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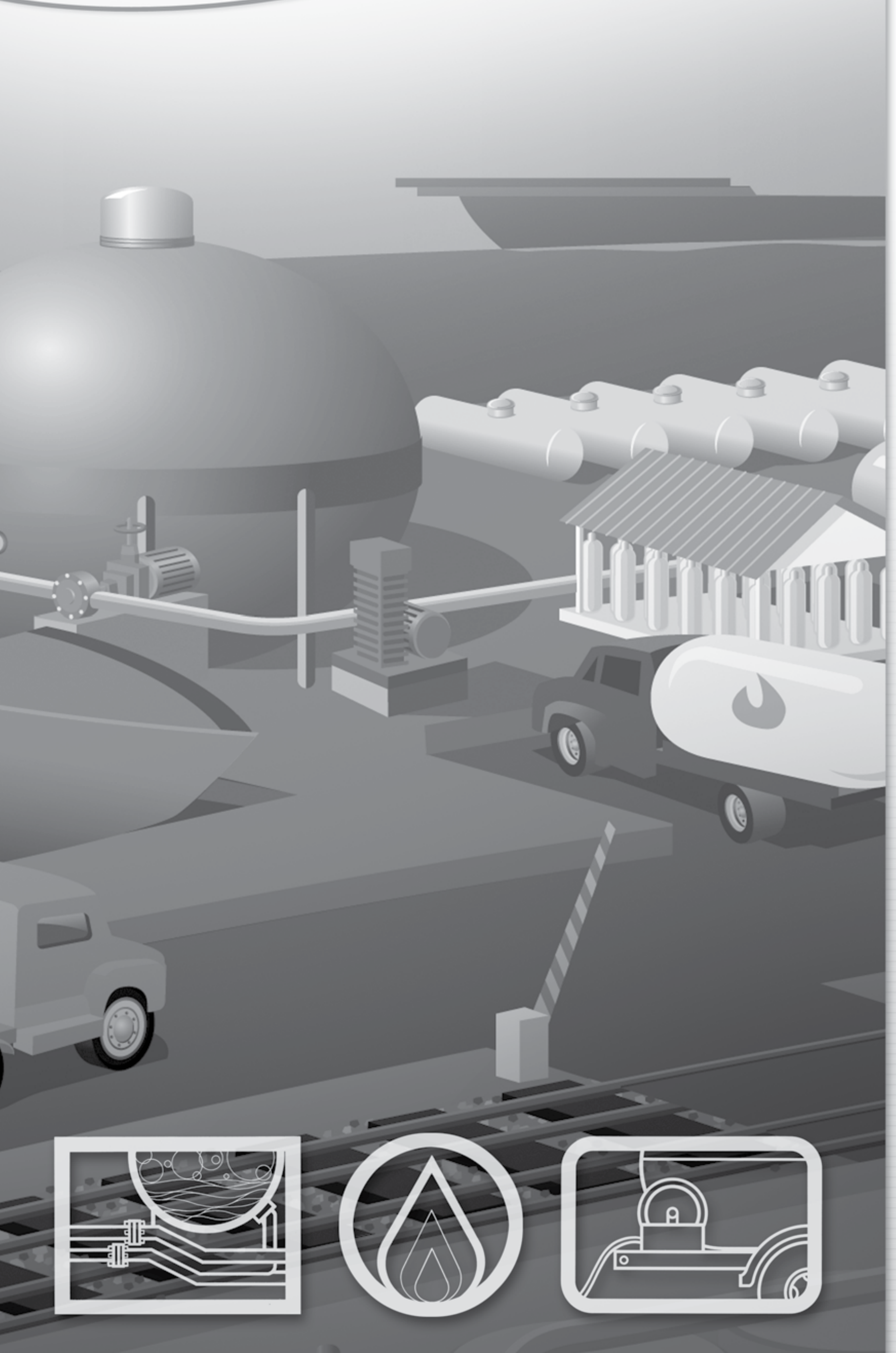
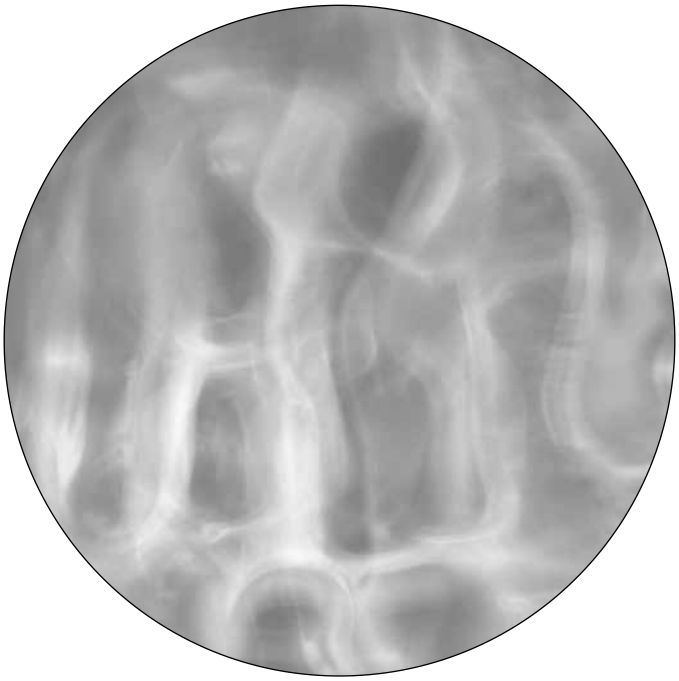


Liquefied Gas Handbook

Practical suggestions on the design and installation of handling systems for propane, butane, anhydrous ammonia and similar liquefied gases

Bulletin 500 – Liquefied Gas Handbook

This handbook is about Blackmer liquefied gas pumps and compressors, their installation and operation. It outlines several practical suggesttions and guidelines that can be used in the design of new trucks and plants as well as the troubleshooting of older installations. It is not, nor is it intended to be, a treatise on the entire LPG industry. There are many excellent publications that cover in detail the various other specialized phases of this business.



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Before installing propane equipment on any mobile vehicle or in a permanent location, 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
1 Batterymarch Park
Quincy, MA 02269-9101
Telephone: 1-800-344-3555
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 laws and ordinances on the subject. Equipment on vehicles used in interstate service must comply with applicable requirements of the Department of Transportation.

www.blackmer.com

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.

About Blackmer

In 1903, Robert Blackmer, inventor of the first Rotary Vane pump, successfully launched a new technology (sliding vane pumps) effectively setting valuable pumping standards for years to come for pump companies around the world. For nearly a century, Blackmer has continued to strengthen its commitment of providing quality products to its valued customers.

Meeting customer's challenges through a combination of expertise, dedication and support, allows Blackmer to provide the most effective products with the information customers need to choose the right product for their applications. It is the people at Blackmer that make the company what it is today. With a diverse range of market segments and experts in the field, Blackmer takes great pride in its services and products available worldwide.

Blackmer's manufacturing facilities are fully equipped with the latest technology and trained technicians needed to provide products to meet the industry's highest global standards. Blackmer's research and design department works around the clock testing not only new products, but also changes and advancements made to existing products.

Experts in the field are continuously providing one-on-one product training throughout the world. Blackmer believes strongly in its team, whose purpose is to service its customer's needs through years of experience and longevity in the workforce.

Blackmer has become a global company, supplying markets around the world with expert flow-technology applications. Blackmer is quick to respond to the industry's rapid advances, through constantly reengineering its products to include new innovations.

However, Blackmer is about more than the latest, cutting-edge technology. The employees at Blackmer work together as a team in order to meet customers' ever-evolving needs with keen knowledge and insight. Blackmer provides outstanding service that enhances its customers' business, from site training to expert engineering support. The customer is always the first priority at Blackmer.

Mission Statement

To be the Value Proposition Leader in strategically identified global applications by providing superior:

- Business Credibility: Blackmer will conduct business in compliance with the Dover Code of Conduct and Ethics
- Applications expertise and equipment selection
- Technical assistance and customer care
- Responsiveness
- Product quality and product value
- Total lifetime life cycle support

Products

LG and LGL Sliding Vane Pumps

These ductile iron pumps, available in 1 in. to 4 in. sizes, are all UL listed for LPG and Anhydrous Ammonia Service. Models are available for motor fueling, cylinder filling, vaporizers, general transfer and truck loading/offloading.

BV Bypass Valves

All positive displacement pumps are to be fitted with a back-to-tank bypass valve. To serve that purpose, Blackmer bypass valves are all ductile iron and available in 1.25 in. to 2 in. sizes.

LB Compressors for LPG and NH_3 Transfer

These ductile iron compressors are available in four sizes to meet any application. Compressors are especially well-suited for unloading rail cars, evacuating cylinders and tanks and anywhere vapor recovery is required.

In addition to products available for the transfer of liquefied gases, Blackmer manufactures a wide range of products for use in many industries and markets worldwide:

- Sliding Vane Pumps
- Centrifugal Pumps
- HD Industrial Process Compressors
- HR Gear Reducers
- Hand Pumps

General Characteristics of Liquefied Gas

LPG is an abbreviation for "liquefied petroleum gas" and encompasses several products in the hydrocarbon family; compounds composed of carbon and hydrogen of varying molecular structures. Propane and butane are the two best known hydrocarbons that are used as fuel in homes, businesses and industries. In the international markets, LPG predominantly refers to a propane-butane mixture. These mixes may vary in composition, from ones that are predominantly butane to ones in which propane is the principal constituent.

LPG, whether butane or propane, is unique in that it can be transported and stored as a liquid, but when released it will vaporize and burn as a gas. LPG can also be easily changed from either liquid state or gas state. No other commercial fuel has these characteristics. Natural gas, for example, cannot be transported in a tank in any meaningful quantities unless it is either compressed to extremely high pressures or chilled to -259°F (-126°C), at which point it liquefies. Even when compressed, it contains only a fraction of the useful energy of the identical volume of liquid-state LPG.

When liquefied, LP gases are always at their boiling point at normal temperatures. The slightest drop in pressure or the least addition of heat will cause them to boil and give off vapor or gas. This characteristic becomes critical when considering the transfer of liquefied gases from one tank to another. Being a liquefied gas, LPG must be stored in an enclosed container under pressure. The fluid in a tank is in state of equilibrium, with the gas vapors on top of the liquid providing the tank pressure to keep the liquid from boiling.

Appendix A shows a chart outlining the physical properties of propane and butane. The specific gravities of the liquids are just over half that of water. This means a gallon of propane or butane weighs only half the weight of a gallon of water. Also, propane and butane have viscosity of about 0.1 centipoise, which make them approximately 10 times thinner than water. This property makes LPG a difficult fluid to pump since a low viscosity fluid is harder to seal and prevent pump slippage.

The single significant difference between propane and butane is their boiling points, the temperature at which each will vaporize. Butane boils at approximately +32°F (0°C), propane at -44°F (-42°C) at atmospheric pressure. Therefore, at 0°F (-18°C), butane will not vaporize at atmospheric pressure while propane will. Consequently, at any given temperature, the pressure for a propane vessel will be higher than a butane vessel. Refer to chart in the Appendix B titled, "Vapor Pressure of Liquefied Gases."

LPG is inherently a safe fuel. Two prime factors contribute to LPG safety; one is its narrow limits of flammability, the other is the fact that the container in which it is stored is extremely strong and airtight. If the confined gas cannot escape, it can't burn. LPG has narrower limits of flammability than most fuels. For propane, the respective limits are 2.4% and 9.6%. This means that when the concentration of LPG in air is less than about 2.4% or more than 9.6%, the mixture will not support combustion.

Properties of LPG

The following properties of LPG should be understood for the purpose of promoting safety in usage and for intelligent action in handling this fuel:

1. The gas or vapor is heavier than air.
2. The gas or vapor will diffuse into the atmosphere very slowly unless the wind velocity is high.
3. Open flames will ignite air-gas mixtures which are within the flammable limits.
4. Gas-air mixtures may be brought below the flammable limit by mixing with large volumes of nitrogen, carbon dioxide, steam or air.
5. Fine water sprays reduce the possibility of igniting gas-air mixtures.
6. The vapor pressure of this fuel is greater than gasoline. It is safely stored only in closed pressure vessels designed, constructed and maintained according to appropriate regulations and equipped with safety devices as required.
7. Liquid in open vessels will evaporate to form combustible mixtures with air, even if the ambient temperature is many degrees below the boiling point.
8. The rapid removal of vapor from the tank will lower the liquid temperature and reduce the tank pressure.
9. The liquids will expand in the storage tank when atmospheric temperature rises. Storage tanks must never be filled completely with liquid. Refer to NFPA 58 for storage tank filling density.
10. Liquid drawn from the storage tank will cause freeze burns on contact. This is due to the rapid absorption of heat by the liquid upon vaporization in the open.
11. Condensation will occur in gas (vapor) distribution lines when surrounding temperatures are below the boiling point of the liquid.
12. Liquefied petroleum gases are excellent solvents of petroleum products and rubber products. Special pipe joint compound and rubber substitutes are available for use in distribution.

Positive Displacement Pumps

The pump is probably the oldest fluid transfer device known. At least two types date from early recorded history: (1) the undershot-bucket waterwheels or norias, used in Asia and Africa 3,000 years ago and still common today and (2) Archimedes' screw pump (around 250 BCE) still being manufactured today to handle solid-liquid mixtures.

A pump is a device for transferring fluids; but if it transfers gases (or vapors), three different terms may be used, depending upon the pressure rise achieved. Up to about 1 psi pressure rise a gas pump is called a fan; between 1-40 psi it is called a blower; and above 40 psi it is called a compressor. In addition to transferring fluid, a pump also is a device which adds energy to a fluid. There are two basic types of pumps: positive-displacement and dynamic or momentum-change pumps. There are several billion of each type in use around the world today.

Positive-displacement (PD) pumps have a moving boundary which forces fluid along by volume changes. A cavity opens and fluid is admitted through an inlet. The cavity is then closed and fluid is squeezed through an outlet. The classic example is the mammalian heart, but mechanical versions are in wide use. PD pumps may be classified into two basic groups: reciprocating and rotary. Both sliding vane and gear pumps are considered rotary pumps.

All PD pumps provide a nearly constant flow rate over a wide range of pressure rises, while the dynamic (centrifugal) pump gives uniform pressure rise over a range of flow rates. **A PD pump is appropriate for high pressure rise and low flow rate and its greatest advantage is the capability to handle some quantity of entrained vapors.**

Blackmer manufactures a Sliding Vane pump specifically designed for LPG applications. A sliding vane pump consists of a slotted rotor attached to a rotating shaft. Vanes are fitted in the rotor slots and freely slide in and out during operation. An eccentric cam profile is machined into the liner, forming the pump chamber.

As the rotor turns, the vanes slide out of the slots and ride along the liner. At the intake port, fluid is drawn into the pumping chamber, which is formed by rotor and liner surfaces. A volume of fluid, trapped between two vanes, is pushed along the pumping chamber. At the outlet port, the vanes slide back into the vane slot and the fluid is squeezed out the discharge piping.

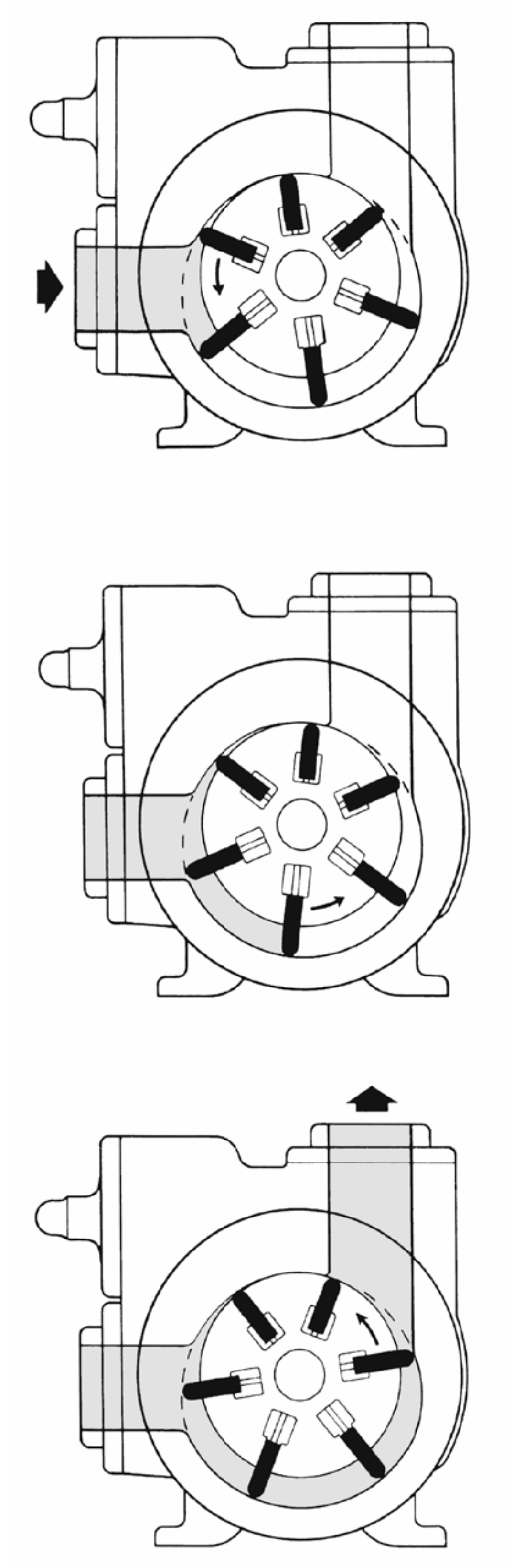


Figure 1

Effect of Vaporization on Pump Performance

As mentioned on the previous page, propane is easily converted from a liquid to a gas, which can be advantageous. However, this property also classifies propane as a highly volatile fluid. The volatility of a liquid is a measure of its ability to remain a liquid at atmospheric temperature and pressure. Water is a stable fluid. It is this volatility that makes LPG so difficult to pump.

Figure 2 illustrates what happens when you transfer liquefied gas from one tank to another. As the liquid level drops, the vapor above expands and its temperature and pressure drop. Immediately, the liquid begins to boil, creating vapor bubbles. The velocity of liquid entering the intake pipe carries some of these gas bubbles with it. Each restriction in the intake 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.

Vapor causes an adverse effect on both pump life and performance. Vapor bubbles prevent liquid from completely filling the pumping chamber cavity, which results in reduced pump capacity. Excessive vapor in the suction lines will cause large pressure spikes, which affects vane actuation and results in increased noise levels. The vanes will rapidly bounce on and off the liner. Also, excessive vapor will prevent liquid from cooling and lubricating the mechanical seal face. Without a liquid film, the seal faces will rapidly wear and lead to premature seal failure.

A globe valve is illustrated in Figure 2 because it increases the amount of vaporization. We recommend full port ball or gate type valves for minimum vaporizing effect.

Some vaporization will occur whenever liquefied gasses are pumped. Proper system design will minimize the amount of vapor formed and significantly increase the pump's performance and service life.

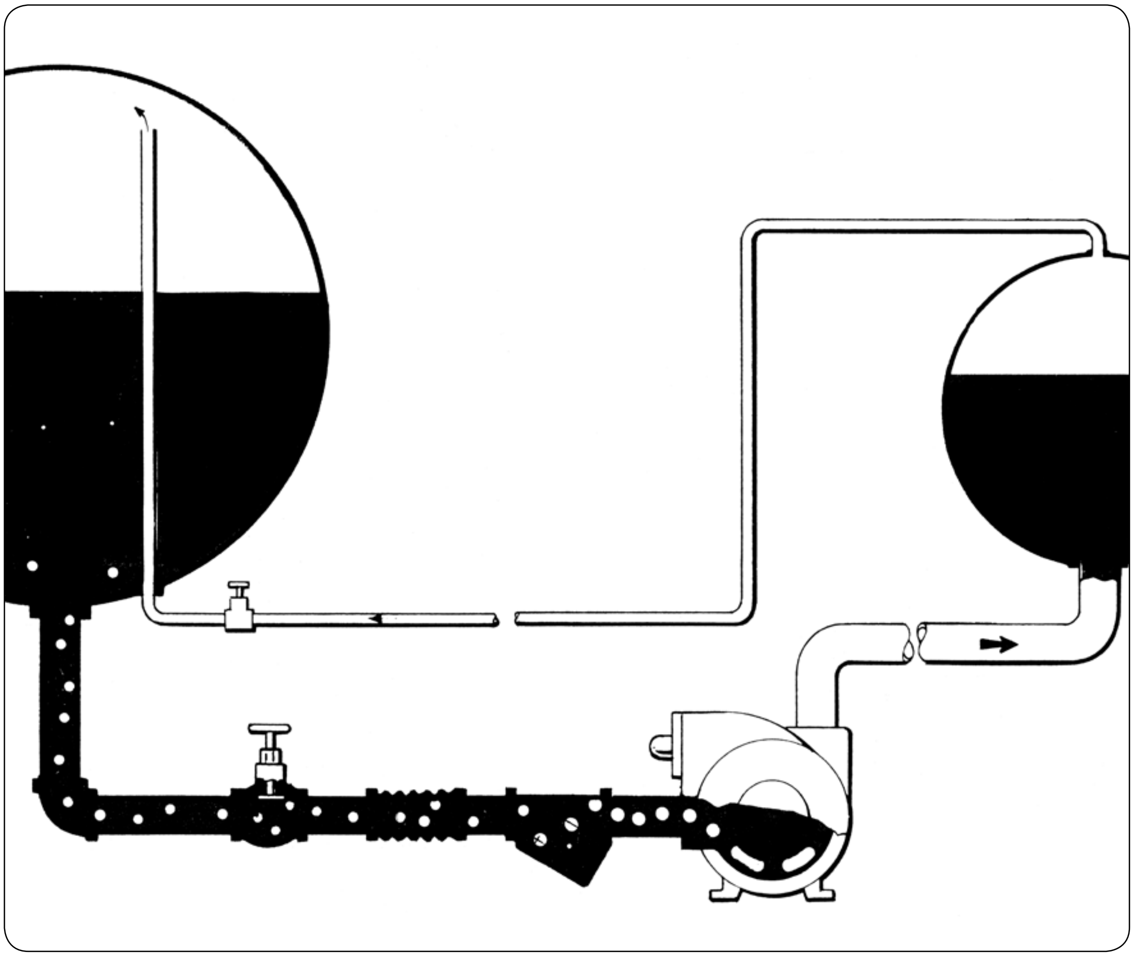


Figure 2

Compressors

General

Blackmer compressors are quite specialized among the many types of compressors offered in the market. They are a positive displacement, vertical, reciprocating design and are available in single or two-stage models. All models have two cylinders and some are available with either air-cooling or water-cooling. Most models have single-acting cylinders, although the largest have double-acting cylinders. Oil-free ductile iron cylinders with PTFE piston rings are standard.

In general, Blackmer compressors may be used on those applications with pressures in the range of 3 - 615 psia (0.2 - 42.4 bar) and 2 - 50 bhp (1.5 - 37 KW). Liquefied gas transfer compressors are available for transfer rates of approximately 40 - 675 gpm (9 - 153 m^3/hr).

A device which pumps a gas at differential pressure above 40 psia is termed a compressor. Like pumps, compressors are classified into two basic classes: positive displacement and dynamic. A positive displacement compressor captures a fixed volume of vapor or gas, compresses the volume and then discharges the gas into the discharge line.

A piston type compressor is classified as a reciprocating positive displacement compressor. Other positive displacement compressor types are screw, sliding vane, wobble plate, diaphragm or lobe.

A vertical compressor orients the cylinders in the vertical plane, resulting in a machine requiring a minimum amount of floor space. Horizontal, “V” or “W” configurations are also on the market.

A single-stage compressor draws gas from the suction line into the cylinder(s), compresses it and discharges it into the discharge line. Only one stage of compression is involved.

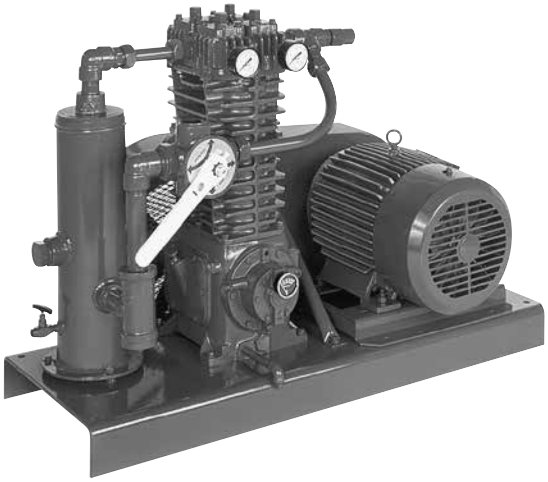
A two-stage compressor draws gas from the suction line into the first stage cylinder, compresses it and discharges the gas into a second stage cylinder, where it is compressed further and pushed into the discharge line. The gas is compressed twice, raising it to a higher pressure than can be done with a single-stage compressor. Two-stage compressors are seldom used for liquefied gas transfer.

Applications

Blackmer compressors may be used in many industries and in many situations. In general, most LPG applications will fall into two categories:

Liquefied Gas Transfer: The compressor is used to pressurize a vessel full of liquid. This pressure then pushes the liquid to another vessel. The most common application of this technique is the unloading of LPG rail cars into stationary storage vessels. If needed, a compressor can also be used for general liquid transfer in the plant, such as storage tank to transport or storage tank to bulk truck or from a transport or bulk truck back to storage. After the liquid has been pushed out of the vessel, a vapor recovery operation is often performed.

Vapor Recovery: Gases that were previously left in the vessel or vented to the atmosphere are now being recovered due to growing environmental, safety or economic considerations. Almost any gas should now be recovered, if at all possible. Some typical examples would be liquefied gas vapors left in a vessel after the liquid has been pushed out, emptying of vessels prior to a maintenance or refurbishment operations, and evacuation of cylinders, hoses and lines.



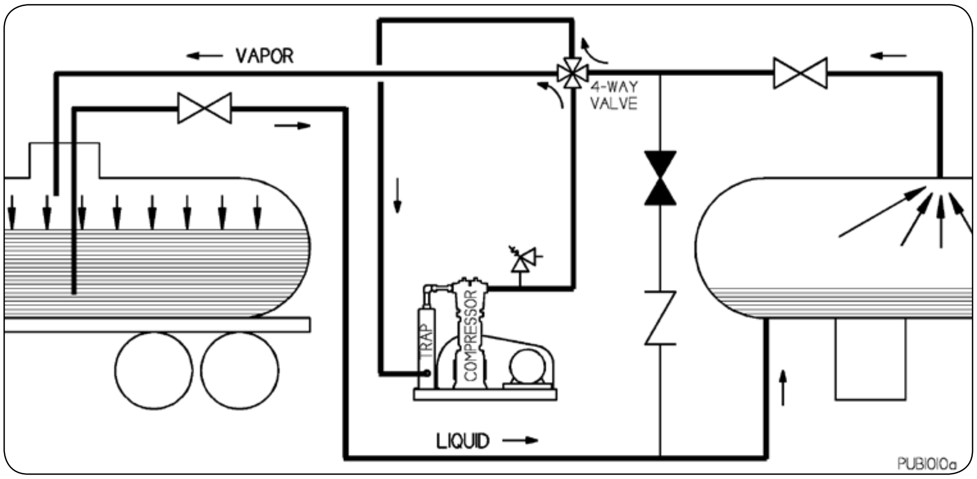


Figure 3

LPG Transfer

A liquid pump cannot completely empty a LPG vessel of all its product. A small amount of liquid (the "liquid heel") will always remain. Even if all of the liquid could be pumped out, the vessel would still be full of vapor at vapor pressure. This remaining vapor can equal approximately 3% of the tank's total capacity. This means that if a plant were to receive its product via transport, 97 transports unloaded with a compressor would be the same amount of product as 100 transports unloaded with a liquid pump. Also, if a vessel needs to be opened to atmosphere for service or repair work, venting the vapor to atmosphere can be expensive and may pose a safety hazard. Using a compressor to recover these vapors before opening the tank to atmosphere can minimize both of these problems.

Many vessels only have openings on top of the tank and none on the bottom of the tank. The most common example is an LPG rail tank car. If you will recall from the pump section, all of the suggestions for a proper piping system show the inlet line coming out of the tank bottom. Trying to pump out of a tank with only a top opening will result in poor pump suction conditions. This will result in very short vane and seal life and noisy operation. Also, as the liquid level lowers during transfer, the pump suction conditions continually worsen until the pump can no longer function. Considerable liquid will be left in the vessel and depending upon the installation, this might be 20 or 30 percent of the vessel's capacity.

Some vessels have no openings at all into the liquid section of the tank. Typical home delivery tanks of under 500 gallons (2,000 liters) and typical small cylinders, such as the 20 pound (5 kg) cylinders, only have a single opening in the top of the vessel. Also, trucks or railcars that have been involved in accidents may be laying on their side in such a position that none of the normally used openings into the tank connect to the liquid section in the tank.

In any of these situations, a liquid pump would be useless in trying to empty the vessel. Compressors, on the other hand, can easily handle all of these situations, while the very best that a pump can do is to empty a vessel of liquid but still leave it full of vapor.

While pumps must be provided with properly designed suction lines, this may be impossible to do with many vessels. A compressor is not subject to these limitations. A compressor can recover both the liquid and the vapor from virtually any vessel under virtually any situation.

Figure 3 shows a typical LPG liquid transfer system with a compressor. In this case, the compressor, with its four-way valve, transfers the contents of the rail tank car into the storage tank. Note that a vapor line connects the top of the storage tank through the four-way valve in the compressor system to the top of the rail tank car. Also, note the liquid withdrawal line with a dip tube connecting the top of the tank car to the bottom of the storage tank. As illustrated, a typical LPG compressor unit is mounted on a baseplate complete with motor and belt guard. Also, shown are a four-way valve, an inlet strainer, liquid trap and the discharge relief valve. Virtually every compressor used for LPG transfer will have these items.

In order to transfer the liquid from the railcar to the storage tank, the compressor will draw vapors from the storage tank vapor portion and into the compressor where they are compressed slightly.

These compressed vapors, which are at a slightly elevated pressure, will be discharged into the top of the rail tank car. This action of pulling vapors from the storage tank, compressing them slightly and then putting them into the top of the rail tank car, will slightly reduce the pressure in the storage tank while raising the pressure in the rail tank car. This difference in pressure will then cause the liquid to move through the liquid line from the railcar over to the storage tank.

Vapor Recovery

Once all of the liquid is pushed out of the railcar, the transfer operation can then continue to recover the remaining vapor in the railcar. Figure 4 illustrates the same installation as shown in the liquid transfer operation, except that some of the valve settings have been changed in order to perform the vapor recovery operation. First, the four-way valve has been rotated 90° so that the compressor will now draw vapor from the railcar and discharge it into the storage tank, which is just the opposite of the liquid transfer operation. Second, the discharge of the compressor is now routed back to the storage tank's liquid portion. This will help prevent excessive pressure rise in the storage tank. Third, the liquid line valve is closed.

With the valves properly set, the compressor can withdraw vapor from the top of the railcar, compress them slightly and discharge them into the liquid section of the storage tank. The liquid in the storage tank will then condense these vapors back to liquid. In this operation, the railcar pressure will gradually drop while the storage tank pressure will rise only slightly. This operation should continue until the pressure in the railcar is at about 25 to 30 percent of the original tank car pressure. Of course, this pressure is going to vary throughout the year and with the actual product being transferred, whether it is propane or butane, because the vapor pressure of the product varies throughout the year. Attempting to go beyond the 25 to 30 percent cutoff point is generally not economical; the time and energy involved versus the amount of product recovered makes it not worthwhile.

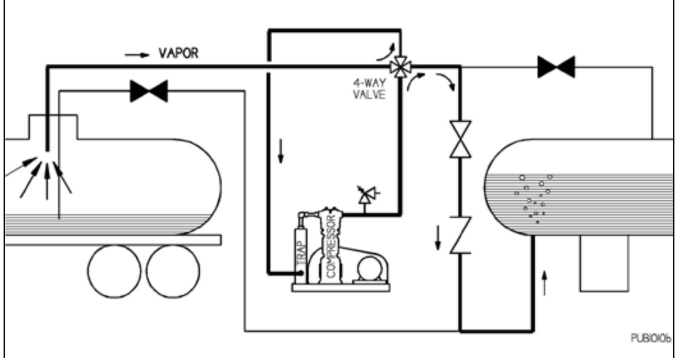


Figure 4

Compressor Components

Figure 5 is a cross-section of a typical LPG compressor. All the pressure containing components are ductile iron. The piston rod seals in the packing box are a series of PTFE V-rings that are spring-loaded. The entire seal assembly is contained in the packing box so that the entire packing assembly may be installed easily. The pistons are a simple one-piece design, fabricated from either steel or ductile iron. The piston rings are PTFE, which allows them to operate without lubrication. Both the suction and discharge valves are designed for non-lubricating service. The suction valves are normally fitted with a liquid relief device. This device will help to protect the compressor in the event that some liquid does enter the compressor.

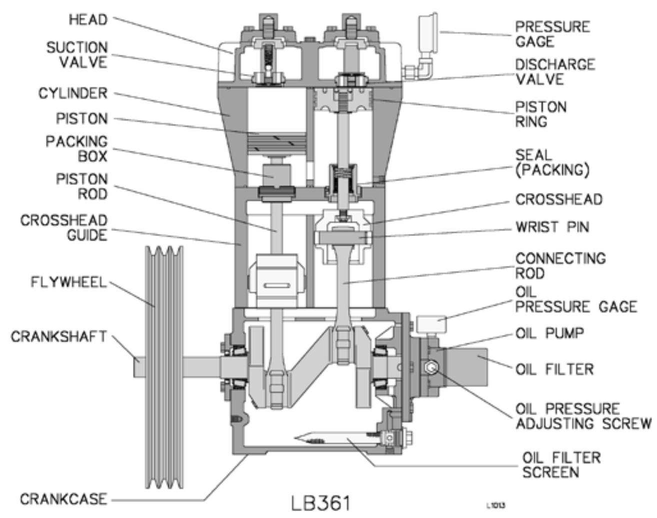


Figure 5

Typical Compressor Packages

Figure 6 illustrates the various components that make up a typical LPG liquid transfer and vapor recovery package. The mounting arrangement consists of the compressor, complete with pressure gauges, a baseplate, the belt guard and the belt drive system. It also includes the four-way valve, liquid trap, inlet strainer, relief valve and possibly a liquid level switch.

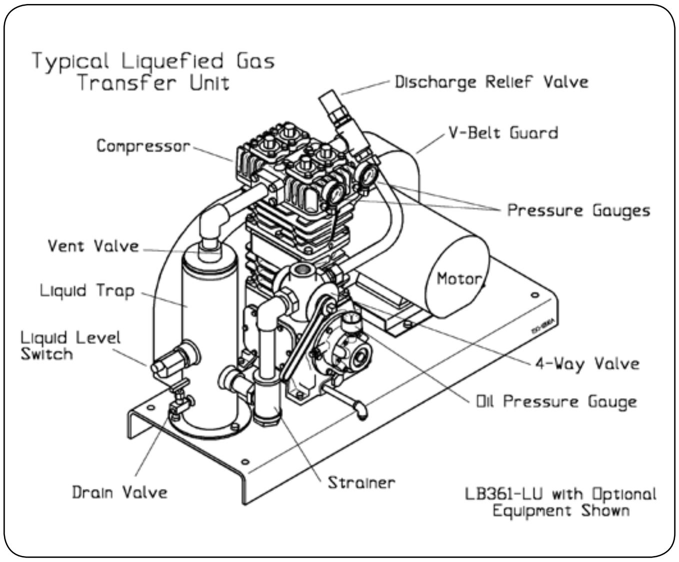


Figure 6

Four-Way Valve

One advantage of using a compressor is that both the liquid and the vapor may be recovered from the vessel. The four-way valve makes this process both practical and easy. The four-way valve reverses the flow of gas through the system without changing the direction of compressor rotation.

Figure 7 shows what happens inside the four-way valve. During the liquid transfer operation vapor is drawn off the top of the storage tank and into the top of the four-way valve where it is routed to the liquid trap and into the compressor suction. The vapor is then compressed slightly and comes from the compressor discharge into the opening at the right of the four-way valve, and is eventually routed to the railcar out the bottom of the four-way valve.

In order to perform vapor recovery, the four-way valve is rotated 90°. In this position, vapor is drawn from the railcar into the bottom of the four-way valve and out the left side of the four-way valve to the liquid trap to the compressor suction. The compressor then discharges into the right side of the four-way valve and the gas is routed to the top of the four-way valve and into the storage tank.

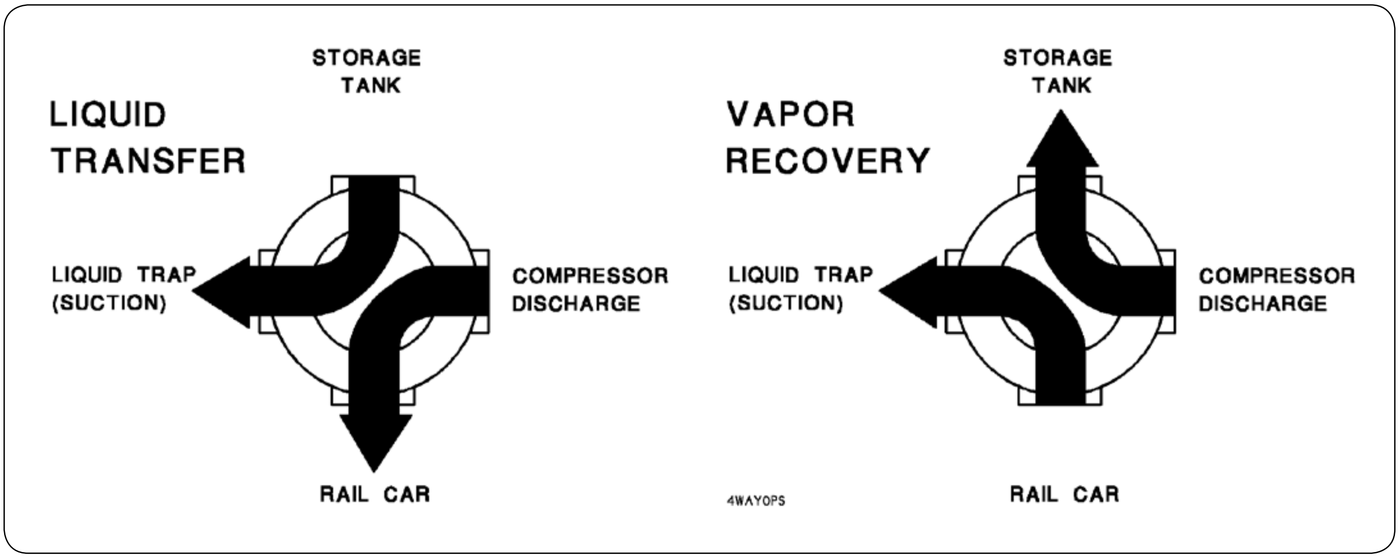


Figure 7

Liquid Traps

Liquid traps are fitted to the suction side of the compressor and must be used on all LPG compressor installations. The purpose of the liquid trap is to trap liquid before it can enter the compressor. Even though the compressor is connected only to vapor lines, these lines will contain some liquid due to changes in temperature, causing some condensation inside the line. Also, on many systems an incorrectly positioned valve may allow liquid into the vapor line.

Liquid traps provide a space for small amounts of liquid, such as that that would normally occur due to condensation in the vapor lines, to collect before entering the compressor. This small amount of liquid will eventually boil off during the course of the transfer operation and usually poses no significant problems.

The liquid trap may be fitted with a mechanical float that will physically block the suction line between the trap and the compressor if too much liquid collects within the trap. Also, an electric float switch may be used to actually stop the compressor's motor in the event of high liquid level in the trap.

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Relief Valves and Strainers

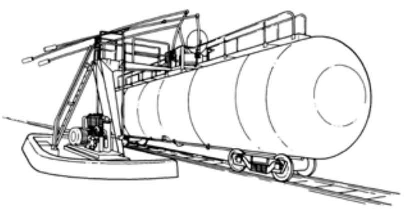
All Blackmer LPG compressors must be fitted with a discharge pressure relief valve. For most LPG services, a relief valve setting of 250-265 psig (17.2-18.3 bar gauge) is typical. Ensure that the proper relief valve for the service is chosen. Valves used for LPG, propane or butane service are typically brass. Brass valves must not be used for anhydrous ammonia service.

Inlet strainers should normally be used with compressors. Clearances inside the compressor are quite small and any foreign material allowed into the compressor would quickly cause severe wear and tear, and expensive repairs would be needed soon. A 30-mesh screen is generally adequate. Clean strainers regularly. Cleaning of the strainer is especially important on any new systems or recently recommisioned systems.

Minimize Line Losses

While pipe and fitting size is not as critical as that on a pump suction, a properly designed system will perform better. In general, lower pressure losses will require less power to drive the compressor and will result in a faster transfer rate. Typically, total system losses should be about 20-30 psi (1.5-2 bar). Pressures higher than 40 psi (3 bar) should be avoided.

Installing piping or fittings that are too small will increase the system differential pressure and will seriously degrade system performance. In general, use larger line sizes and keep them as short as possible. Eliminate any unneeded fittings, particularly on the liquid line, as this is where most of the pressure losses will occur. Use low restriction fittings and valves, which will minimize pressure losses and always ensure all strainer elements are clean.



Mimimize Heat Losses

The compressor should always be placed next to the vessel being emptied. If the compressor discharge line length is excessive, too much heat will be lost before reaching the vessel being emptied. The hot compressed gases will then start to condense. Any gas that condenses back to a liquid is essentially useless to the transfer process and the net effect is that the overall transfer rate will decline. It may be desirable to insulate discharge lines that are longer than is typical.

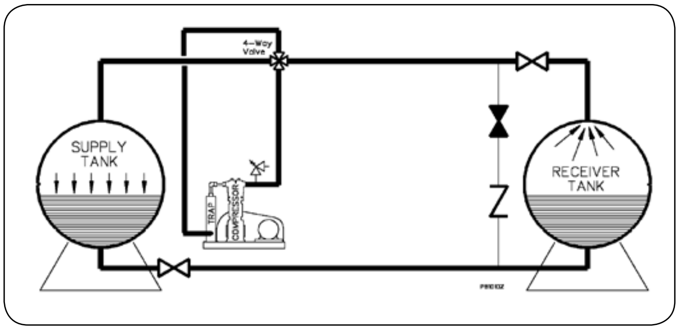


Figure 8

Watch Out For Liquid

Allowing liquid to enter a compressor can result in an extremely expensive failure. As mentioned earlier, a liquid trap must always be used with a LPG compressor system.

If the distance between the two vessels is longer than normal, a larger liquid trap should be considered. For most installations, the optional ASME trap will provide sufficient volume, although in some cases, an even larger vessel may be required.

Whenever possible, place the compressor so that it is physically slightly higher than most of the piping used in the system. This will cause any liquid that does collect in the lines to drain away from the compressor.

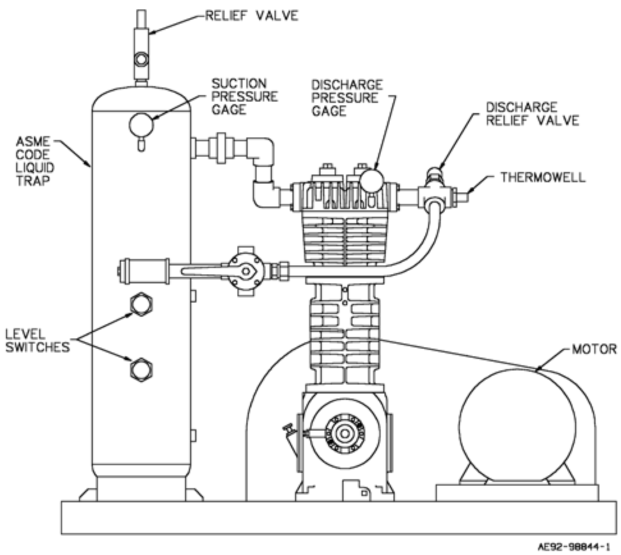


Figure 9

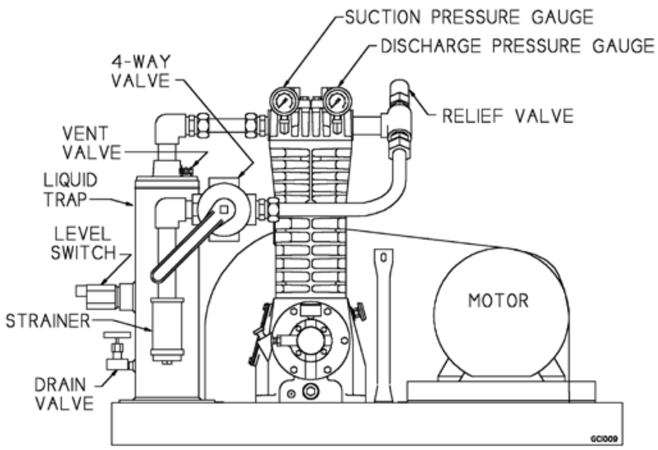


Figure 10

Installation Guidelines

Figure 11 shows a typical compressor installation. Since Blackmer compressors are reciprocating rather than a rotating devices, a proper foundation for the compressor and support for the piping is very important. A 8-10-inch (20 to 25 cm) foundation depth is recommended.

The compressor baseplate must be well supported, along with its entire length, and be firmly bolted to the concrete foundation. Pipes leading to and from the compressor should be well supported as near to the compressor as feasible. Flex connectors may be used to help dampen any vibration induced by the compressor.

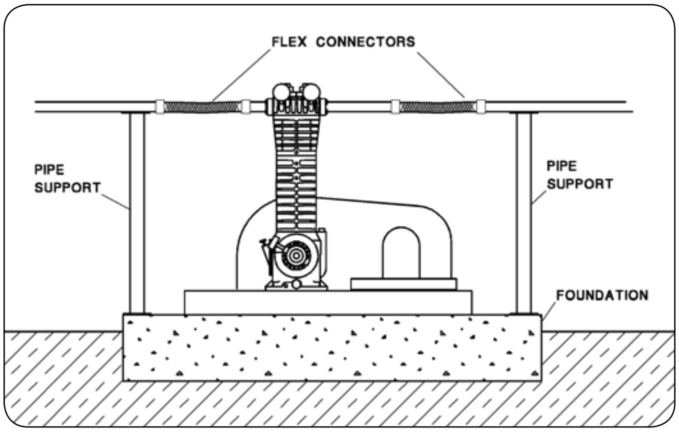


Figure 11

Propane Pump Installations

Pumping systems on bobtail trucks, truck transports or bulk plants all contain similar components; vapor return lines, bypass piping, suction and discharge piping which can affect the liquid transfer delivery rates. Proper pump suction design is a common consideration for any propane installation and is particularly critical for motor speed pumps, underground pumping and cold weather pumping.

Vapor Return Line

The vapor return line from the top of the receiving tank to the supply tank helps to keep the pressure up in the supply tank and reduces the amount of boiling. Also, relieving vapor pressure in the receiving tank as the liquid rises in the tank equalizes pressures in both tanks and reduces the differential pressure across the pump. Consequently, the pump can deliver more product at the lower differential pressures.

The effect of this vaporization can be demonstrated on a bobtail delivery truck by attaching the hose to the supply tank and recirculating the liquid. The flow rate when recirculating is always more than when delivering to another tank because the pressure in the supply tank does not drop. The amount of flow reduction will indicate how much vaporization has occurred in the tank and inlet line.

Vaporization in the intake line imposes a rather rigid limit on the maximum delivery rate when no vapor return line is used. This limit is about 2 to 2½% of the tank's capacity per minute, but will vary somewhat with temperatures of liquid and atmosphere and intake line restrictions. For example, a 1,000 gallon (3,785 liter) tank will be limited to a 25 gpm (95 L/min), maximum withdrawal rate. **Overspeeding the pump or using a larger pump will have little or no effect once this barrier has been reached.**

Quite often, vapor return lines are too small to be effective. To check the efficiency of existing return lines, observe the pressure gage on the supply tank during a delivery. If it shows a drop of more than two or three psi, vaporization can be seriously affecting the delivery rate. A more exact check would be to time the delivery rate during the first minute of pumping with a stopwatch, then wait several minutes and time the rate again. The second reading will typically be less than the first.

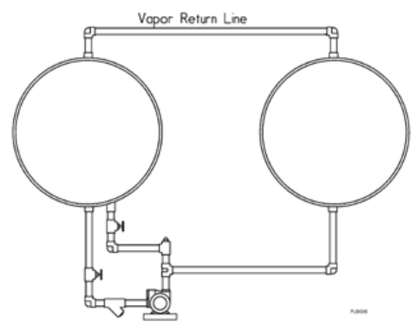


Figure 12

Bypass Piping System

All pump installations must be fitted with a bypass line back to the supply tank. All PD pumps deliver a fixed volume of fluid with each revolution. Therefore, provisions must be made to route any excess flow back to the tank.

If a bypass piping system is not present, fluid will recirculate within the pump. The liquid recirculating in the pump will rapidly heat up and vaporize. The pump may run completely dry, greatly decreasing vane and seal life. A bypass line routed to the suction line will have the same effect. A back-to-tank bypass line extends the recirculation loop allowing the recirculated liquid to cool. The back-to-tank bypass line may go either to the bottom of the tank, the liquid section, or the top of the tank.

Set the bypass valve at least 25 psi (1.7 bar) lower than the pump's internal relief valve setting. This will ensure the bypass valve opens first. The pump's internal relief valve should open only as a final system protection device. The pump's internal relief valve routes discharge fluid back to the pump inlet, which will quickly cause wear and tear on the pump if used excessively.

The "Alternate Discharge to Storage Tank" line and manual valve may be used to unload transports without pumps into the storage tank. The manual valve in this line must remain closed during all other transfer operations.

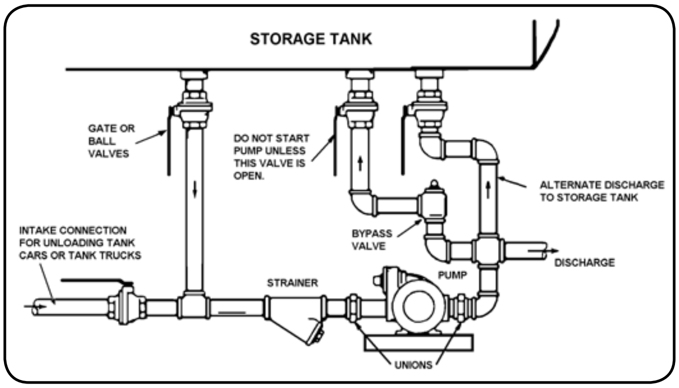


Figure 13

Suction Line Piping

One of the most important considerations for a proper installation is the suction line piping. A properly designed suction line will minimize vapor formation by limiting the line restrictions and preventing vapor pocket formations. In light of the tendency of LPG liquid to vaporize, the design of the intake piping plays a critical role in the efficiency of every system. The following paragraphs outline some good design practice for LPG suction line installations. Adhering to these guidelines will promote longer pump service life.

a) Inlet piping from the tank to the pump should be as short as possible.

b) The pump should always be at a lower level than the tank's lowest liquid level.

c) For stationary applications, the storage tank should shield the pump and inlet piping from sun's heat. Also, the suction lines should be painted white or silver to reduce the radiant heat absorption.

d) Suction line pressure losses should be less than 2 psi (0.14bar). To minimize pressure losses in the suction line, use low restriction type valves and fittings. Also, long sweep radius ells are preferred.

e) The nearest fitting or strainer should be at least 10 pipe diameters from the pump inlet.

f) Check and clean the inlet strainers regularly.

g) Use eccentric reducers with the flat side up.

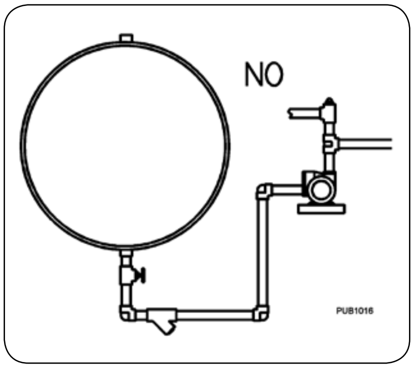


Figure 14

h) Long intake lines should be avoided, even when they are so large that they have practically no friction loss. At night or in cold weather, the liquid will cool. Then, as the day warms or, or sunlight shines on the pipes, the cool liquid will be heated, causing some liquid to be vaporized. This vapor will decrease the pump's flow rate and increase the noise and vibration. To minimize this problem, intake lines should be sloped upward toward the supply tank so vapors can flow back into the tank.

i) Avoid up-across and down pipe loops where vapors can accumulate.

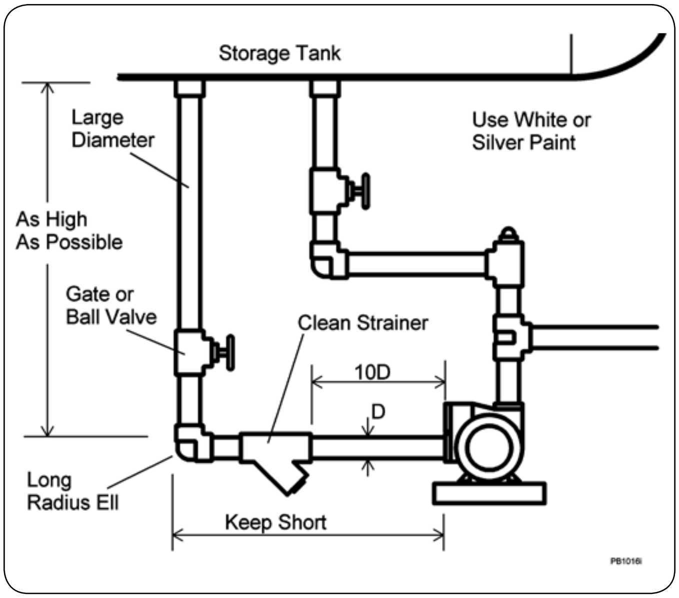


Figure 15

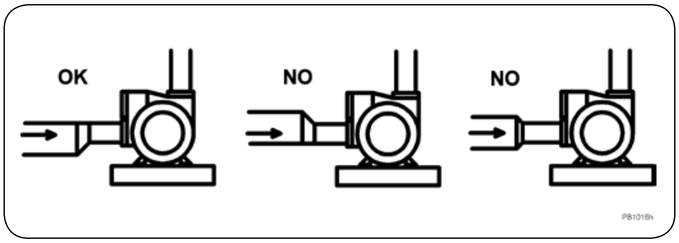


Figure 16

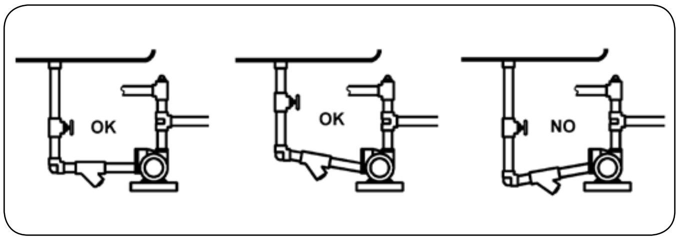


Figure 17

Net Positive Suction Head

Net Positive Suction Head Required (NPSHR) is the minimum inlet pressure required at the pump inlet to avoid excessive cavitation. The Net Positive Suction Head Available (NPSHA) must be greater than required (NPSHR) to prevent pressure at some regions in the pump suction area from dropping below the liquid's vapor pressure. If the inlet pressure is lower than the vapor pressure, bubbles will form in the liquid. As the bubbles travel through the pumping chamber to the higher discharge pressure region, the bubbles will collapse. The collapse of the vapor bubbles causes pressure spikes, resulting in noise, vibration and damaged hardware.

In addition, the vapor bubbles reduce a pump's capacity since the pumping chamber volume is being filled with a mixture of vapor and liquid. The vapor bubbles will occupy a volume, which under normal conditions, is filled by liquid. Although PD pumps are less susceptible to vapor lock than a centrifugal pump, under severe conditions, PD pumps will vapor lock as well.

NPSH becomes more of a concern in certain applications such as pumping from an underground tank, cold weather pumping and running a pump at motor speed.

All typical propane transfer applications operate with some degree of vapor in the suction line. As observed on a bobtail delivery, the pump will deliver more flow when recirculating to the supply tank versus delivering to a cylinder. This reduced flow rate is due to the increased amount of vapor in the suction line during the delivery operation. As the supply tank liquid level drops, the tank pressure drops and the liquid boils, creating vapor bubbles. The vapor bubbles travel along the inlet piping to the pump. As the fluid trapped between the vanes rotates through the pumping chamber, the high-pressure discharge fluid collapses the vapor bubbles. The implosion of the vapor bubbles creates the noise that characterizes cavitation.

NPSH required is normally determined with room temperature water per the Hydraulic Institute's standards. However, a typical LPG installation operates with less NPSHA than when testing with water. Other pump manufacturers, both centrifugal and PD, have reported the same findings.

These general facts have been established from years of experience regarding PD pumps for LPG applications:

1. PD pumps can handle some entrained vapors without adverse affect to pump service life.
2. A flooded inlet condition is sufficient head for a PD pump to operate.
3. Pumps handling LPG will operate with less NPSHA than would be required for water.
4. Even pumps with properly designed suction piping may have a negative NPSHA.

Cold Weather Pumping

As the ambient temperature and product temperature drop below 40°F (4°C), a noticeable reduction in pump capacity is observed. An installation located in a cold weather region must consider this capacity reduction when selecting the proper pump size. As shown in Figure 18, pump efficiencies are significantly lower in a cold environment.

There are several guidelines that can minimize the effects of cold weather pumping:

1. Avoid high friction fittings in the inlet such as tees, globe valves, plug valves, angle valves, check valves and standard port ball valves.
2. Use as few fittings on the inlet piping as possible.
3. Use an inlet pipe one size larger.
4. Install the pump as far below the source tank as possible.
5. Install the pump as close to the source tank as possible and avoid long horizontal runs.
6. Avoid low spots in the inlet piping where vapor bubbles can accumulate.
7. Use a larger size pump to compensate for the lower efficiency at cold temperatures.
8. Keep discharge pressures as low as possible by using vapor return lines.

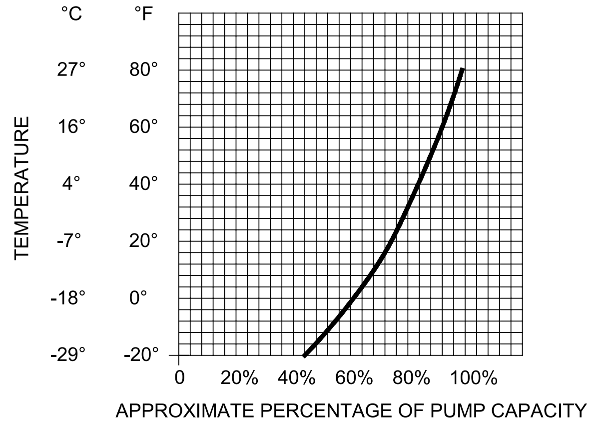
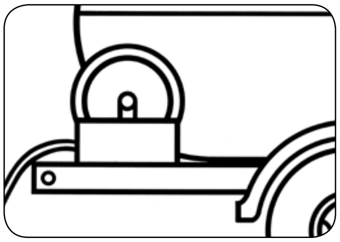


Figure 18

Delivery Systems On Bobtail Trucks

Bobtail Trucks are trucks used for local delivery to fill end-use tanks. They generally provide a metered delivery and have tanks of 3,000 to 5,000 gallons (11,000 to 19,000 liters).



Pump Drive

Pumps on bobtails are commonly driven by the power take-off through a jackshaft connected by universal joints.

A well lubricated, splined slip joint is recommended for the drive shaft. Also note that the PTO and pump's shafts must always be parallel, that the universal yokes at the ends of the jackshaft must be parallel and in phase, and thatthe angularity between two adjacent shafts must not exceed 15 degrees. Failure to heed these suggestions will result in a "gallup" or uneven turning of the pump rotor, which will result in a premature bearing, shaft or seal failure. Figure 19 illustrates the correct mounting of the driveline when universal joints are used.

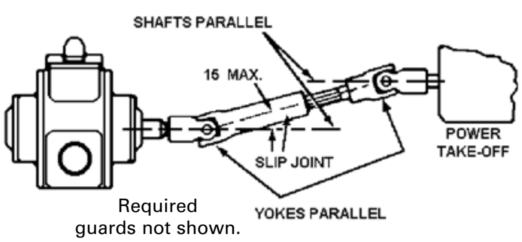


Figure 19

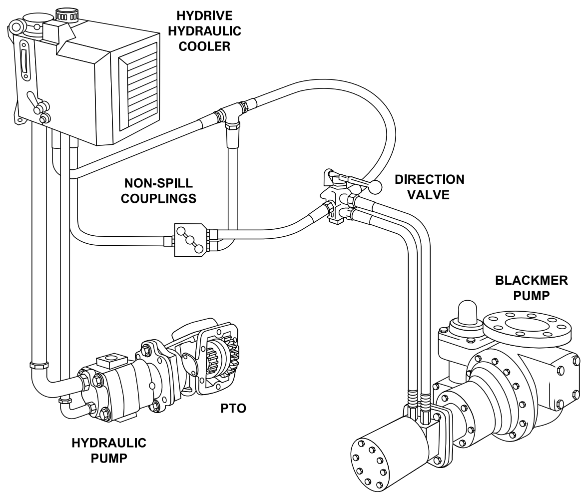


Figure 20

Hydraulic driven units are becoming more prevalent. They increase pump service life by eliminating the external loading on the pump shaft, which is inherent with a power take-off. They also provide, for more consistent speed control and "soft starting" of the pump.

Pump Mounting

There are several methods of mounting and piping pumps on bobtails. Figures 21 and 22 show the arrangements most common, both of which use an internal tank valve with excess flow capability. An internal valve is mandatory. NFPA Pamphlet No. 58 requires that liquid unloading connections on tank trucks be equipped with remotely controlled internal shut-off valves. They are either flanged to the tank, as shown in Figure 21, or threaded, as in Figure 22. The valve can be actuated in any of several ways: hydraulic, using pump discharge pressure or an oil hydraulic system, cable control or pneumatic power.

Ordinarily, internal valves are ideal for maximum pump performance because of their low-pressure drop. However, they should be checked from time to time to make sure they open completely when the pump is delivering. Testing procedures are outlined in NPGA Safety Handbook, bulletin no. 148-90, titled “Internal Valve Operation and Maintenance.” If they stick or do not open completely for any other reason, the restriction will cause vaporization, with a resulting loss of pump capacity and shorter pump vane and seal life.

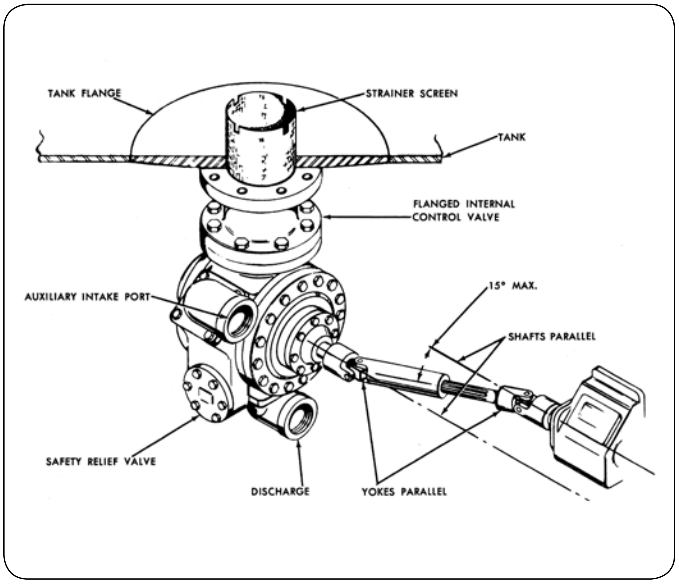


Figure 21

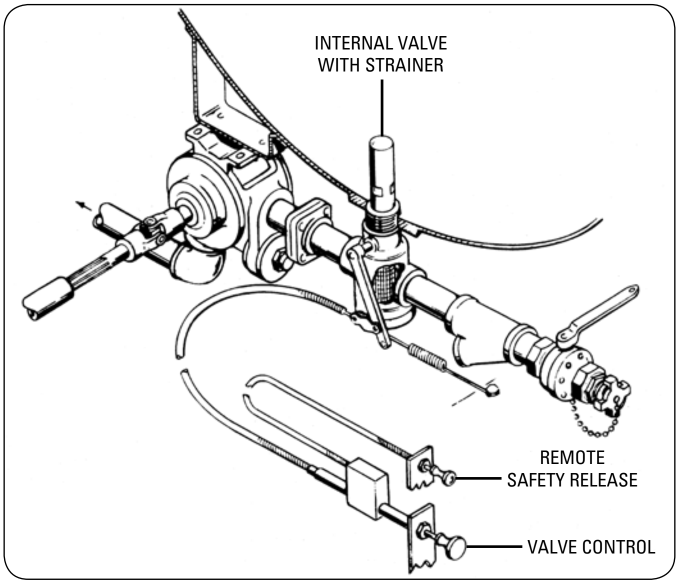


Figure 22

The Flange-mounted Pump (Figure 21) is the ultimate in simplicity of mounting and has the least restriction of flow into the pump. This style is particularly valuable when flow rates of 60 gpm (227 L/min) or more are desired.

The Foot-Mounted Pump (Figure 22) can be mounted on a pad welded to the tank when an internal valve with a sided outlet is used. This eliminates the need for a flexible pipe connector, which is usually necessary on pumps attached to the chassis. The foot-mounting arrangement requires the use of flanged connectors. The internal valve is equipped with a strainer which must be cleaned periodically.

Typical Bobtail Discharge Piping System

1	Flexible Connector	**12**	Clutch Control
2	Vapor Eliminator	**13**	Liquid Delivery Hose
3	Meter	**14**	Vapor Return Hose
4	Differential Regulator	**15**	Thermometer
5	Manual Shut-off Valve	**16**	Pressure Gage with Valve
6	Bypass Valve	**17**	Rotary Liquid Level Gage
7	Tachometer	**18**	Pressure Gage
8	Power Take-Off Control	**19**	Back Check Valve
9	Throttle Control	**20**	Excess Flow Valve
10	Tank Outlet Valve Control	**21**	Vapor Equalizing Valve
11	Hydrostatic Relief Valve	**22**	Filler Valve

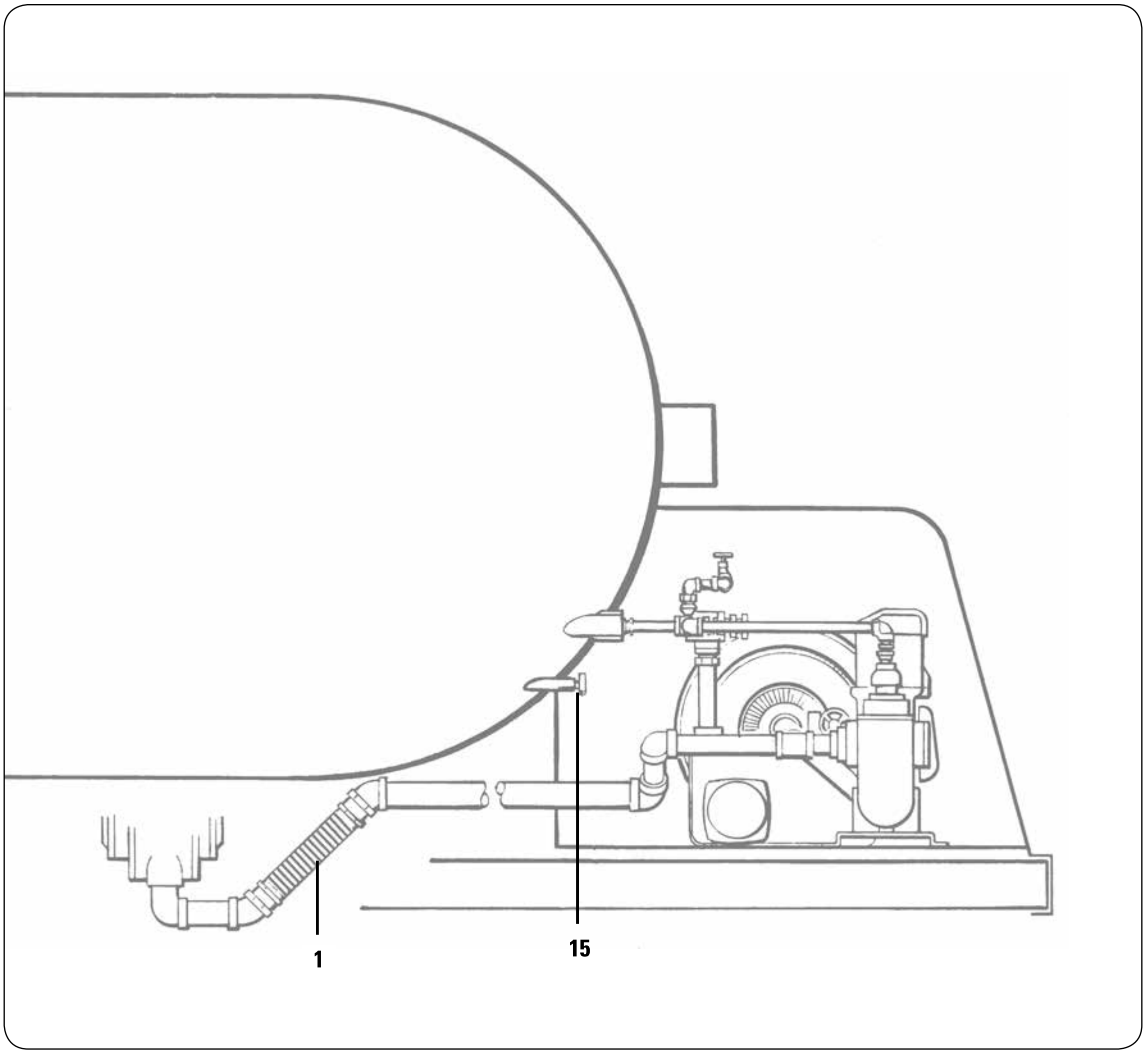


Figure 23

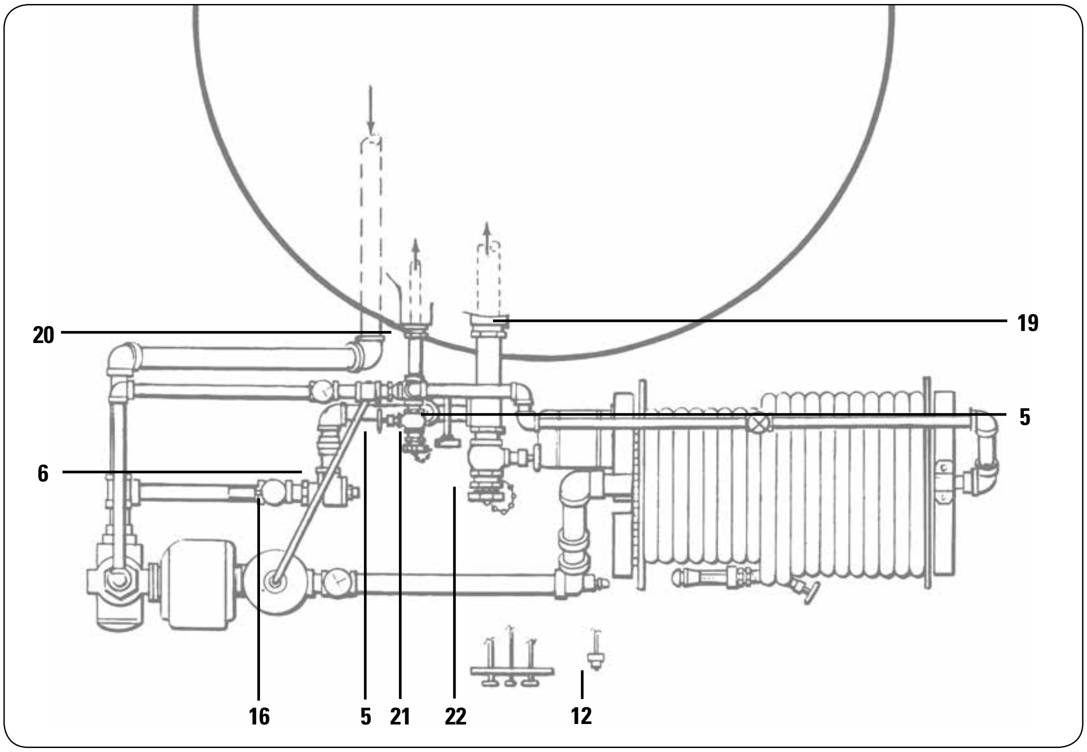


Figure 24

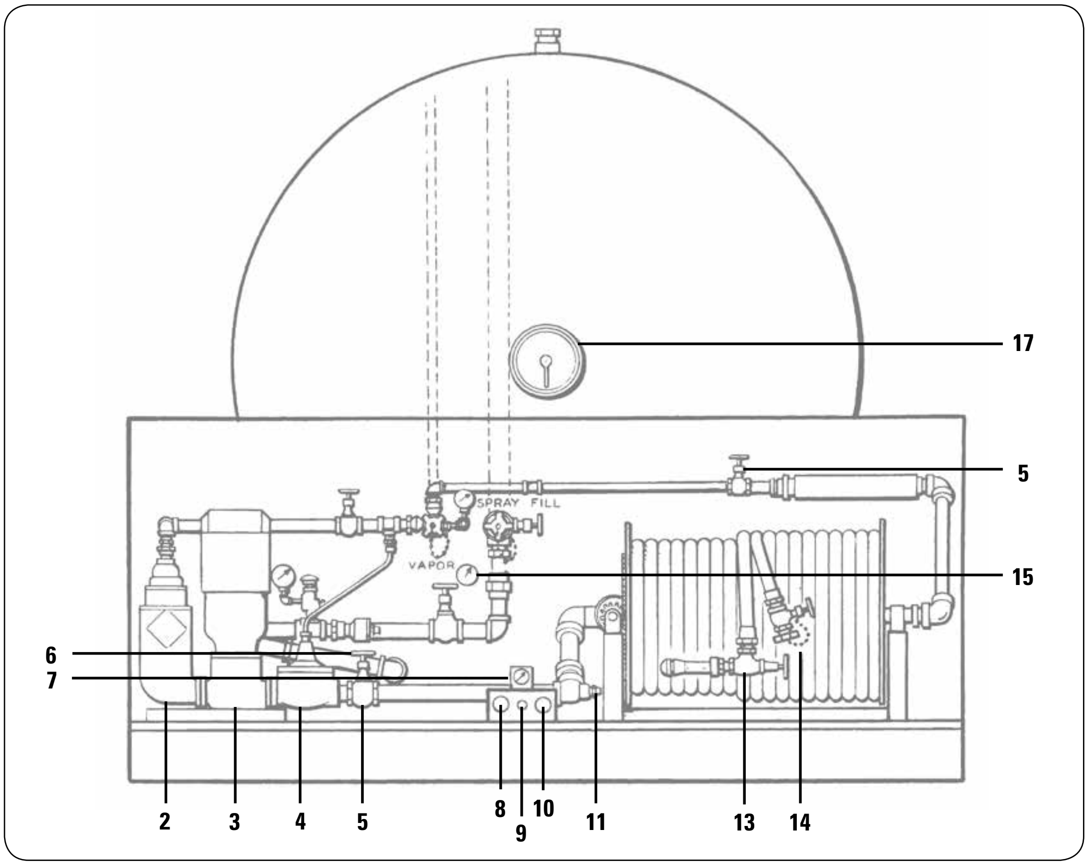


Figure 25

Excess-Flow Valves

Excess-Flow Valves are still in use in the liquid unloading connections of many older trucks. Delivery rates from these older trucks are usually lower than from new ones because their intake piping design and excess flow valves offer significantly greater restriction to flow.

Often these older trucks can be improved by revamping the piping system between the tank and the pump. Improvements might include using 3 inch (7.5 cm) pipe instead of 2 inch (5.0 cm), replacing the excess-flow valve with an internal valve (which also eliminates the need for a separate strainer) and replacing globe valves with gate or ball valves.

Measuring Pressure Loss

As explained before, almost nothing affects the flow rate through the piping system more than the intake line friction losses. You can measure the exact pressure drop due to friction in any existing system. Simply install a pressure gauge in the tapped opening on the pump intake. With the pump not running, the pump inlet pressure and tank pressure should be equal so long as the gauges are properly set. With the pump operating at its normal capacity, a well-designed intake line should not allow more than 1 or 2 psi (0.07 to 0.14 bar) total pressure drop. A higher loss than this will have a critical effect on both pump capacity and life.

A high-pressure loss on trucks equipped with an internal valve indicates that the valve is not opening or the strainer is dirty. It might also indicate that there are unseen restrictions to the valve inside the tank.

The Discharge System
Figure 23 shows a typical discharge system for bobtail trucks with all the various fittings detailed in the schematic.

Discharge Piping can be smaller than the intake piping because pressure build-up by the pump to overcome friction losses in a discharge line does not seriously affect the pump's capacity. Generally speaking, a 1¼ inch (3.2 cm) piping system is satisfactory for flow rates up to 30-35 gpm (132 L/min) and 1½ inch (3.8 cm) for flow rates up to about 50 gpm (189 L/min).

A Union should be used in the discharge piping next to pumps with threaded connections.

A Flexible Connector is required by NFPA Pamphlet No. 58 in discharge piping, which is subject to stresses. System vibrations are dampened by the flexible connectors, which reduces the attachment loading.

A Bypass Valve piped back to the supply tank as shown in Figure 26 is absolutely necessary for maximum pump performance and long pump life. The bypass line is never to be piped back into the pump intake line. The Blackmer 2 in. Bypass Valve (BV 2 w/ Companion Flanges) is recommended for use on bobtails to ease piping installation and maintenance as well as increase pump service life.

Though all Blackmer pumps are built with an internal relief valve, these internal relief valves are for emergency protection only and must not be used for normal recirculation. If a bypass valve is stuck shut or a manual bypass line valve is inadvertently closed, the pump's internal relief valve prevents system overpressurization. Sometimes it is difficult to determine whether liquid is bypassing back through the separate back-to-tank line or recirculating through the pump's internal relief valve. A sight glass in the bypass line, as shown in Figure 26, is helpful in determining bypass flow when adjusting the bypass valve setting.

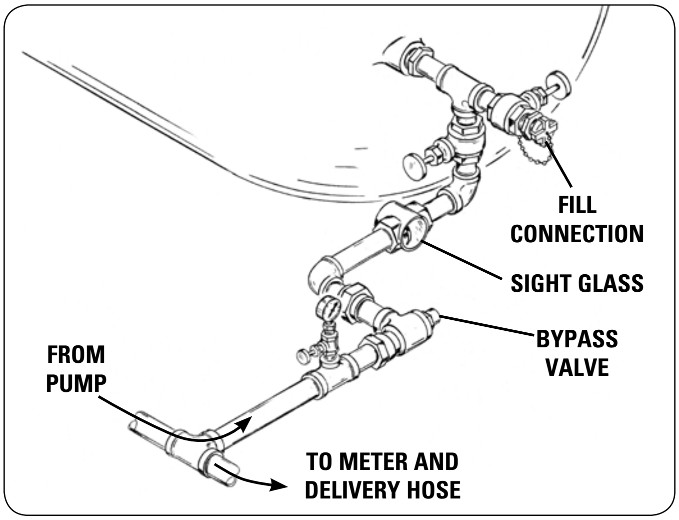


Figure 26

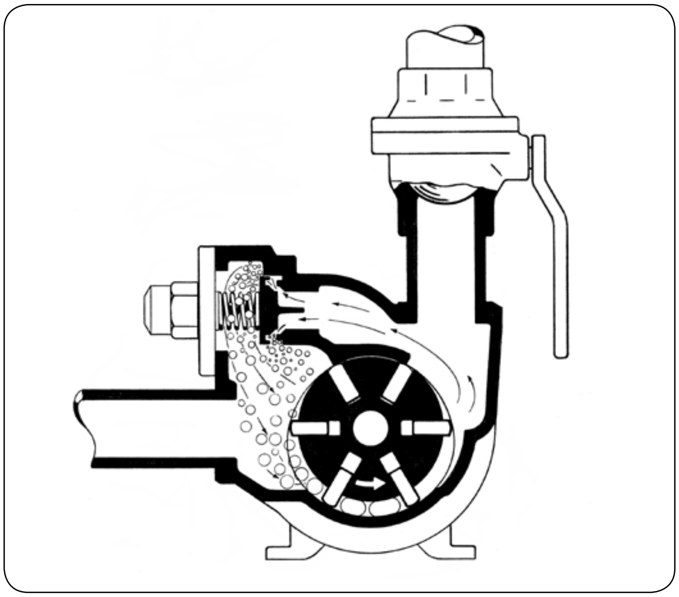


Figure 27

Figure 27 illustrates the vapor formation when fluid is recirculating through the pump's internal relief valve. It rapidly transforms to vapor because of turbulence within the valve, the heating of the liquid and the sharp pressure drop between pump discharge and inlet. The recirculation results in noise, vibration and excessive wear within the pump. Consequently, a back-to-tank bypass valve is critical to longer, trouble-free pump operation.

To set the bypass valve, first check the pressure setting of the pump's internal relief valve. Shut off the separate bypass line, then gradually shut off flow through the delivery line while watching a pressure gauge on the pump discharge. The pump's internal relief valve setting is the peak pressure which shows on this gauge. (After recirculation starts through the pump's internal relief valve, vaporization will cause the pressure to fall quickly).

The bypass valve must be set at least at 25 psi (1.7 bar) less than the peak pressure reading for the pump's internal relief valve. To do this, open both the pump discharge line and the bypass return line, allowing a few minutes of recirculation to be sure of purging any vapors from the pump and lines. Then turn the adjusting screw on the separate bypass valve out far enough to be sure the valve is set lower than the pump's internal relief valve. Close the discharge line, causing liquid to return to the supply tank through the bypass line. Finally, screw in the adjusting screw on the bypass valve until the proper reading is shown on the pump discharge pressure gauge.

Caution: Never set the bypass valve for a pressure higher than the differential pressure rating of the pump or higher than the maximum 125 psi (8.6 bar) differential recommended by Underwriters Lab.

There are several makes of bypass valves on the market, but their pressure characteristics are widely different. Many tend to leak below the pressure for normal full-flow delivery, causing a loss of delivery rate. Some of them have a rising pressure, referred to as "tail," which results in higher and higher backpressure as flow rates increase. Often, with slight pump overspeeding, the backpressure will crack the pump's internal relief valve, resulting in undesirable circulation through the pump valve.

Some types of bypass valves are sensitive to fluid debris, and small particles will tend to stick the valve in either the open or closed position. Bypasses valves that stick closed, have poor pressure profiles or are improperly set, are the most common causes of rapid vane wear in the pump. Blackmer's bypass valve (Figure 28) is quiet and simple in construction, won't stick and has ideal pressure characteristics.

Take extra care in sizing the bypass valve and its piping. Pumps on trucks with inaccurate speed controls are often oversped. If either the bypass line or valve is too small, liquid will be forced back through the pump's internal relief valve. Use at least a 1¼ inch bypass valve and piping on a 2 inch pump, and an 1½ inch valve and piping on a 3 inch pump.

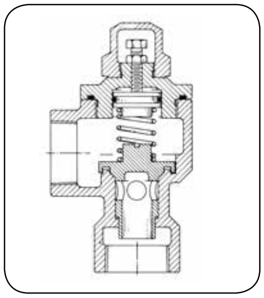


Figure 27

Here's a simple method of checking the efficiency of a separate bypass valve: with the delivery hose closed and the full discharge of the pump flowing through the bypass line, observe the pump discharge pressure as the engine is oversped a moderate amount. The separate bypass valve and bypass line must be large enough to take the extra flow from moderate overspeeding without an excessive pressure rise.

It is desirable to use an automatic engine speed control, throttle stop or some other speed-limiting device to make sure that the pump can't be seriously oversped. If there is an engine tachometer, it should be marked for correct pump speed.

Meters should be used at capacities recommended by the meter manufacturers. Overspeeding on liquefied gases will shorten the life of the meter.

The Vapor Return Line from the vapor eliminator should be at least as large as the vapor opening at the top of the eliminator and should not contain any fittings which would restrict the free flow of vapor back into the tank. If this line is too small or too long, or if there are too many restrictions in the line, vapor will pass through the eliminator and register on the meter, especially when the tank is nearly empty.

A Differential Regulator (Figure 29) serves two purposes. It provides backpressure on the meter and vapor eliminator, thus helping the eliminator drive vapors back into the tank.

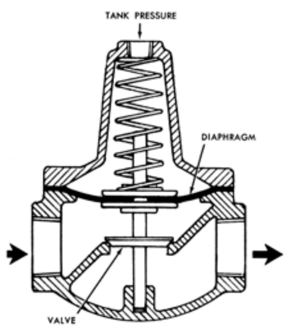


Figure 29

The regulator also serves as one more safety device since it opens only when the pump is running. There have been accidents when the delivery hose was pulled off a moving truck. However, the differential regulator blocked the flow since the pump was not running.

Figure 29 explains the principle of the differential regulator. The area above the diaphragm is maintained at tank pressure while the area below the diaphragm is filled with liquid at pump discharge pressure. When the pump is not running, these pressures are identical, so the spring keeps the valve closed. But as soon as the pump is operated, the discharge pressure increases. This pressure build-up overcomes the force of the spring and opens the valve. However, a ruptured or leaking diaphragm in the regulator can restrict or completely block flow.

Hydrostatic Relief Valves must be installed in any section of liquid piping that can be blocked off by closed valves.

Higher Delivery Rates

There is an ever-increasing trend to deliver liquefied gas at higher and higher rates. Newer trucks are using larger pumps, piping, hose and accessories. Older trucks can be revamped to improve delivery, usually by installing a larger intake line. Yet installing a larger pump or a larger intake line may not increase flow at all; the flow rate could be limited by the supply tank size, restrictions in the discharge line or the restriction of the receiving tanks. If the pump has been running at its maximum differential pressure rating, faster delivery with the same pump can only be achieved through changes in the discharge system that will reduce the pressure drop. In no case should the pump be made to operate at more than its rated differential pressure.

The greatest restriction in a delivery system is most often the hose and filler valve on the receiving tank, although newer filler valves are now available which allow much greater flow rates. Quite understandably, drivers prefer to use a smaller diameter, lightweight hose. But to achieve delivery rates of 50 gpm (189 L/min) or more, it is necessary to use at least a 1 inch (2.5 cm) hose.

Troubleshooting

No Product Delivery

On trucks equipped with lever-operated internal valves, when the lever is moved to the open position, the excess-flow valve may remain closed if the pressure on the pump side is lower than in the tank. A leak in the piping system will lower pressure. Also, putting the pump in gear before opening the valve sometimes will keep the excess flow valve from opening. In this case, the driver must wait until the pressure equalizes. This is accomplished by an orifice hole in the valve, which allows the fluid to slowly bleed through the valve. Manually trying to actuate the valve to the open position will also help the situation.

Low Capacity

If the pumping rate is not as fast as it should be, the operator will usually suspect something is wrong with the pump. All too often, he will attempt to compensate by over-speeding, which only causes more liquid to bypass. Instead of boosting the delivery rate, it will only damage the pump.

In a great majority of these cases, the difficulty will be found in the system, not in the pump. Pressure gauges on the pump inlet and discharge, as well as the bypass valve, can help isolate the problem. Based on the pressure readings, the fittings and valves in trouble section should be carefully analyzed.

Keep in mind, delivery rates will be slower when pumping Butane than Propane. They will also be slower when the weather is cold. As mentioned earlier, delivery rates will be slower when pumping without a vapor return line than with one.

On older trucks that once enjoyed good delivery rates, a gradual slowing could possibly be due to pump wear. Worn pumps are usually noisier than new ones.

To diagnose a system, install pressure gages in the inlet and outlet connections on the pump. These connections are tapped gage holes usually found near or on the internal relief valve. In order to avoid variation, caused by boiling in the supply tank and pressure build-up in the receiving tank, run all tests while recirculating liquid back into the same tank. Before starting the pump, check the difference in the readings of the gages against the tank gage. Run the pump at normal speed.

Case A: If the pump inlet pressure decreases more than 2-3 psi (0.14 - 0.21 bar), vaporization in the line will seriously reduce delivery rate. Check the internal valve to see if it is opening all the way. An internal valve may not completely open for several reasons: insufficient equalization time, broken internal parts or insufficient excess flow valve sizing. An undersized excess flow valve will tend to close prematurely. Also, inspect the strainer and clean it if necessary.

A Rego Flowmatic type valve requires approximately 20 psi (1.38 bar) differential pressure to actuate. If the pump is running too slow or the bypass valve is stuck in the open position, the pump will not develop sufficient differential pressure to activate the valve.

Case B: If pump discharge pressure only increases slightly, the problem is most likely related to the bypass valve or the pump.

A possible cause of low delivery is loss through the back-to-tank bypass line, either because the separate bypass valve is set too low or the bypass valve is leaking. To determine if this is the problem, close the manual valve in the bypass line while delivering. If pressure and flow rate increases, the bypass valve is at fault.

To determine the setting for the bypass valve, follow the procedure outlined in the “Bypass Valve” discussion. If both the pump’s internal relief valve and the separate bypass valve are properly set, yet you still can not find the problem, the cause might be excessive pump wear. While recirculating through the delivery hose with the pump running at normal speed, check the pump’s delivery against its catalog rating. If it is too low, check the wear on the pumpÆs moving parts, particularly the vanes.

However, if you find the separate bypass valve is set properly and also find that the discharge pressure while recirculating through the delivery hose is just as high as the bypass valve setting, then there is too much restriction in the discharge system to allow higher flow rates.

Case C: If the pump discharge pressure rises substantially, the problem is most likely downstream of the pump. Check for a damaged meter, differential valve, vapor eliminator, clogged meter strainer or a restriction in the discharge piping from the pump, i.e. a partially closed valve.

Pump Troubleshooting

Excess Vane Wear

The life of pump vanes can vary widely, depending on operating conditions. Unusually rapid vane wear is an indicator of poor system design, improper bypass valve adjustment, sticking bypass valve, pump overspeeding or severe operational abuse.

A set of vanes should pump 1 to 2 million gallons (3.8 to 7.6 million liters) or more on average service. Of course, a truck operated on two or three daily shifts will subject the pump vanes to more wear than a truck on single shifts.

The most frequent cause of vane wear is pump overspeeding, overpressure and running dry. Remove the pump’s internal relief valve and examine it. If its surface is shiny and worn, liquid has been recirculating through it, thereby causing excessive vane wear.

If the system lacks a strainer or has one that is too coarse, dirt will abrade the vanes with coarse markings and leave scratches and grooves around the liner.

Occasionally, a driver forgets to disengage the power take-off and drives away with the pump in gear. This is a very severe operating condition for the pump and will result in melting the vanes. The other reason for rapid vane wear is pumping excessive vapors, usually the result of a restricted inlet caused by:

1. Inadequate pipe size.
2. Too many elbows, tees and other fittings.
3. Too long of a suction line.
4. A dirty strainer basket, too small of a strainer or too fine of a basket mesh.
5. On lever operated internal valves, sometimes the wire from the control knob in the meter compartment slips on the lever so that pulling the knob does not fully open the valve.
6. On pressure-actuated internal outlet valves, dirt may cause them to stick in a partially closed position.

Pump Troubleshooting (continued)

Seal Leakage

The life of a seal is unpredictable. Most last several years, but there are many things that can shorten its life. One cause is foreign material, such as tank scale, rust, welding slag or dirt. Others are running the pump dry or overspeeding the pump, resulting in overheating the seal faces. This is tough on both vanes and seals. When a pump is de-pressurized frequently, the alternating heating and chilling causes deterioration of the seal o-rings. Pumps operating in cold climates should be lubricated with low-temperature grease. If the lubricant comes in contact with the seals, some greases that freeze hard will damage the seal components.

If the separate bypass is closed off, the flow is recirculated through the pump's internal relief valve. This causes the liquid to flash into vapor, and the seals and o-rings will overheat since no liquid is present to cool the pump. Sometimes internal valves will malfunction and close unnoticed during a delivery, or a tank may be completely emptied without the operator noticing it. If the pump runs dry long enough, heat will buildup and damage the mechanical seals.

Noise and Vibration

One of the most common causes of noise and vibration is in the driveline from the power take-off. Figure 21 illustrates the proper alignment of universal joints. If the pump shaft is not parallel with the power take-off shaft, or if the two universal joints are out of phase, the pump shaft will rotate with an irregular or jerky motion and impart a surging pulsation to the liquid stream.

If the system suddenly develops noise and vibration when there were none before, check the following:

1. Recirculation through pump's internal relief valve.
2. Dirty intake strainer.
3. Other line restrictions such as partial closing of outlet valve.
4. Overspeeding the pump.
5. Worn pump vanes.
6. If pump was recently repaired, installation of liner or vanes backwards.

Delivery Systems On Transports

Over many years, the propane industry has developed a progressive transportation system. In the early days, LPG was transported only in small metal containers, commonly referred to as cylinders or bottles. In the late 1920s, railroad tank cars suitable for hauling LPG in large volumes were introduced. A later development was highway transport, which enabled gas to be consumed in substantial volumes in areas far removed from railroad terminals. Around the mid 1960s, transports were being equipped with their own unloading pumps. Today, an unloading pump or compressor (see compressor section) is standard equipment for a transport.

The economies of transport-mounted pumps become apparent when you compare unloading times. It is not uncommon for motor-driven stationary pumps to require between 3 and 4 hours to unload an 11,000 gallon (41,600 liter) transport. But a 4 inch pump mounted directly on the transport can do the job in 35-45 minutes. Spending less time in the plant and more on the road not only increases driver and rig efficiency, but it can also mean a substantial reduction in the number of transports needed in the fleet.

When planning these higher unloading rates, it is very important to have proper mounting of the pump with a carefully engineered piping system and driving mechanisms. Of equal importance is the consideration of the piping at the bulk plant where the transport is to be unloaded. Small diameter piping will cause excessive pressure losses.

Pump Drives

Traditionally, transport pumps have been driven by a PTO shaft from the tractor and mounted near or between the landing gear brackets or just ahead of the rear wheels. More recently, hydraulic drive systems have become more popular as they allow more flexibility with pump placement, greater speed control and increased pump service life.

A typical hydraulic drive system includes a PTO, hydraulic pump, Hydrive cooler/controller, speed control valve, hydraulic motor and mounting adaptor. Hydraulic drives make use of hydraulic oil to power rotating equipment. The Hydrive cooler protects the system during cold start-up, allows for system on/off control and provides both controlled system cooling and oil filtration monitoring. The speed control valve provides overspeed protection, and Hydraulic motor adapters provide close-coupled connections between the pump and hydraulic motor.

Hydraulic motor adapter kits are also available to easily mount on Blackmer pumps.

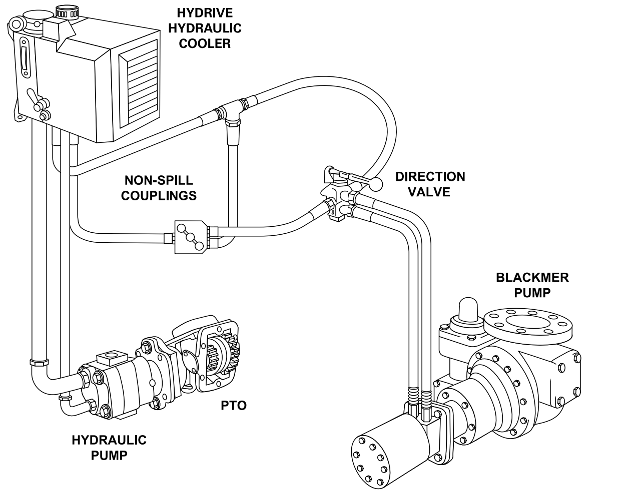


Figure 20

Pump and Valve Operation

The 4 inch flange-mounted transport pump (Figure 30) requires an internal valve. Two valve types are typical. One is a lever-operated internal valve with excess flow protection as manufactured by Fisher. The other is the Rego Flowmatic valve, which is pressure-operated and remains closed until opened by differential pressure. It is usually necessary to start the pump with the discharge closed to actuate the Rego valve. In winter, the receiving tank is sometimes colder than the transport. In this case, the pump discharge pressure may be lower than the inlet. Consequently, the pressure-operated valve will remain closed. Under these conditions, you can either throttle a manual valve on the discharge to build up pressure, or operate the internal valve manually.

Pump and Valve Operation (continued)

The function of an excess flow valve mounted in the tank bottom is to shut off flow in the event that a pump is sheared from the mounting flange. An excess flow valve will not necessarily close in the event of a line rupture downstream of the pump. Shutting off the pump or disengaging the PTO will not prevent liquid from flowing out of the transport. In such a scenario, the internal valve must be closed to prevent the transport's load from spilling. Recent events have brought this limitation to light and both NPGA and DOT are working toward improving the transport system's excess flow protection.

Bypass Valve

The internal relief valve on Blackmer pumps is there to protect the system, not for continuous recirculation during normal operation. When ordering a new transport, always specify that a 2 in. bypass valve in a back-to-tank bypass line be furnished. Though a very small added investment on a new truck, it will greatly reduce pump maintenance costs and extend pump-operating life. This is particularly important if the transport will be delivering to plants with long or restrictive piping.

If a transport has no bypass and it is impractical to add one, the operator must be instructed to operate the pump slow enough so that the pump's internal relief valve will not open. Liquid recirculation through the pump's internal relief valve usually makes a noticeable noise.

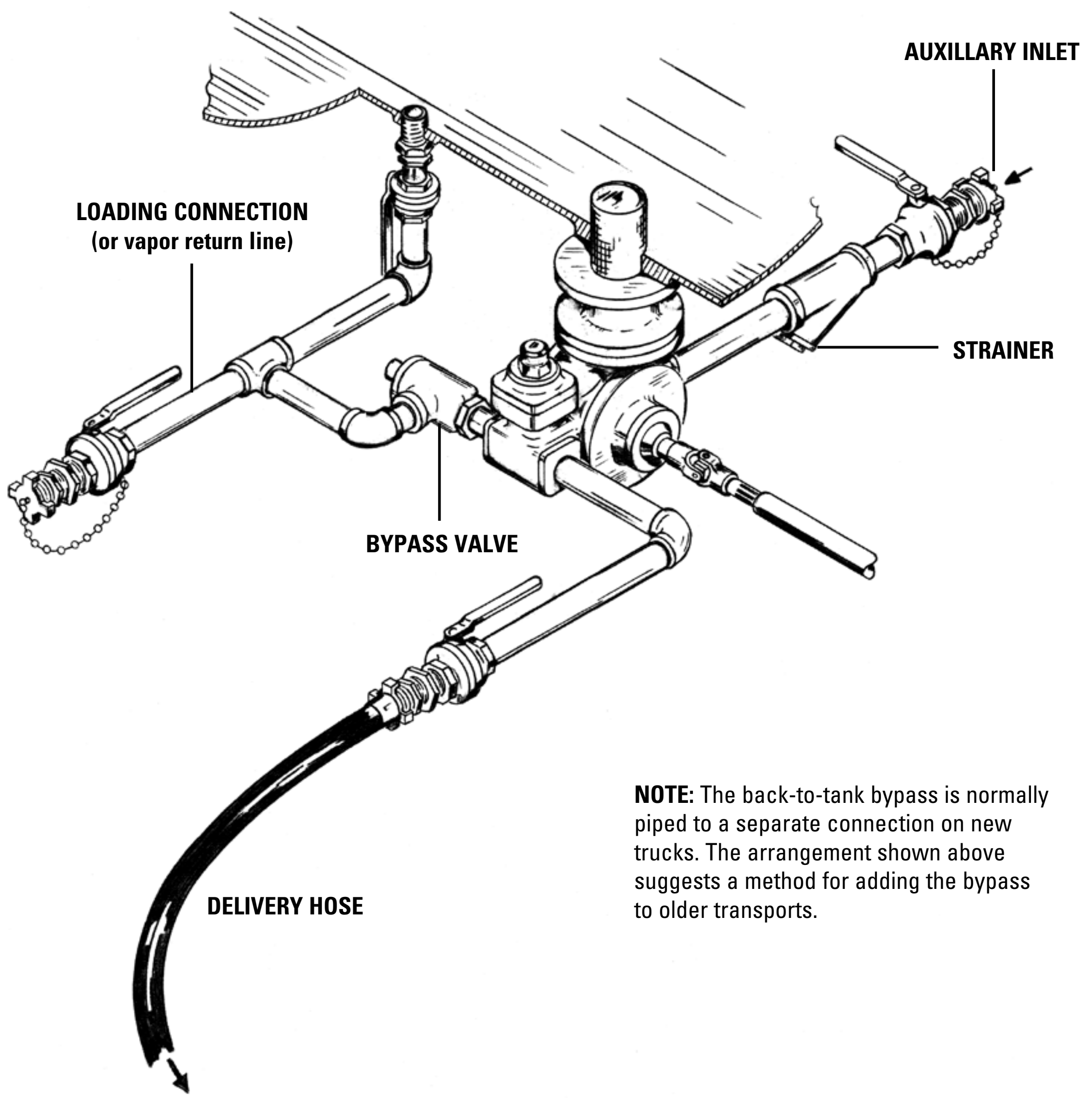


Figure 30

Pump Drive

Refer to Figure 31 and follow these simple rules to avoid problems when using jackshafts and universal joints to drive the pump from the power takeoff:

1. Always use the least practical number of jackshafts.
2. Use an even number of universal joints.
3. The pump shaft and every other jackshaft must be parallel to the PTO shaft both vertically and horizontally.
4. The remaining jackshafts do not have to be parallel with anything, but they should not exceed 15 degrees of angularity at any joint.
5. If a U-joint is used to couple two shafts with no angularity, ignore its presence; consider the two shafts as one and omit the joint from Rule No. 2.
6. To keep the driveline in proper alignment and balance, the tractor should always be lined up with the tank while unloading.
7. Guards must be provided on exposed PTO shafts.

Always remember that an improper driveline will cause the pump to “gallop” or turn with an uneven, jerky rotation. This will impart a surging pulsation of liquid through the piping and hose, causing the entire system to vibrate. Failure to heed these suggestions will result in premature bearing, shaft or seal failures.

A 4 inch Blackmer pump needs about 150 ft-lbs (203 N-m) of torque to develop a 75 psi (5.2 bar) differential pressure. Since most popular PTO models are rated at 150 ft-lbs. (203 N-m), design unloading systems which will not require more than 75 psi (5.2 bar) differential pressure on the pump. For overall performance, including faster delivery rates, the piping at the bulk plant should be designed so that differential pressures can be kept to less than 75 psi (5.2 bar) for transport unloading.

Salt Corrosion

Salt water can seep into the propane from poorly serviced calcium chloride dehydrators or underground storage domes. LPG pumps were never designed to pump brine. They have little corrosion resistance. If the slightest trace of salt water corrosion turns up on pumps or other system equipment, investigate at once. Find the source of the brine and correct it immediately. Then clean out the complete pumping system and repair any damage. Obviously, an extremely dangerous condition would exist if for example, relief valves should freeze up from this salt water corrosion.

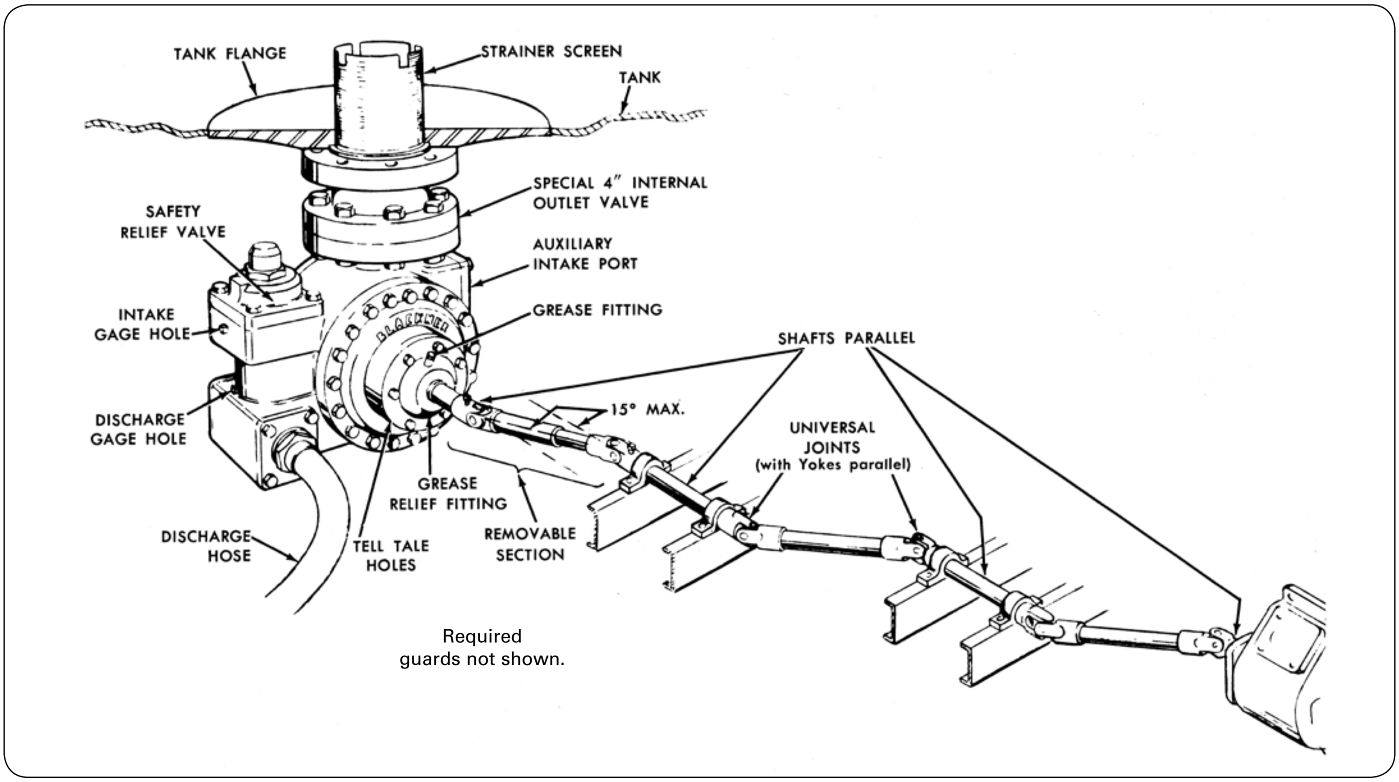


Figure 31

Stationary Motor-Driven Pumps

Motor-driven pumps are used for a variety of services from unloading transports to filling bottles and dispensing fuel to motor vehicles. In general, everything that has been said on the preceding pages about bobtail and transport trucks applies to stationary pumps as well.

There is one important rule: keep the pump as close as possible to the supply tank. It is difficult to locate a stationary pump as close to the supply tank as a truck pump. For that reason, larger intake lines should be used to help reduce friction. Figure 32 shows the piping arrangement for a typical bulk plant, using a single pump to both deliver to and from the tank.

Where the stationary pump is only needed to unload the tank, a flange-mounted pump arrangement, such as the one shown in Figure 33, has become increasingly popular. By mounting directly to the tank's internal valve, the intake line and virtually all vaporization problems usually associated with the intake line are eliminated. Loading of the tank can be done, if necessary, through the pump's auxiliary intake port, using either a separate stationary pump or the transport-mounted pump.

When unloading transports, it is important to use the largest practical size of hose, or multiple hoses.

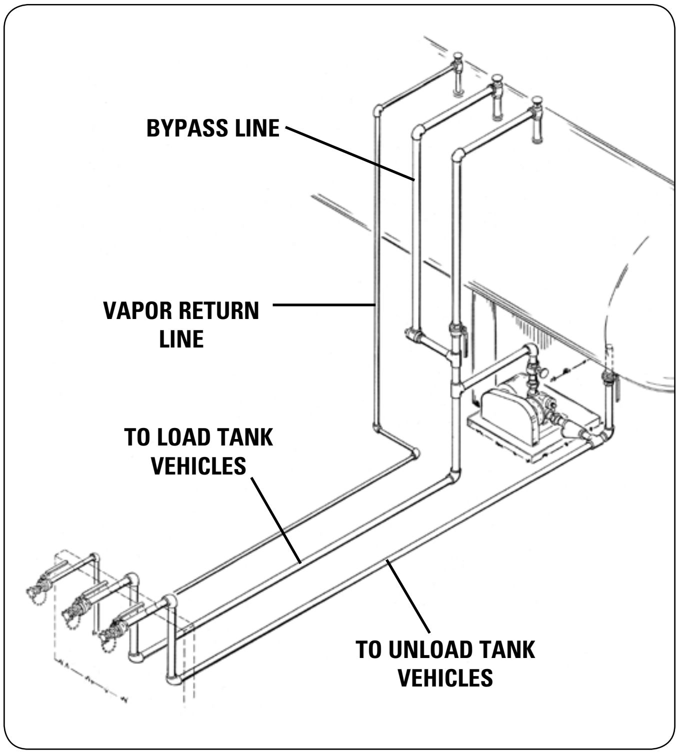


Figure 32

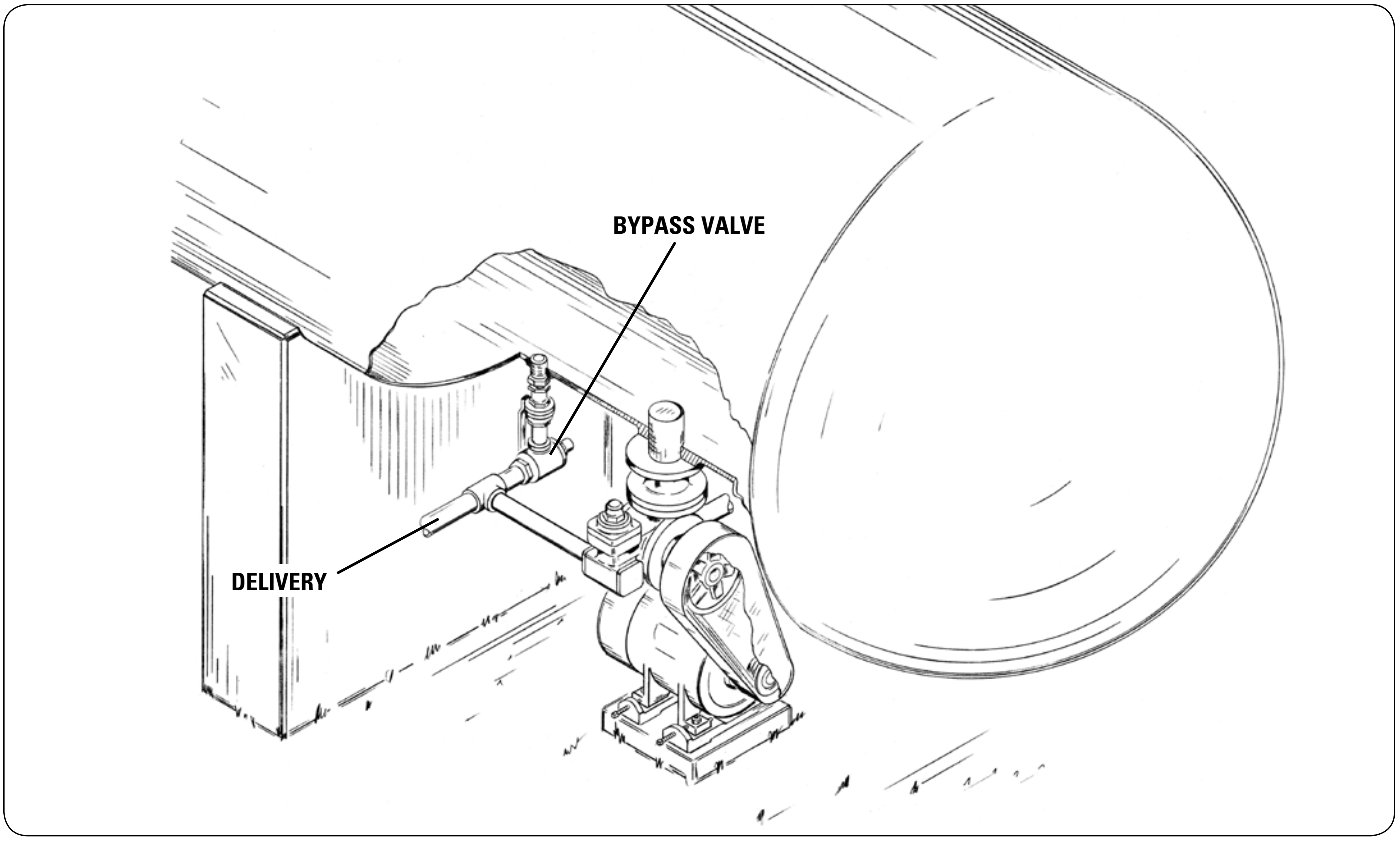


Figure 33

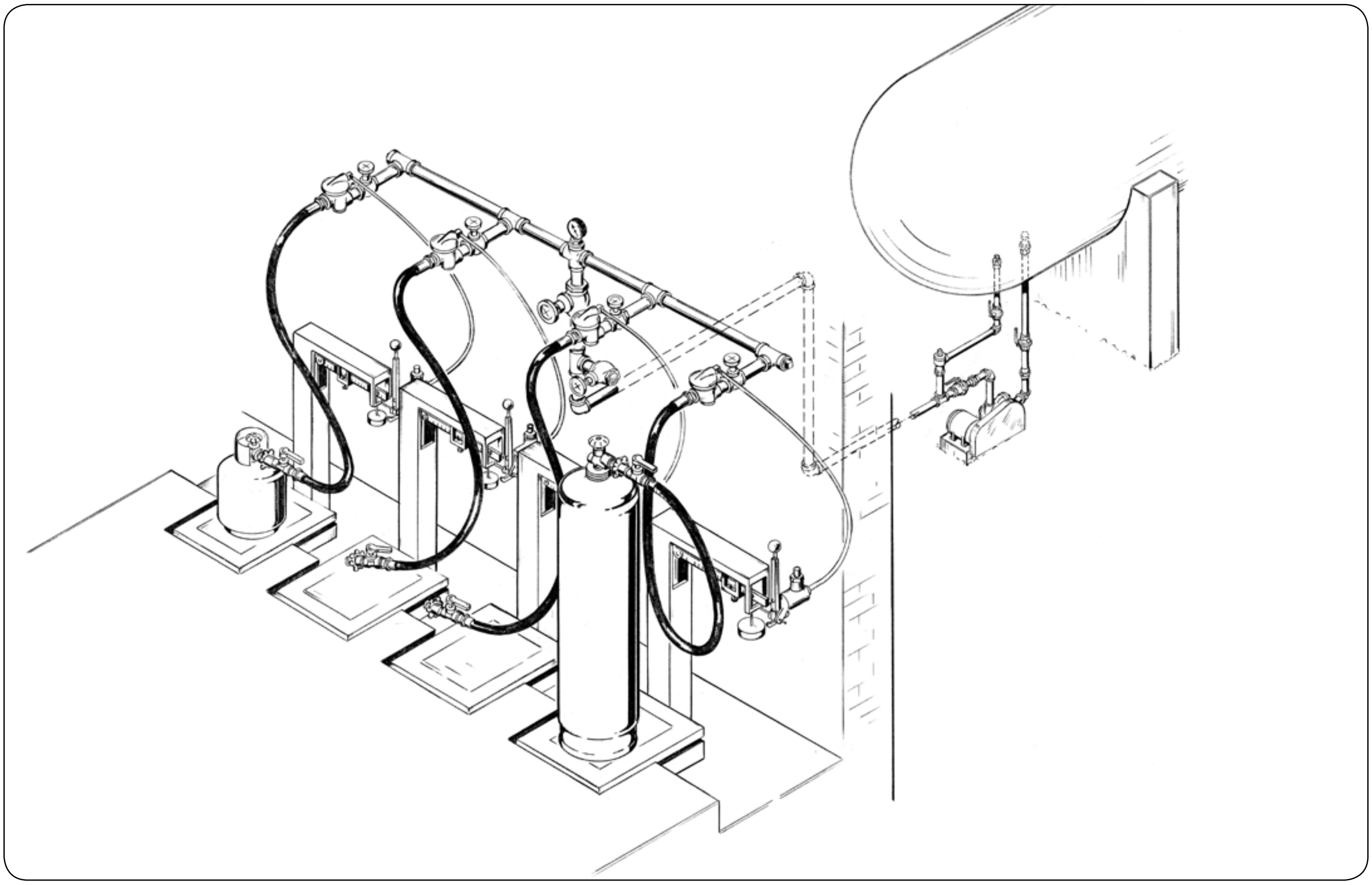


Figure 34

Bottle Filling

Cylinders or bottles are usually filled by weight. Scales with automatic trip-valves, such as those shown in Figure 34, are widely used for this service. When selecting pumps for filling bottles, use this rule of thumb; it takes about 1½ minutes to fill a 100-pound (45 kg) cylinder at 85 psi (5.9 bar) differential pressure. To fill one bottle at a time, a motor-mounted pump should do the job. For larger operations, the pump size depends on the number of bottles to be filled at any one time. One man can handle three filling points by moving from one scale to another in turn. A 2 inch, 50 gpm (189 L/min) pump has proven most popular for a three-station setup.

Figure 35 shows a frequently used arrangement for a Blackmer dispensing pump involved in single-cylinder filling such as motor fueling. Because this motor-mounted Blackmer pump has a combination bypass and internal relief valve, the bypass line is piped directly from a port on top of the pump. A bypass line size of at least ½ inch (1.25 cm) is recommended for this type of pump, since smaller lines are excessively restrictive to flow.

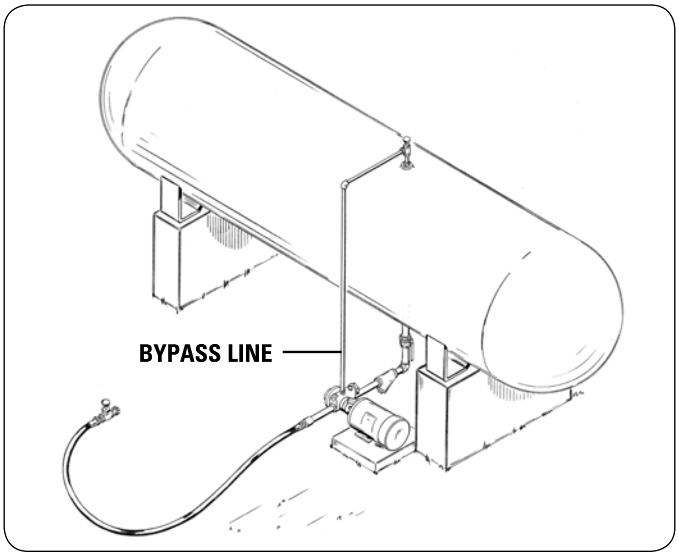
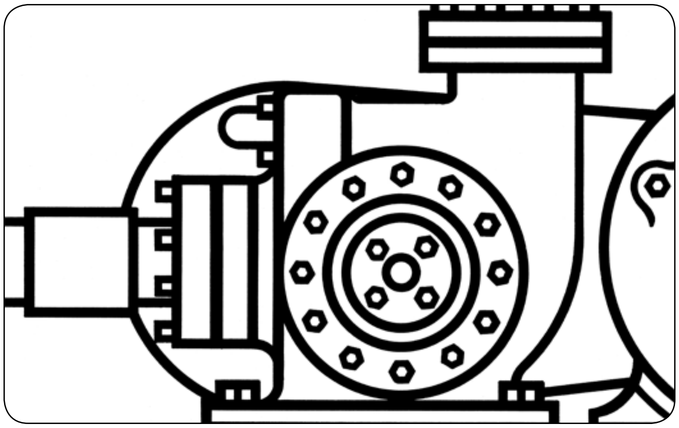


Figure 35

Vaporizer/Standby Plant Applications



Commercial or industrial users of natural gas often require a standby plant as a secondary energy source. When quantities of natural gas are limited, these customers may have their regular supply curtailed or cut off during peak seasons, or they may pay a premium price when their usage goes beyond a pre-determined level.

An LP gas standby plant is the answer to both situations. It can provide a source of fuel compatible to natural gas whenever the existing service is interrupted, or it may function as a peak-shaving plant to supplement normal supplies and reduce the cost of natural gas during periods of high demand.

Components of a Standby Plant

In addition to a liquid supply and vapor surge tank, a standby plant includes the following equipment categories: vaporizers, mixers, pumps, piping and valves.

Vaporizers

Commercial applications using large size burners such as grain dryers, tobacco dryers or industrial furnaces require large quantities of vapor. Vaporizers employ heat to accelerate the normal vaporization rate and are used to meet this high demand.

Vaporizers are made in a wide range of sizes and are usually rated in BTU-per-hour or in gallons-per-hour. This usually indicates average flow rates of liquid propane required to supply them. These rates can vary from less than one to several hundred gallons per minute. Some models are direct-fired by a flame in contact with the vaporizing chamber while others may use a heat transfer medium such as steam, water or electric heaters to convert the liquefied propane into vapor.

There are three main considerations in planning for the use of vaporizer:

1. Gallons per hour of liquid propane required.
2. Amount of discharge pressure required from the vaporizer.
3. Peak flow demand of the vaporizer.

Air Mixers

There are two basic types of mixers. One type is known as the batch type, in which vapor under pressure is drawn through an orifice into a venturi. One or two air check valves may be incorporated between the orifice and the venturi. The force of the gas passing through draws air into the gas train and the resultant mixture is discharged into a surge tank. This type of system usually has a mixed gas discharge pressure of 10 psig or less, but higher pressure may be achieved by using compressed air.

The other type is called the modulating type, in which a system of pressure control valves, regulating valves and controller modulate the air and gas pressures to achieve the desired mix ratios.

Low pressure mixers sometimes use a booster blower to achieve the desired mix gas pressure. Higher pressure types will require a separate source of compressed air in order to achieve higher mixed gas pressures. Both types of mixers usually require a storage tank and a vaporizer.

Pump & Piping Layout

Pump and piping layout systems designed for standby plants follow the same general guidelines as most other LP gas applications. In practice, one of the first considerations is to keep the length of the intake piping runs to a minimum by locating the pump as close as possible to the supply tank and keeping the number of valves, fittings and elbows to a minimum.

Friction losses within the system can result in a pressure drop sufficient enough to allow liquefied propane or butane

to vaporize. This can lead to pump cavitation, not only reducing pump efficiency but also creating undue wear. A simplified piping system layout can avoid these problems.

Oversized inlet piping, at least one size larger than the pump inlet, with a short run will minimize friction losses. The pump speed should also be such that the resulting suction line velocity is approximately 3 ft/sec (0.9 m/sec). Studies have shown the optimum inlet velocity is in the range of 160-200 fpm (49 - 61 m/min). This is the speed range which minimizes both heat transfer and friction losses.

Pump Selection

Because of the critical function of the standby plant in providing an uninterrupted fuel supply, the sizing of its components should be governed by the maximum peak demand of the system at the coldest temperature, even though the standby plant will normally operate at somewhat less than this demand.

Most vaporizer manufacturers make general recommendations on the gpm rating of the supply pump. A common rule of thumb is to specify a pump with a flow rating 3 to 4 times the rating of the vaporizer. Manufacturers have suggested that factors might differ. There are two principle factors which make this oversize rating necessary.

A vaporizer operating at full rated output will have its heat exchange chamber nearly full of liquid propane. This is necessary to maintain maximum contact area between the liquid and the heating surface. If the vapor demand is suddenly reduced to near zero, as will happen when the using furnace is shut down or modulating, the liquid continues to boil. Accumulating vapor drives liquid from the chamber back through the piping toward the pump.

Renewed vapor demand requires a rapid refilling of the vaporizer and the pump must have enough capacity to provide the necessary surge in addition to the normal liquid flow rate. If the total flow is insufficient to maintain proper pressure at the vaporizer, automatic controls should shut down the system.

The second consideration in sizing a pump for vaporizer service is the range of anticipated operating temperatures for the system. Standby plants usually operate in very cold weather when the demand for natural gas is highest or premium rates are in effect. As shown in Figure 18, page 14, pump efficiencies are significantly lower in a cold environment. This reduced efficiency is a thermodynamic property of the liquid propane.

Return Lines and Bypass Valves

If the pump has been sized correctly, its capacity will be enough to supply a demand greater than the normal maximum vaporizer flow, at the lowest design temperature. Therefore, in normal operation, the excess discharge from the pump must be recirculated through a valve and a return line back to the supply tank. This return line must be large enough to bypass the full pump output, plus the back-flow from the vaporizer.

Two types of valves are used to regulate and maintain the system pressure: either a differential type or a constant static pressure type. A differential valve is dependent upon supply tank pressure and will require pressure-setting changes throughout the year to compensate for temperature changes. A constant static pressure valve, on the other hand, is independent of supply tank pressure and once set will not vary, regardless of temperature.

Appendix

Appendix A

Properties of Liquefied Gases*

English

	ANHYDROUS AMMONIA	PROPANE	BUTANE
Formula	NH_3	C_3H_8	C_4H_{10}
Boiling Point, °F	-28	-44	32
Specific Gravity of Gas (Air = 1.00)	0.596	1.50	2.01
Specific Gravity of Liquid (Water = 1.00)	0.616	0.504	0.582
Lbs. per Gallon of Liquid at 60°F	5.14	4.20	4.81
BTU per Gallon at 60°F		91,502	102,032
BTU per Lb.		21,548	21,221
BTU per Cu. Ft. of Vapor at 60°F		2,488	3,280
Cu. Ft. of Vapor / Gal. of Liquid at 60°F	14.14	36.38	31.26
Cu. Ft. of Vapor / Lb. of Liquid at 60°F	2.75	8.66	6.51
Latent Heat of Vaporization at Boiling Point BTU/Gal.	3,027	773	808
Ignition Temperature in Air, °F		920 – 1,120	900 – 1,000
Maximum Flame Temperature in Air, °F		3,595	3,615
Limits of Inflammability, Percentage of Gas in Air Mixture:			
At Lower Limit – %		2.15	1.55
At Upper Limit – %		9.60	8.60
Octane Number (ISO-Octane = 100)		Over 100	92

***Commercial quality. Figures shown in this chart represent average values.

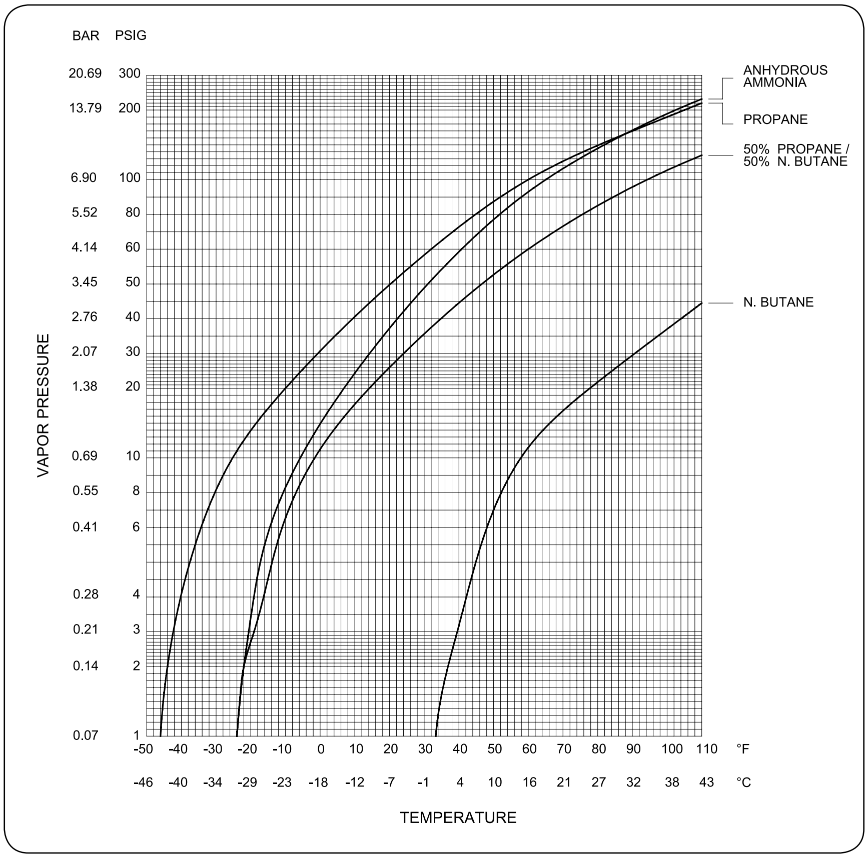
Metric

	ANHYDROUS AMMONIA	PROPANE	BUTANE
Formula	NH_3	C_3H_8	C_4H_{10}
Boiling Point, °C	-33	-42	0
Specific Gravity of Gas (Air = 1.00)	0.596	1.50	2.01
Specific Gravity of Liquid (Water = 1.00)	0.616	0.504	0.582
Kgs. per Cubic Meter of Liquid at 15.56 °C	616	504	582
Kilojoule per cubic meter of Vapor at 15.56 °C		92,430	121,280
Kilojoule per kilogram of Vapor		49,920	49,140
Kilojoule per liter at 15.56 °C		25,140	28,100
Cubic Meter of Vapor per liter of Liquid at 15.56 °C	0.105	0.271	0.235
Cubic Meter of Vapor per kilogram of Liquid at 15.56 °C	0.171	0.539	0.410
Latent Heat of Vaporization at Boiling Point, Kilojoule/liter	846	216	226
Ignition Temperature in Air, °C		493 – 549	482 – 538
Maximum Flame Temperature in Air, °C		1,980	2,008
Limits of Inflammability, Percentage of Gas in Air Mixture:			
At Lower Limit – %		2.15	1.55
At Upper Limit – %		9.60	8.60
Octane Number (ISO-Octane = 100)		Over 100	92

***Commercial quality. Figures shown in this chart represent average values.

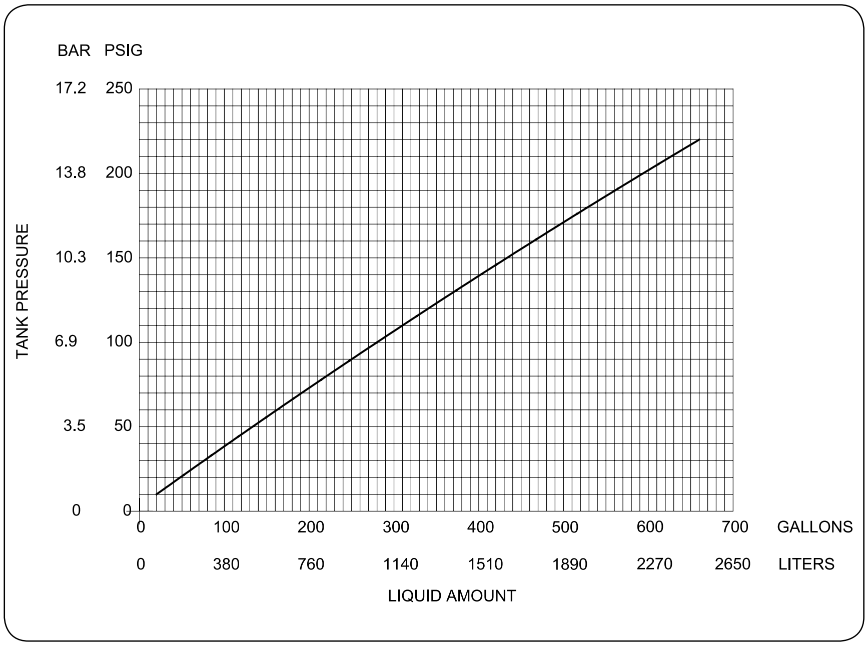
Appendix B

Vapor Pressure of Liquefied Gases



Appendix C

Saturated Propane Vapor in 10,000 Gallon Tank



Appendix D

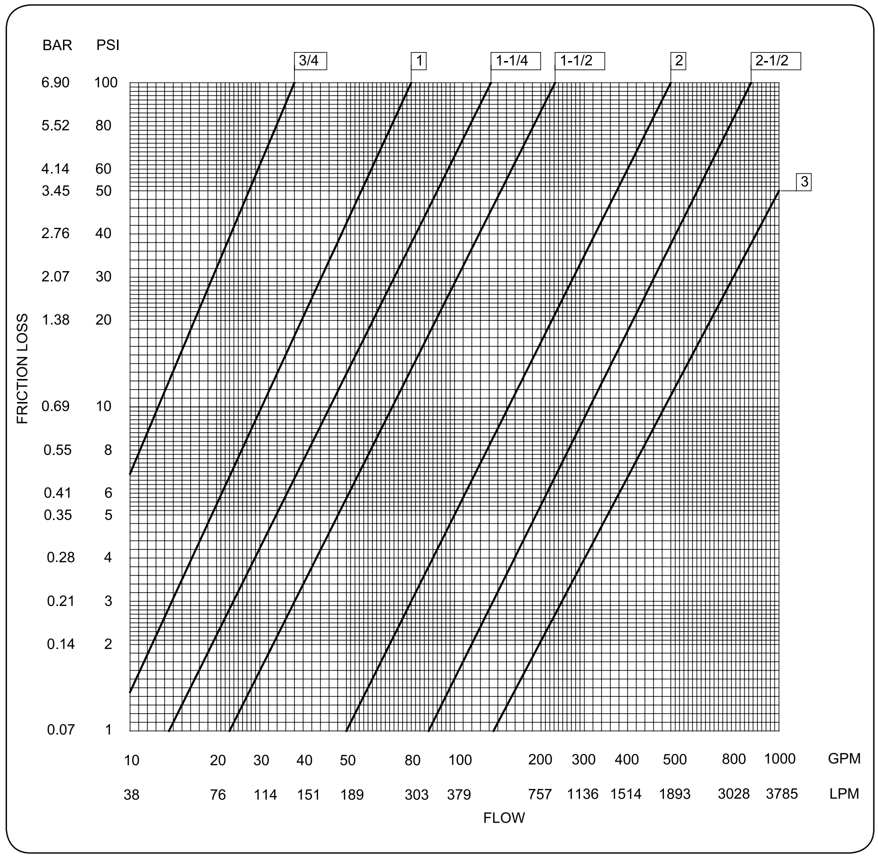
Friction Loss in LPG Hose
Hose Friction loss in psi for 100 ft. smooth bore rubber hose with inside diameters as shown, for propane. (These values will vary because of manufacturing tolerances on hose diameters.)

For Butane:

- Multiply friction loss values by 1.15

For Anhydrous Ammonia:

- Multiply friction loss values by 1.21



Appendix E

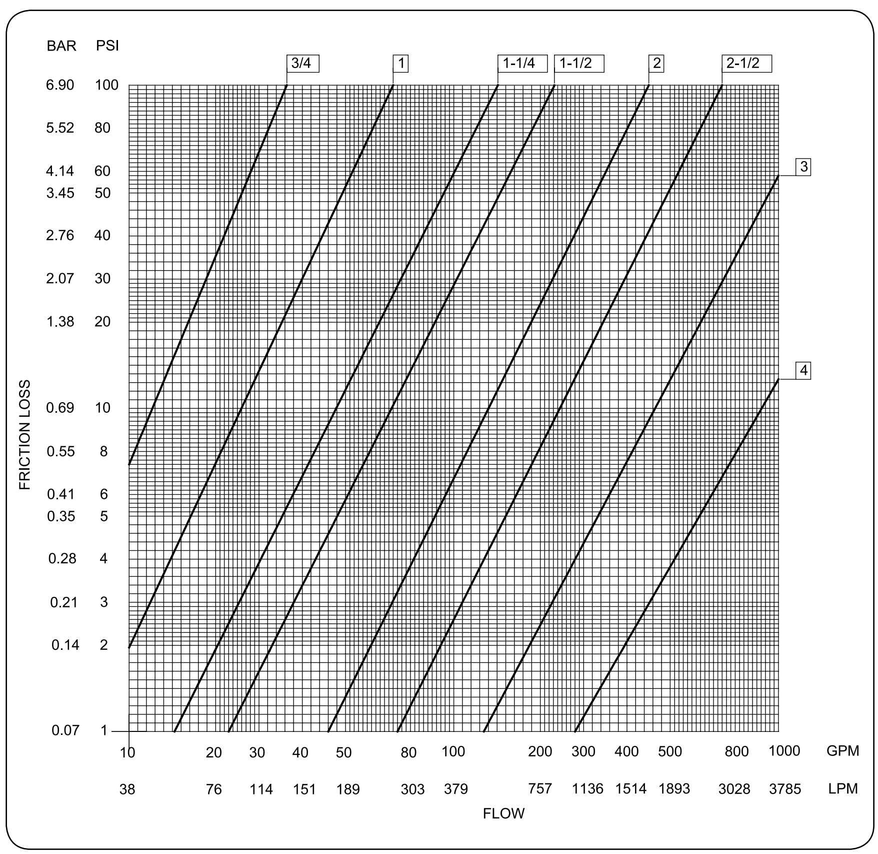
Friction Loss in Pipe
Pipe Friction loss in psi for 100 ft. new, clean extra strong schedule 80 pipe for propane

For Butane:

- Multiply friction loss values by 1.15

For Anhydrous Ammonia:

- Multiply friction loss values by 1.21



Appendixes F and G

Appendix F

Resistance of Valves & Fittings in Equivalent Feet of Pipe

	PIPE SIZE						
	1	**1.25**	**1.5**	**2**	**2.5**	**3**	**4**
Elbow 90°	4	4.5	5	6	8	9	11
Elbow 45°	1	2	2	2.5	3	4	5
Tee thru side	6	8	9	12	14	17	22
Y strainer same size as pipe	25	25	25	42	42	42	60
Y strainer next size larger	16	16	16	16	14	20	
Globe valve	28	35	45	60	65	85	120
Angle valve	15	19	22	28	35	42	57
Ball valve	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Quick-closing gate	3	3	3	3	3	3	3

Above values are approximate and will vary from one manufacturer to another.

Appendix G

Other Reference Materials From Blackmer

500-002	Application Guide – Pumping from Underground Tanks
500-003	Liquefied Gas Pump Installation Guide
CB254	LPG Equipment Training Manual
CB047	Emptying LPG Cylinders with a Compressor
CB048	Liquefied Gas Transfer with a Compressor
LBLTRAN	Computer Program for LPG / NH_3 Transfer Compressors
CB296	Transfer LPG From Underground Tanks With a Compressor / Pump Combination
—	LGL Pump Maintenance, Powerpoint Presentation
—	Compressor Disassembly, Powerpoint Presentations

Notes

Notes

Notes

Every Blackmer Product Comes With A Value-Added Extra:

Applications Engineering/Technical Support/Customer Care

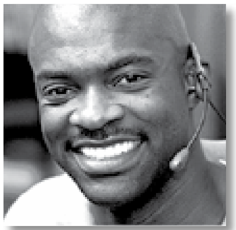
When it comes to flow solutions, uptime, output, reliability and profitability are critical to every operation's mission. To this end, Blackmer knows that reliable, proven flow technologies are critically important, but we also know that this represents only one part of the overall equation. The other, equally important part involves having trained, knowledgeable and customer-focused staff, which is why we make substantial investments in our people. It is through their collaborative effort with customers that the greatest achievements are realized.

- **Applications Engineers** – experts in peace-of-mind assurance, making sure your equipment is always right for the job
- **Market & Product Specialists** – unparalleled technical knowledge, on-site product training, troubleshooting, installation and product-selection consultation, and total life cycle attention
- **Regional Sales Management** – proven technicians with an "above an beyond" commitment to every customer's mission
- **Customer Care Specialists** – action-oriented specialists committed to making sure every order receives immediate attention, is accurately processed and followed up, and to helping keep your process flowing smoothly

When you put it all together, for mission critical flow solutions, it's easy to see why leading companies around the world have one common demand… **Better Get Blackmer**.

Customer Life Cycle Support

Developing innovative equipment is just one part of the benefits and profitability equation. Trained, knowledgeable and customer-focused staff are committed to the customers' success as well as the customers themselves. Blackmer is proud to boast the highest quality customer-centric professionals in the business, including applications engineers that are experts in peace-of-mind assurance; market and product specialists that provide total life-cycle expertise; regional sale management and action-oriented customer care specialists.



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