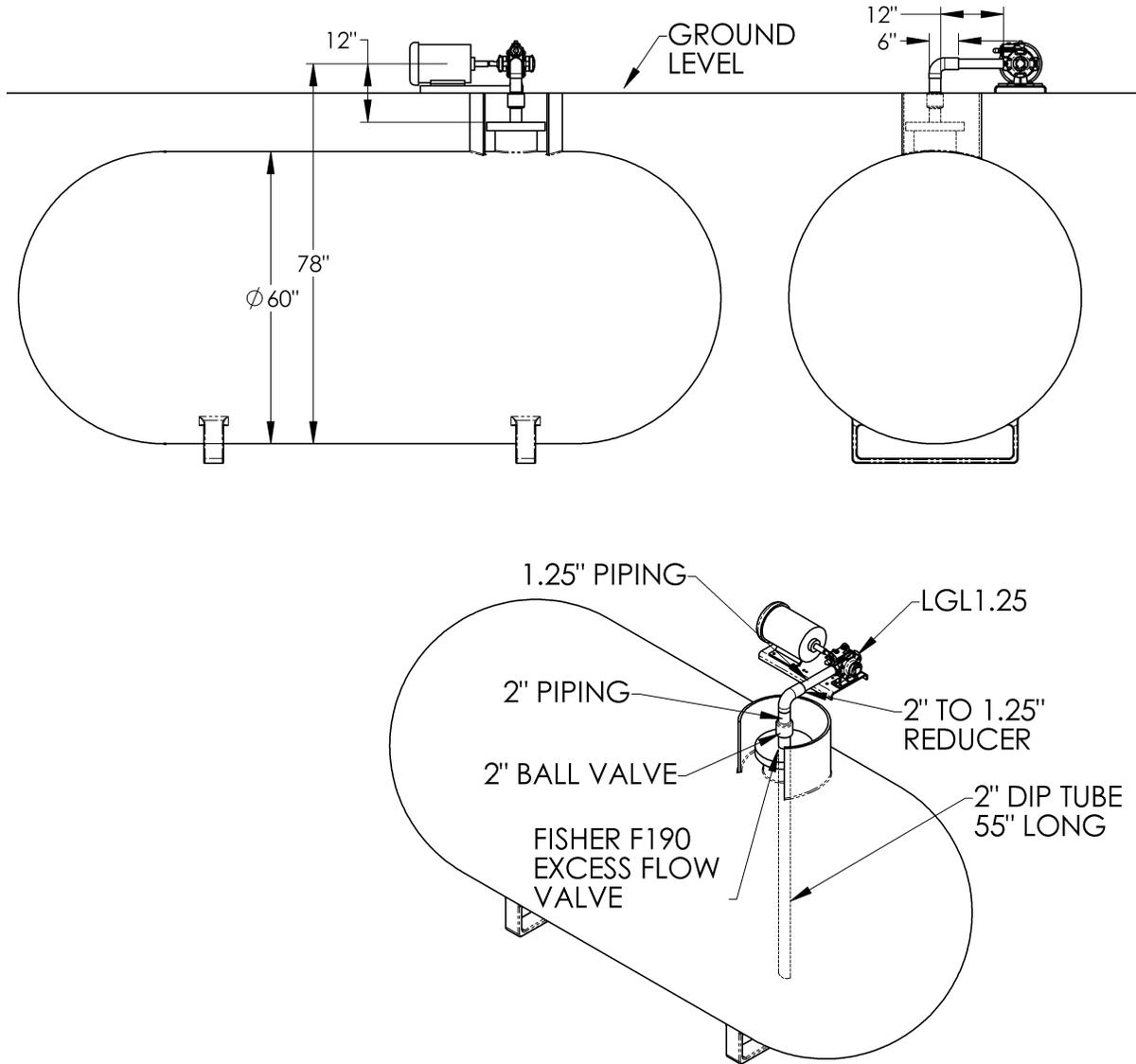
Figure 7. Improved Example Installation

APPENDIX
List of Figures

APPENDIX

Pressure Drop through Schedule 80 Piping

Friction Loss Vrs Flow Rate for 100 Feet of Various Pipe Sizes

100% Propane

Figure A-1. Friction Loss in Various Size Piping – English Units

Pressure Drop through Schedule 80 Piping
Friction Loss Vrs Flow Rate for 100 Meters of Various Pipe Sizes
100% Propane
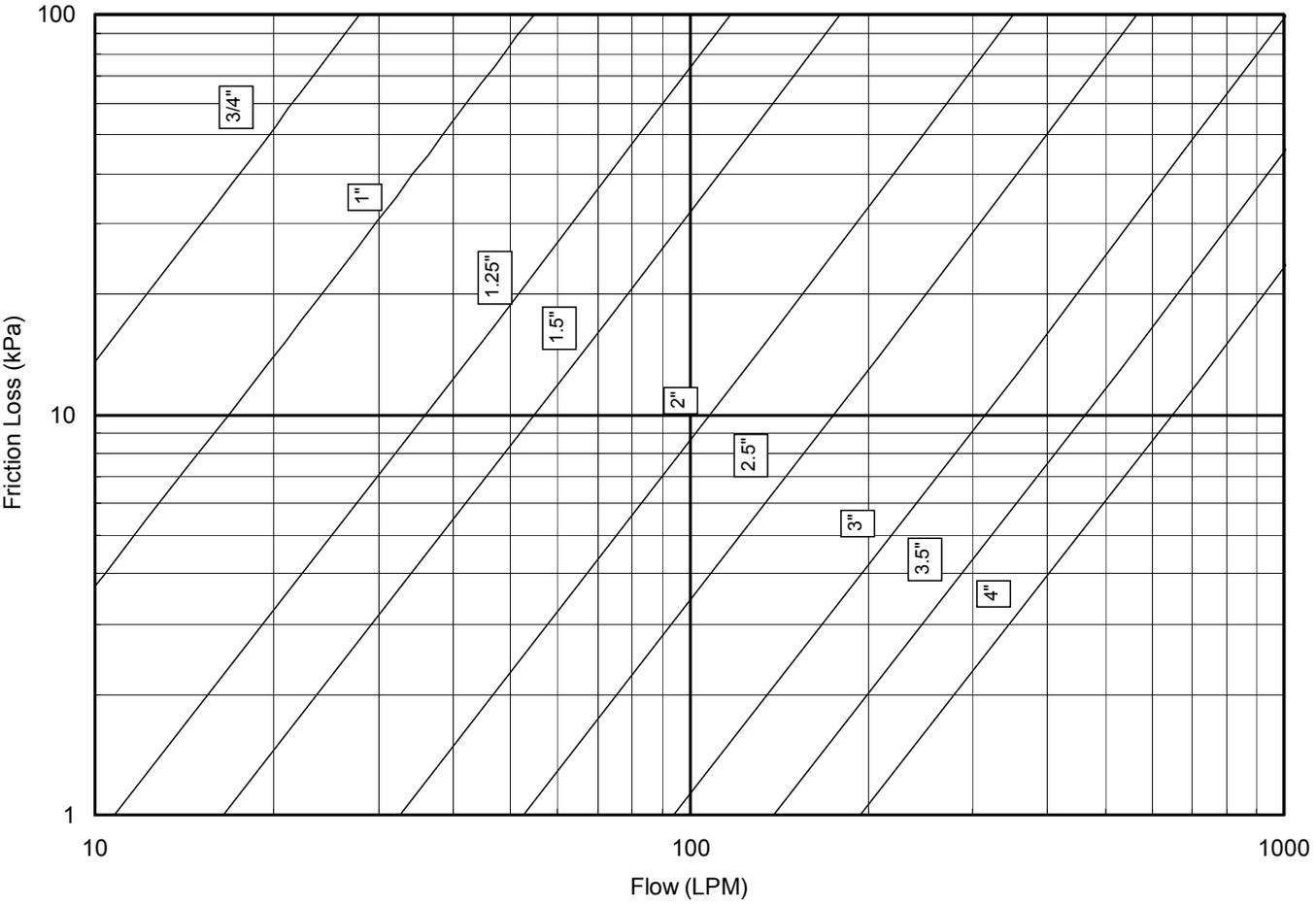
Figure A-2. Friction Loss in Various Size Piping – Metric Units

APPENDIX

Complete Turbulent Flow of Propane vrs Nominal Pipe Diameter
Schedule 80 Pipe
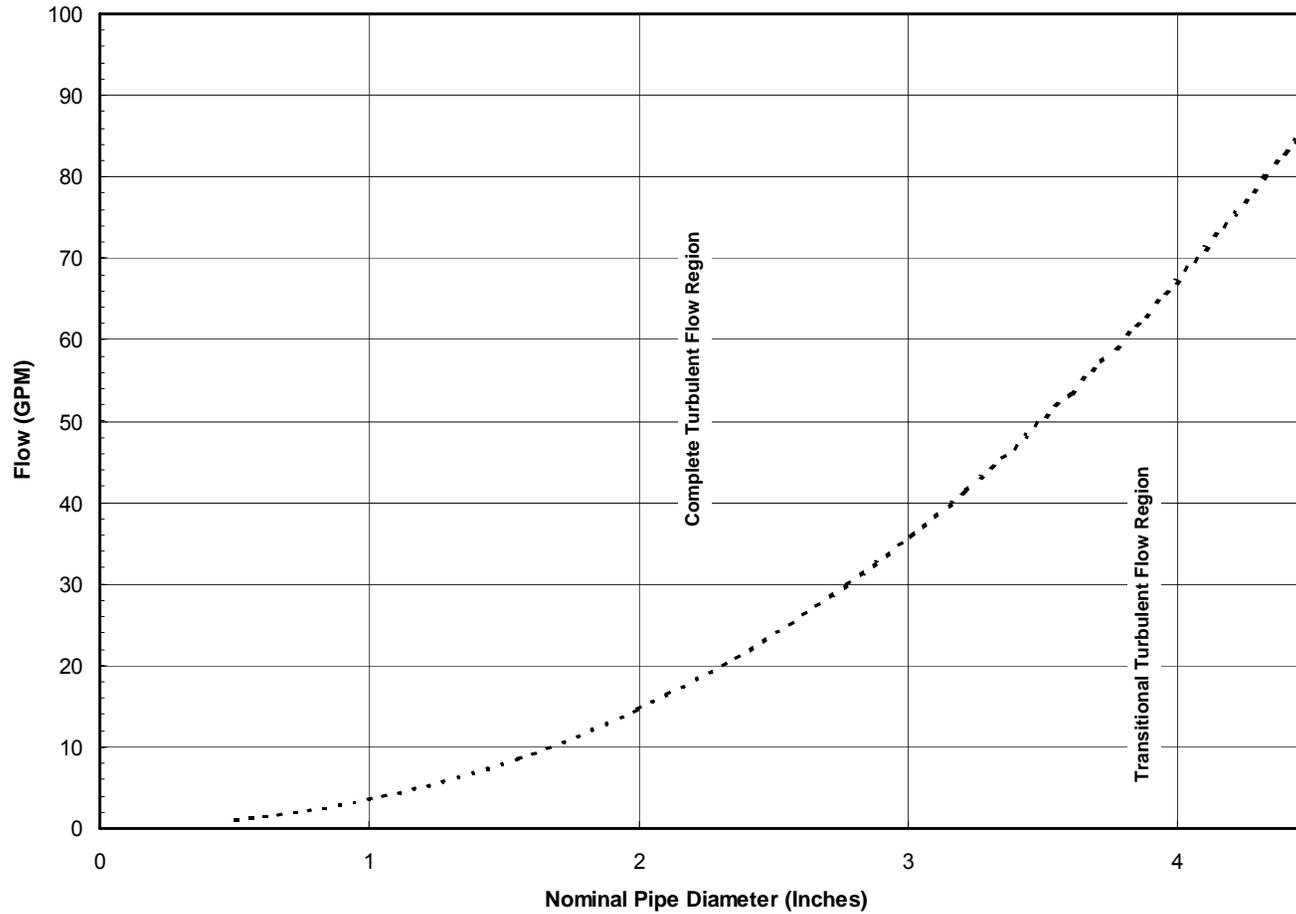
Figure A-3. Flow Rates for Turbulent Flow Assumption for Various Size Piping

APPENDIX

TOO LONG

PUMP

TOO HIGH

SHORT

PUMP

PUMP

TANK

TANK

TANK

BAD
High lift causes severe
cavitation.
Long Horizontal run exposes
fluid in piping to temperature
changes.

BETTER
Short vertical distance between
pump and tank.
Short horizontal run (~10 pipe
diameters max).

BEST
Use shortest possible vertical
distance between tank and
pump.
If possible, rotate pump inlet
vertical and in line with inlet
piping.
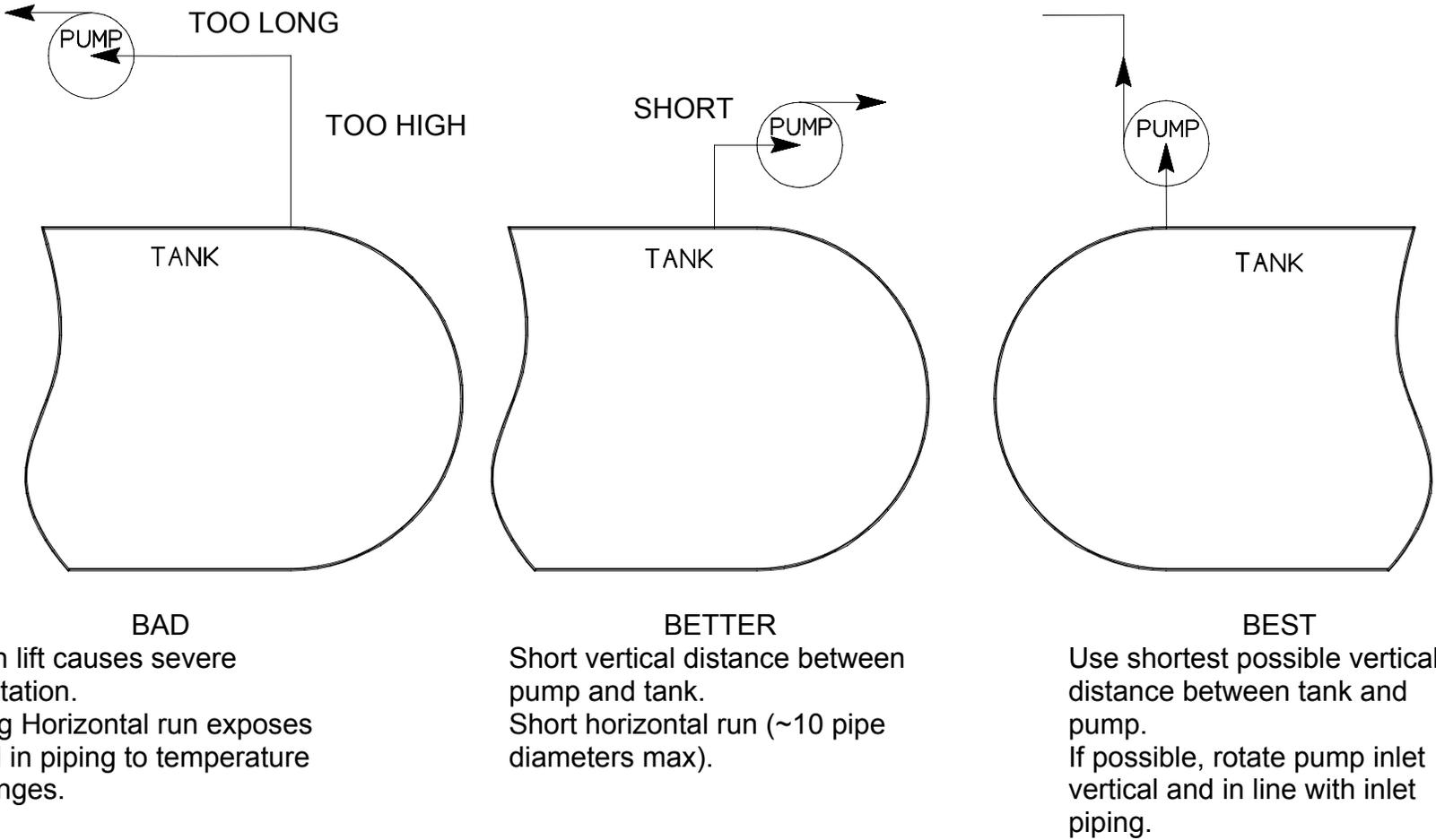
Figure A-4. Location of Pump Above Tank

APPENDIX
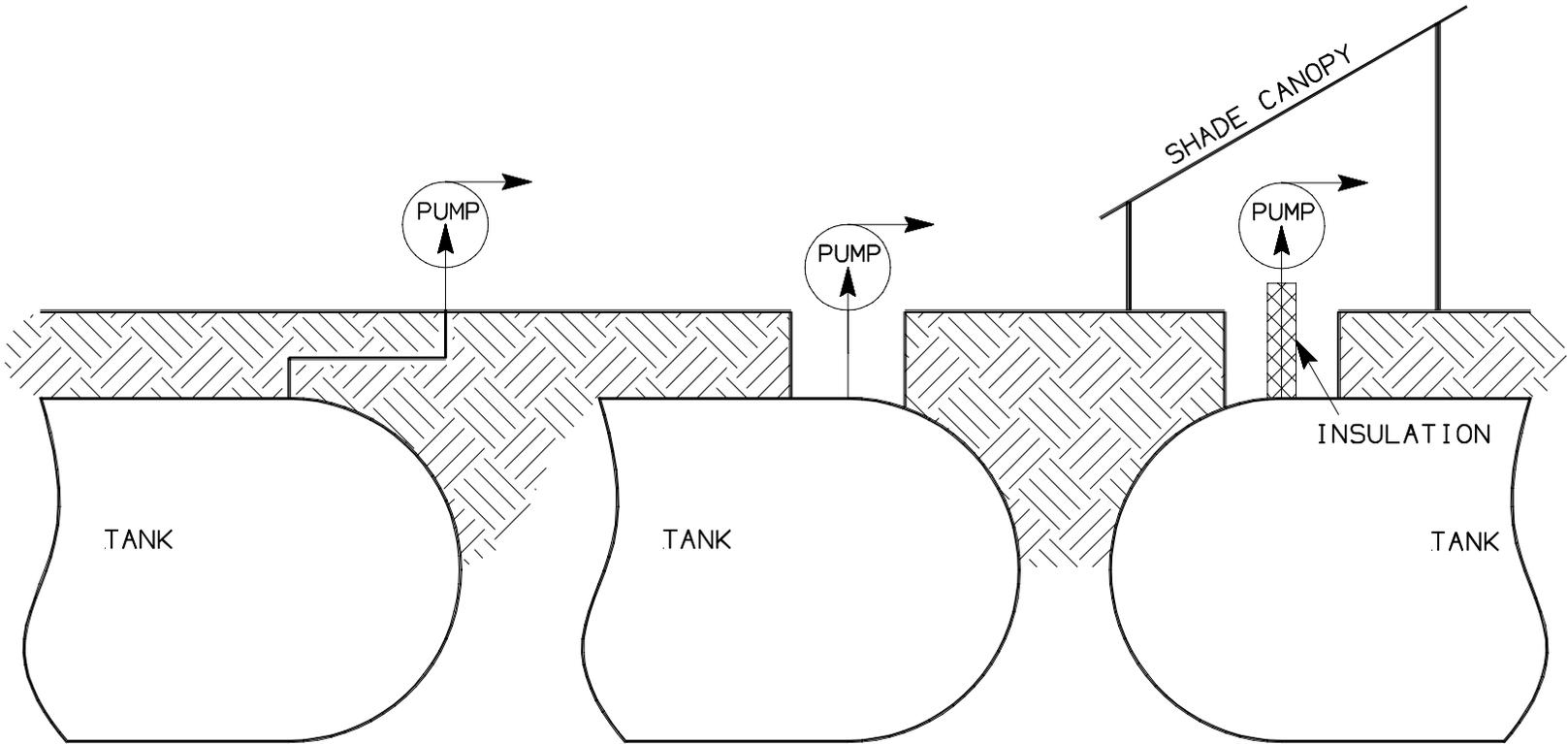
BAD
Do not bury inlet piping. Contact with the ground can heat fluid and cause vapor formation.

BETTER
Short inlet piping reduces friction loss as well as heat gain.

BEST
Very short inlet.
Insulation on inlet piping greatly reduces heat gain.
Shade canopy reduces temperature during shutdown and heat gain during operation.

Figure A-5. Protecting the Inlet Piping from Heat Gain

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APPENDIX
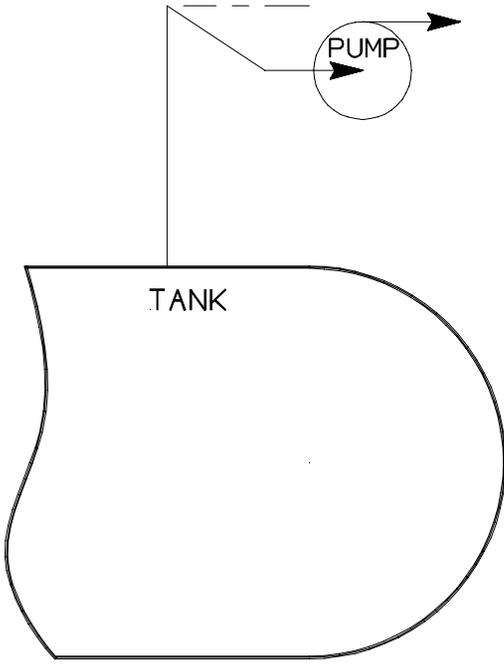
BAD
Horizontal run sloping down toward pump creates high spot in inlet. Vapor pockets can form at the high spots.
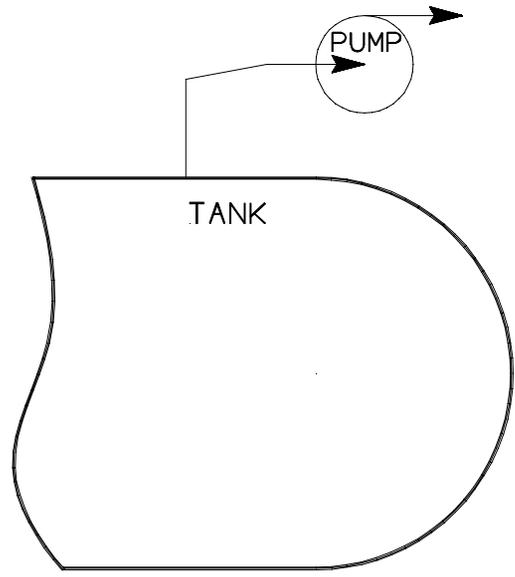
BETTER
Horizontal runs should be level or sloping up toward pump. If piping is sloping up toward pump, vapors will rise to the pump and be removed.
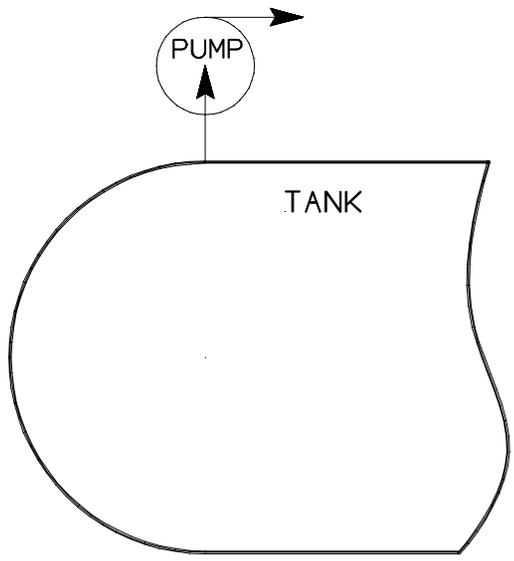
BEST
With only vertical piping, no vapor pockets can form.

Figure A-6. Eliminating Vapor Pockets in the Pump Inlet

APPENDIX
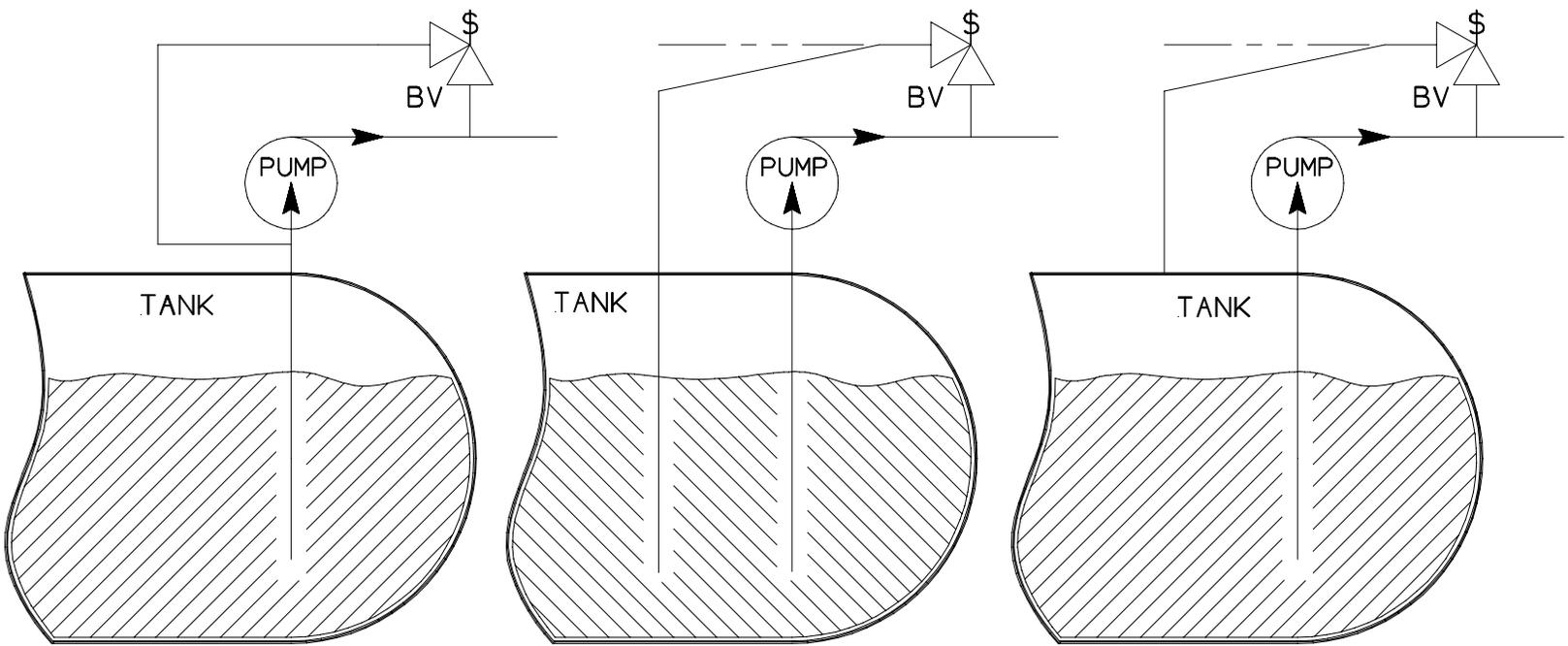
BAD
Never pipe returning vapor or liquid to the pump inlet. Pump will loose prime and all liquid in the piping will vaporize, causing severe damage to the pump.

BETTER
Bypass line returns to liquid space of the tank. Do not pipe vapor excess flow valve to bypass piping if bypass piping returns to liquid space of the tank.

BEST
Bypass line returns to vapor space of the tank. Any horizontal piping is sloped downward toward the tank.

Figure A-7. Back-to-Tank Bypass Valve

APPENDIX
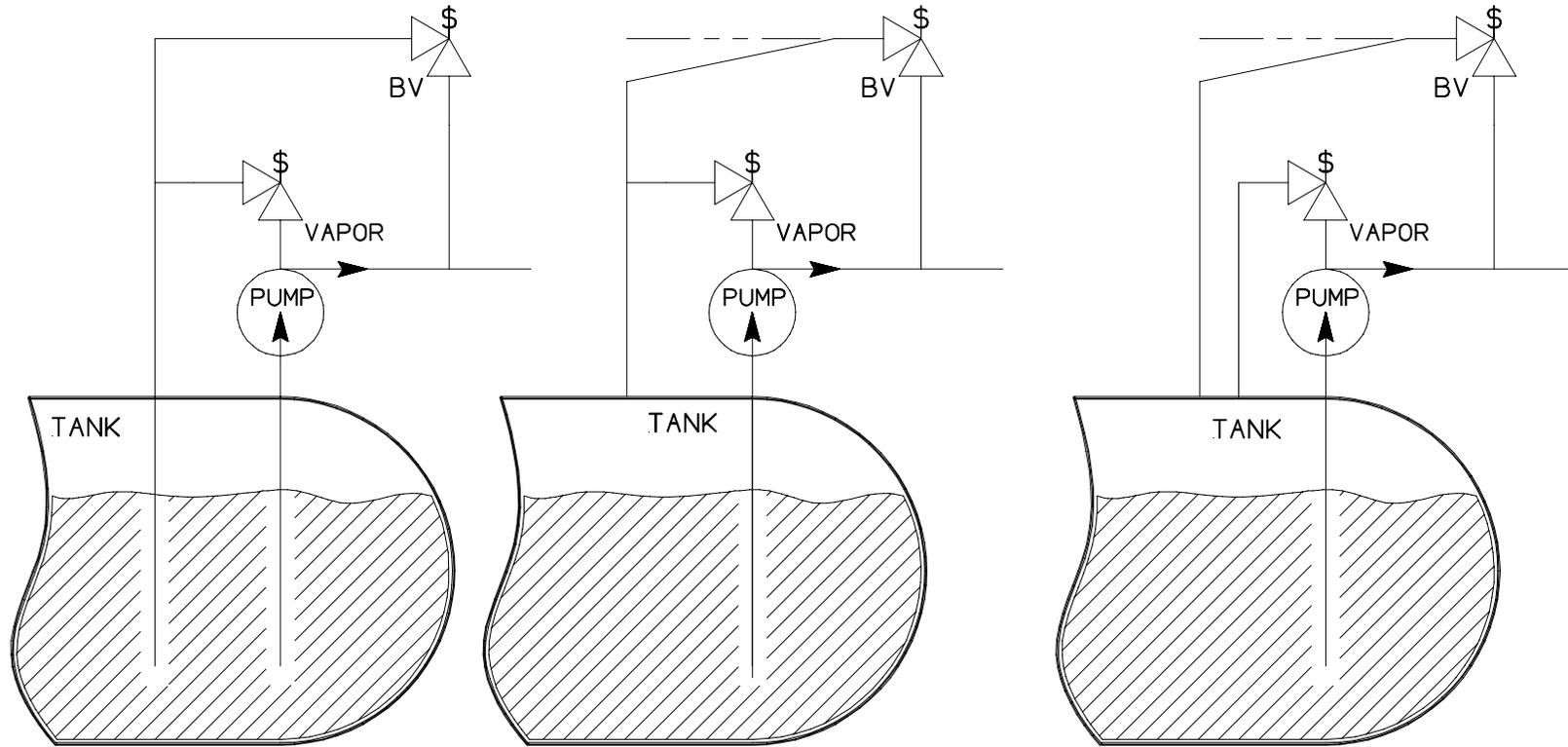
BAD
Do not pipe vapor excess flow valve to liquid space of the tank. If liquid is present in vapor return line, vapor excess flow valve will fail to function properly.

BETTER
Vapor excess flow valve and BV piped to vapor space in the tank. All horizontal piping is sloped downward toward the tank to allow liquid to drain back into the tank.

BEST
BV and vapor excess flow valve piped separately to the vapor space in the tank. All horizontal piping is sloped downward toward the tank to allow liquid to drain back into the tank.

Figure A-8. Use of Vapor Return Lines

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