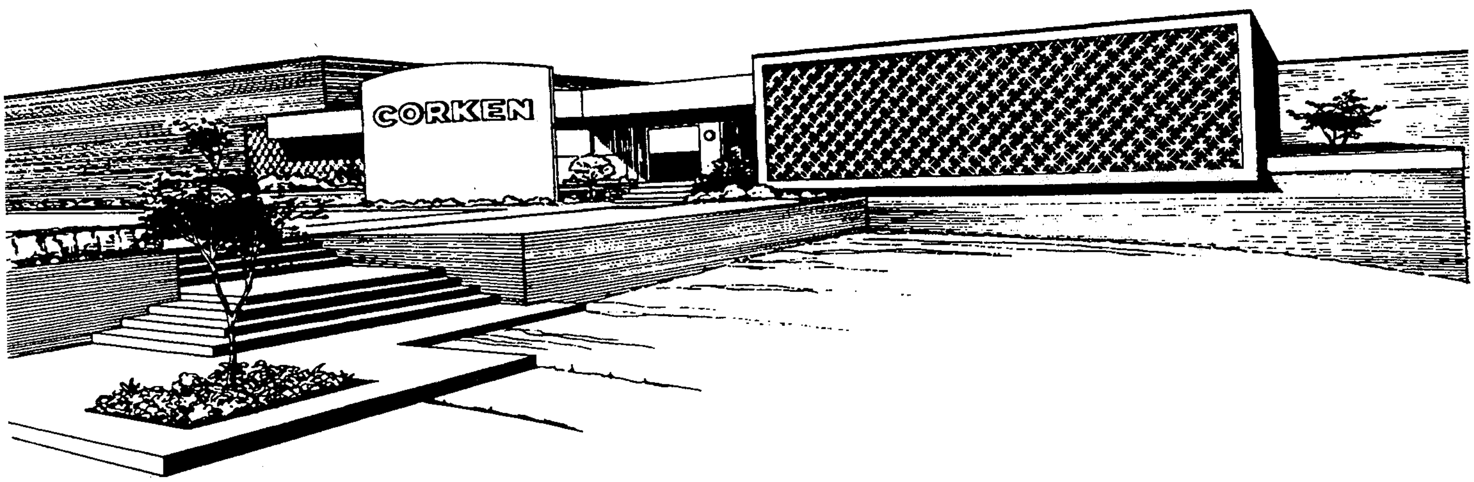
GUIDE TO CORKEN
LIQUIFIED GAS TRANSFER EQUIPMENT



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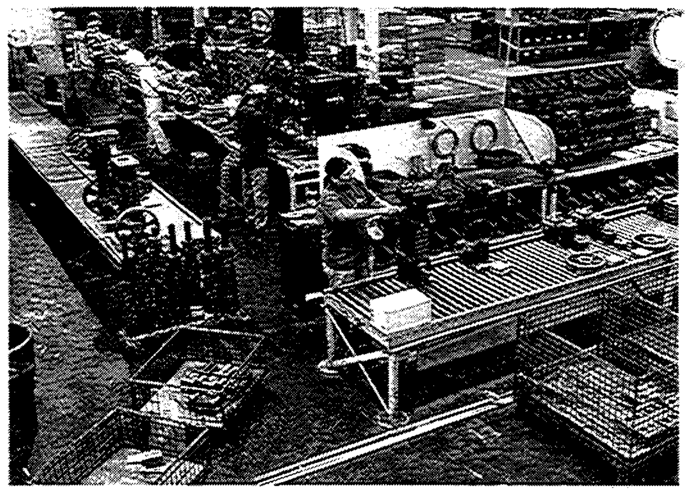
All products are designed and manufactured to meet industry standards, such as Underwriter's Laboratories (UL), Canadian Standards Association (CSA), High Pressure Gas Safety Institute of Japan (KHK), Bureau Veritas of France and many others. Corken is very proud to join the elite group of companies that have achieved registration to the International Quality Standard ISO 9001.



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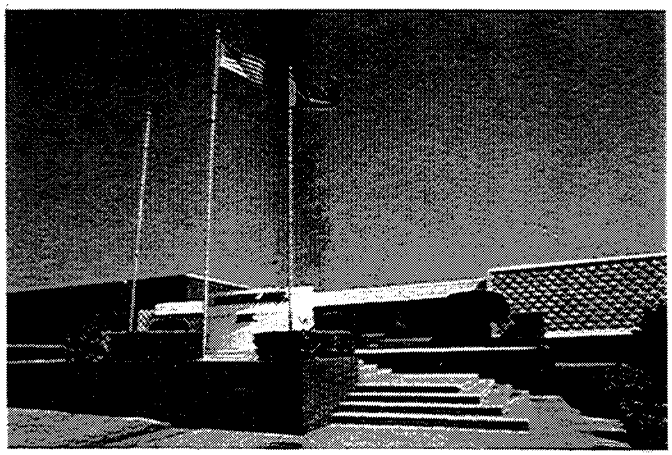

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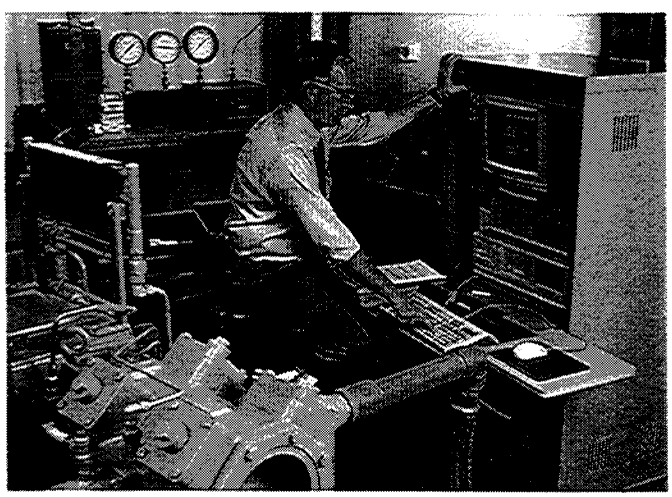

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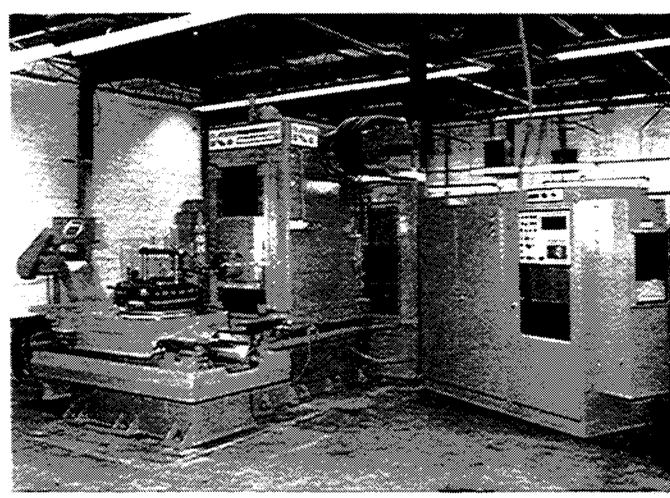

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GUIDE TO CORKEN LIQUIFIED GAS TRANSFER EQUIPMENT

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CHAPTER 1
Properties of LP Gas

Pumps and compressors are devices used to move fluids from one point to another. They do this by creating a differential pressure between the two points which causes the fluid to flow from the higher pressure point to the lower pressure point.

The difference between a pump and a compressor is quite simple. Pumps are designed to handle liquids and compressors are designed to handle vapors. It is very impractical and very seldom desirable to move a fluid as a vapor/liquid mixture. LP gas pumps and compressors must be specially designed, installed and maintained to keep only liquid in pumps and only vapor in compressors. This is not an easy task with LP gas. This is because propane is stored and transferred at its boiling point. In this state, any addition of thermal energy to liquid propane results in vapor formation and any removal of energy from propane vapor results in vapor condensing into liquid.

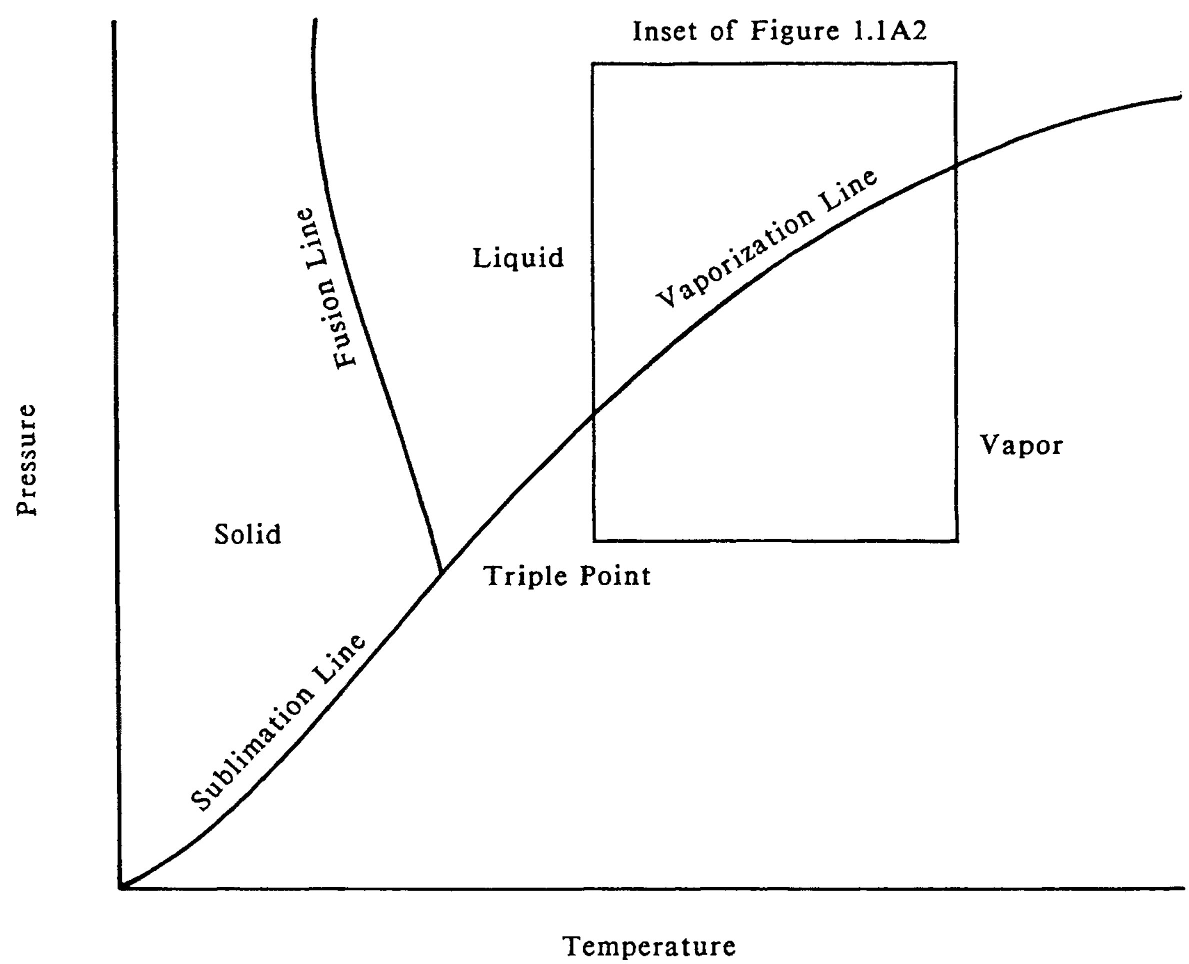


Figure 1.1A1 Phase Diagram For Propane (Not to Scale)

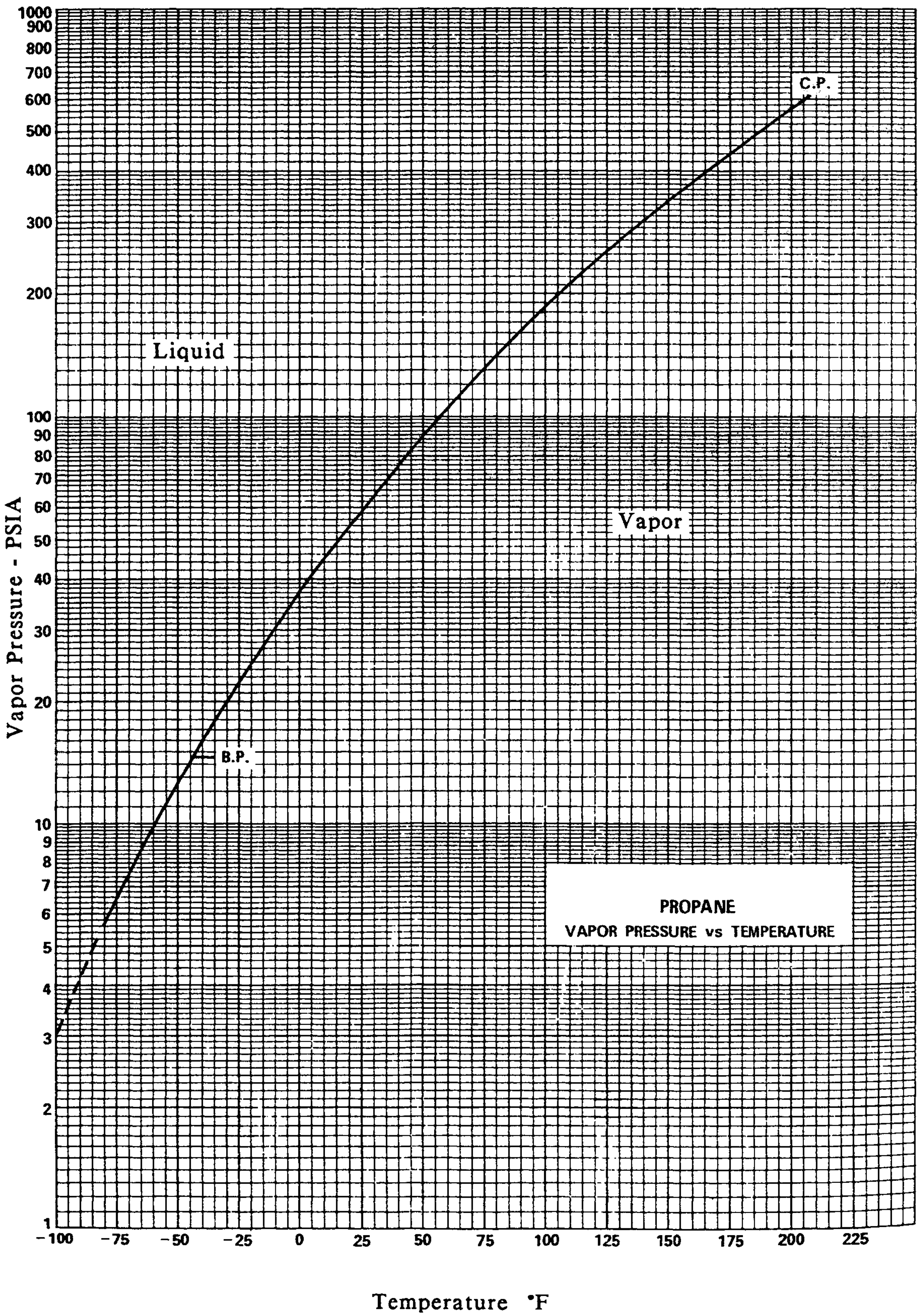


Figure 1.1A2 Phase Diagram For Propane

One property that both liquids and vapors have in common is that they are both fluids. Do not confuse "fluid" with "liquid". Fluidity is a property of both vapors and liquids. A scientific definition of a fluid is "a substance that undergoes continuous deformation when subjected to a shear stress". Since this is rather obscure and difficult to remember, simply think of a fluid as a substance that can be poured, blown or squeezed. Fluidity is the property that allows us to move liquids and vapors between two points by creating pressure differences.

The most important difference between liquids and vapors is that liquids have little or no compressibility and vapors are very compressible. A fluid is compressible if it expands and contracts when subjected to a lower or higher pressure.

There are two other important differences between liquids and vapors. Liquids are generally much better coolants and lubricants than vapors. This property allows pumps to have longer wearing rubbing surfaces and more rubbing surfaces than compressors.

LP gas, like many other substances, can exist as one of three states: solid, liquid or vapor. Each one of these states is referred to as a "phase" (i.e. solid phase, liquid phase or vapor phase).

Pressure and temperature are the two primary properties that determine what phase a substance like propane will exist in. In certain cases a third property must be considered, the amount of thermal energy present in the substance.

A "phase diagram" may be drawn based on experimental data that can tell us in what states propane can exist based on temperature and pressure. This chart is shown in Figure 1.1A1. Figure 1.1A2 shows an exploded view of part of the diagram.

The parts of this chart that interest us the most are the lines that separate the different regions: the vaporization line, fusion line and sublimation line. Along these lines the substance may exist as either of the two phases it is dividing. At the triple point it may exist as any of the three different phases. Along these lines we cannot determine what phase a substance is in simply by knowing the pressure and temperature; we must take a third factor into consideration - thermal energy.

Thermal energy is the amount of heat contained in a certain amount of matter. The flow of energy between two different objects is created by a difference in temperature. Heat flows from the hotter object to the cooler one in a process called "heat transfer". When heat is added to a substance, two things can happen. The temperature can increase or the substance can transform part of its mass into a different phase. The dividing lines of the phase diagram represent energy barriers that must be crossed before the substance can begin to heat up again.

A good example of this is converting a block of ice into steam by heating it on a stove. Imagine a block of ice at 10°F(-12°C) with a thermometer in it. When the ice is heated to 32°F(0°C) it begins to melt. The temperature will not rise again until the ice is completely melted but the ice will continue to absorb heat at the same rate. When the ice is completely melted, the temperature of the water will rise again until it starts to boil again at 212°F(100°C). Once again, the temperature will remain at 212°F until the water has completely boiled off into the air. The flat areas of Figure 1.1B represent the "energy barrier" being transversed at the vaporization and fusion line of the phase diagram chart for water (see Figure 1.1C). The temperature at which the ice-water and water-steam phase change takes place is determined by pressure. At sea level, atmospheric pressure is 14.7 PSIA and water boils at 212°F. At 6500 feet, where atmospheric pressure is 11.5 PSIA, water will boil at 200 F.

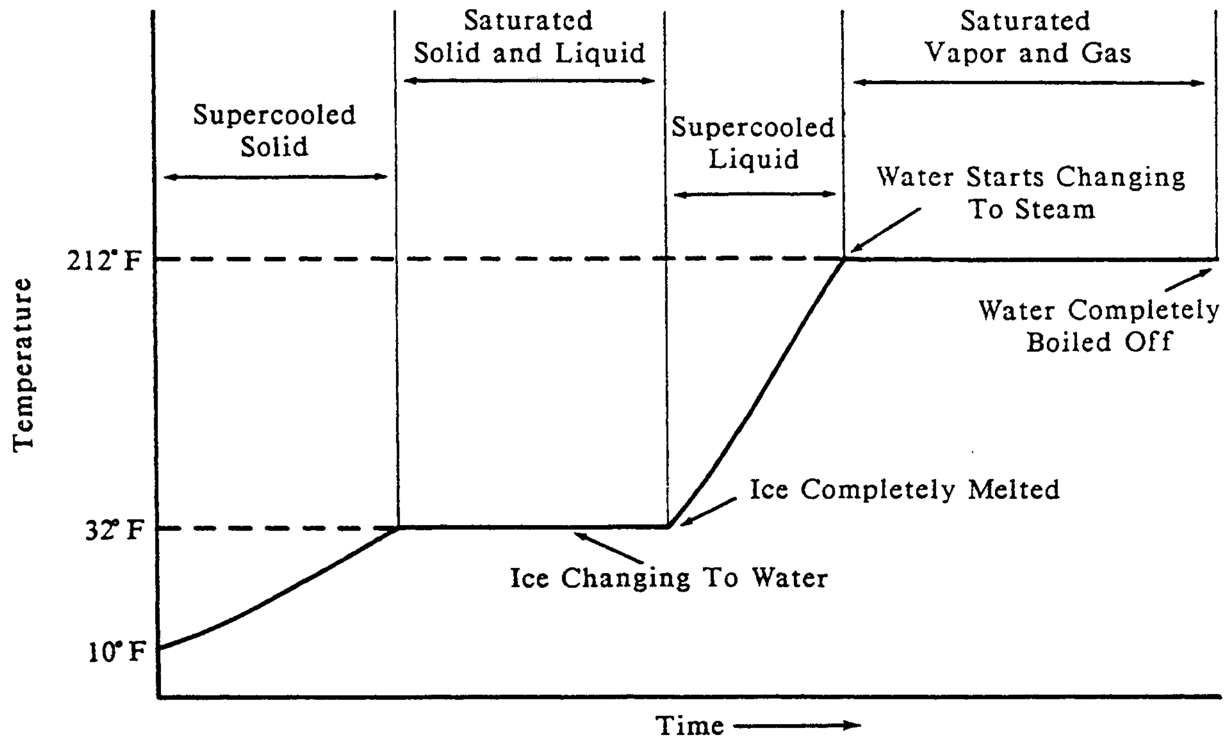


Figure 1.1B Phase Change In Water

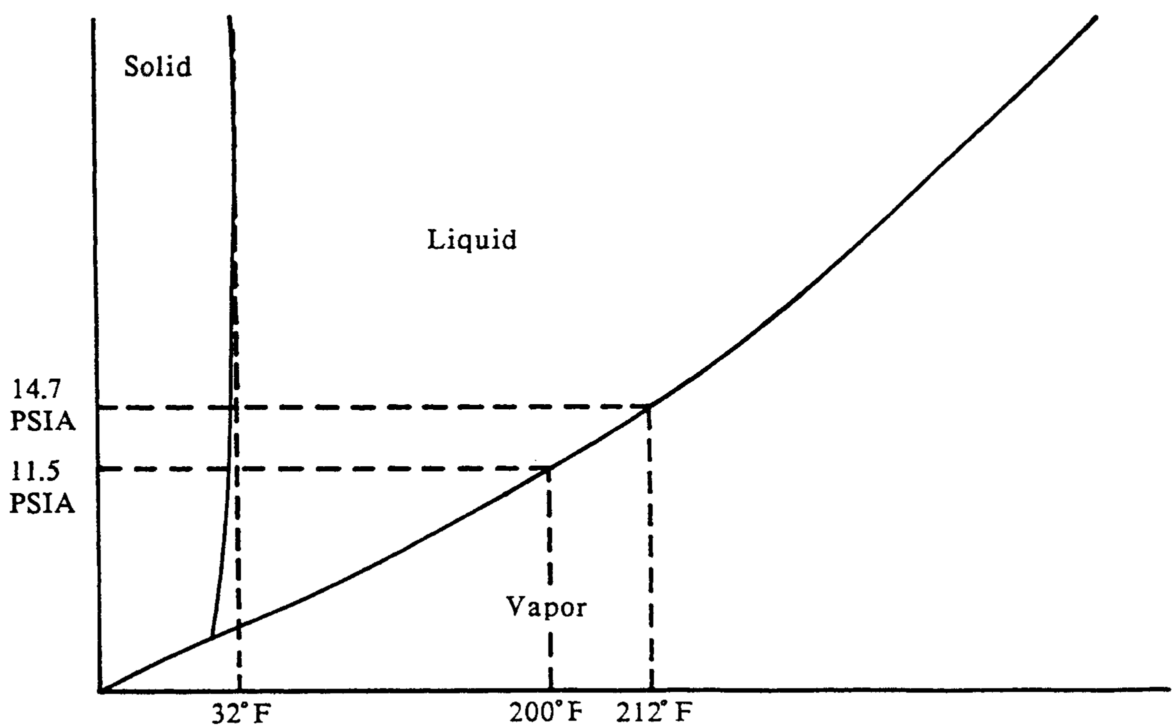
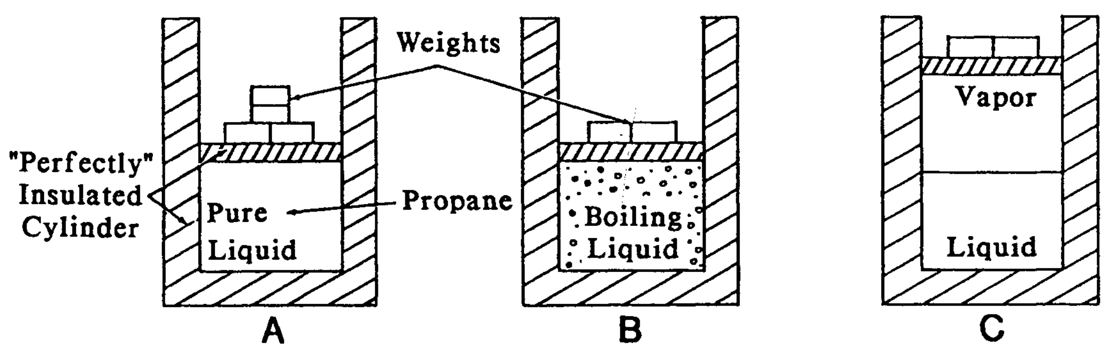


Figure 1.1C Phase Diagram For Water
(Not to Scale)

In the phase-change example just given for water, the water is subjected to constant atmospheric pressure. When we examine phase changes in propane there is one significant difference - propane is handled in constant volume vessels (or cylinders) that are closed off from the atmosphere. Propane must be stored in a closed vessel because at atmospheric pressures and temperatures the propane will boil away into the atmosphere. When propane is stored in a closed vessel, it will only boil if the pressure-temperature conditions define a point to the right of the vaporization line in Figure 1.1A2. When the liquid begins to boil, the pressure in the cylinder will begin to increase, just as it does in a boiler or a pressure cooker. From Figure 1.1A2 you can see that as the pressure increases, the boiling temperature increases so boiling in a propane cylinder ceases when the pressure rises to a high enough pressure. The pressure at which boiling ceases is called the vapor pressure. The vapor pressure changes with the temperature. Higher temperatures result in higher vapor pressures being required to stop the liquid from boiling. The vapor pressure for each temperature makes a pressure-temperature pair that lies on the vaporization line. A liquid or vapor that is at a pressure and temperature that lies along the vaporization line is in a "saturated" state. Liquid that is in a pressure-temperature state that lies above or to the left of the vaporization line is called a "supercooled liquid". Vapor in a pressure-temperature state that lies to the right or below the vaporization line is a "superheated vapor".

Boiling is the creation of vapor by the addition of heat to liquid. Boiling in LP gas systems can be separated into two types. The first type is "externally driven" boiling. Externally driven boiling is caused by addition of heat from an external source to liquid. The example in Fig. 1.1B is an example of externally driven boiling. The fundamental difference between LPG boiling and water boiling is that LPG can be boiled without addition of heat from an external source. This process is called "internally driven" boiling. Internally driven boiling is demonstrated in Fig. 1.1D. In frame A, a perfectly insulated cylinder is filled with liquid propane. A perfectly insulated piston is held in place by sufficient weight to keep the propane completely liquid. (i.e. piston pressure is above vapor pressure). Since the system is perfectly insulated, no heat can be absorbed from outside the cylinder. If enough weight is removed (frame B) to allow the piston pressure to fall below the vapor pressure, the liquid will boil. In this case, the heat to create vapor is supplied from the liquid itself. Since the liquid loses heat, it refrigerates. The boiling continues until the liquid is refrigerated to a point where the piston pressure equals the vapor pressure.

How Liquid Can Be Boiled Without
The Addition Of Heat From An External Source



A	B	C
Sufficient Pressure Is Applied To Keep Propane In Pure Liquid State	Weight On Piston Is Reduced. Liquid Boils And Refigerates Contents Of The Cylinder	Boiling Stops When Equilibrium Point Is Reached

Figure 1.1D Internally Driven Boiling

Externally driven boiling is caused by adding heat from an outside source above the boiling temperature. Internally driven boiling is caused by lowering the internal pressure below the boiling pressure (same as vapor pressure). Since LPG plants aren't insulated, both types of boiling can occur simultaneously. Internally driven boiling causes liquid to refrigerate so a temperature difference is created which in turn causes heat absorption and more externally driven boiling.

When a substance such as propane is handled in a closed vessel, temperature and pressure are directly related. Changes in pressure result in changes in temperature and vice versa. These pressure-temperature relationships are of vital importance in the design, installation and maintenance of LP gas pumps and compressors. In order to completely understand this important relationship, we will review two different examples to show 1)How changes in temperature affect propane and 2)How changes in pressure affect propane.

Example 1 Figure 1.1E

Imagine a 2 cubic foot cylinder that has been completely evacuated of air so that the pressure inside is 0 PSIA (#1). The cylinder is in a room maintained at 80°F. Next the cylinder is half filled with liquid propane at 80°F (#2). Since the cylinder is in a vacuum, the cylinder pressure is below the boiling pressure which means internally driven boiling must occur. Internally driven boiling causes the liquid to loose heat so the cylinder contents refrigerate (#3). The refrigeration results in heat absorption and additional boiling. Externally driven boiling continues until the cylinder contents heat up to 80°F and heat transfer stops (#4).

If the room is now heated up to 100°F, the cylinder will begin to absorb heat again which will cause externally-driven boiling (#5). As the liquid and vapor in the cylinder heat up to 100°F, the vapor pressure will rise to 189 PSIA and once again the boiling will cease (#6).

If the room is now cooled to 50°F, the cylinder will begin to give off heat to the room which will cause part of the vapor to begin to condense into liquid (#7). As the liquid condenses, the vapor pressure will begin to fall. The condensation will cease when the vapor and liquid have cooled to 50°F.

Example 2 Figure 1.1F

In this example imagine a cylinder with a sliding piston that can move up and down in the cylinder and that forms a tight seal between the piston and the wall of the cylinder. The pressure in the cylinder may be controlled by the amount of pressure exerted on top of the piston. The ambient temperature will remain at 80°F for the entire experiment. In step 1, the cylinder is filled with propane gas at 80°F at 50 PSIA. From Figure 1.1A2 we can see that the vapor is in a superheated state. In step 2 the pressure on the piston is increased to 200 PSIA. This compresses the gas into a smaller space. Another result of compressing the vapor is that it heats up, in this case to 140°F. Since the cylinder is hotter than the surrounding environment, it will start to cool by giving off heat to the surrounding 80°F atmosphere. When the cylinder cools to 104°F, as in step 3, it will be at a pressure-temperature condition that lies along the vaporization line. This means that the vapor will begin to condense into liquid. The temperature of the liquid and vapor propane will remain at 104°F until the vapor is completely condensed as in step 4. The liquid will continue to cool to the ambient temperature as shown in step 5. At this point the liquid is supercooled.

The Effect of Changes In Temperature on LP Gas

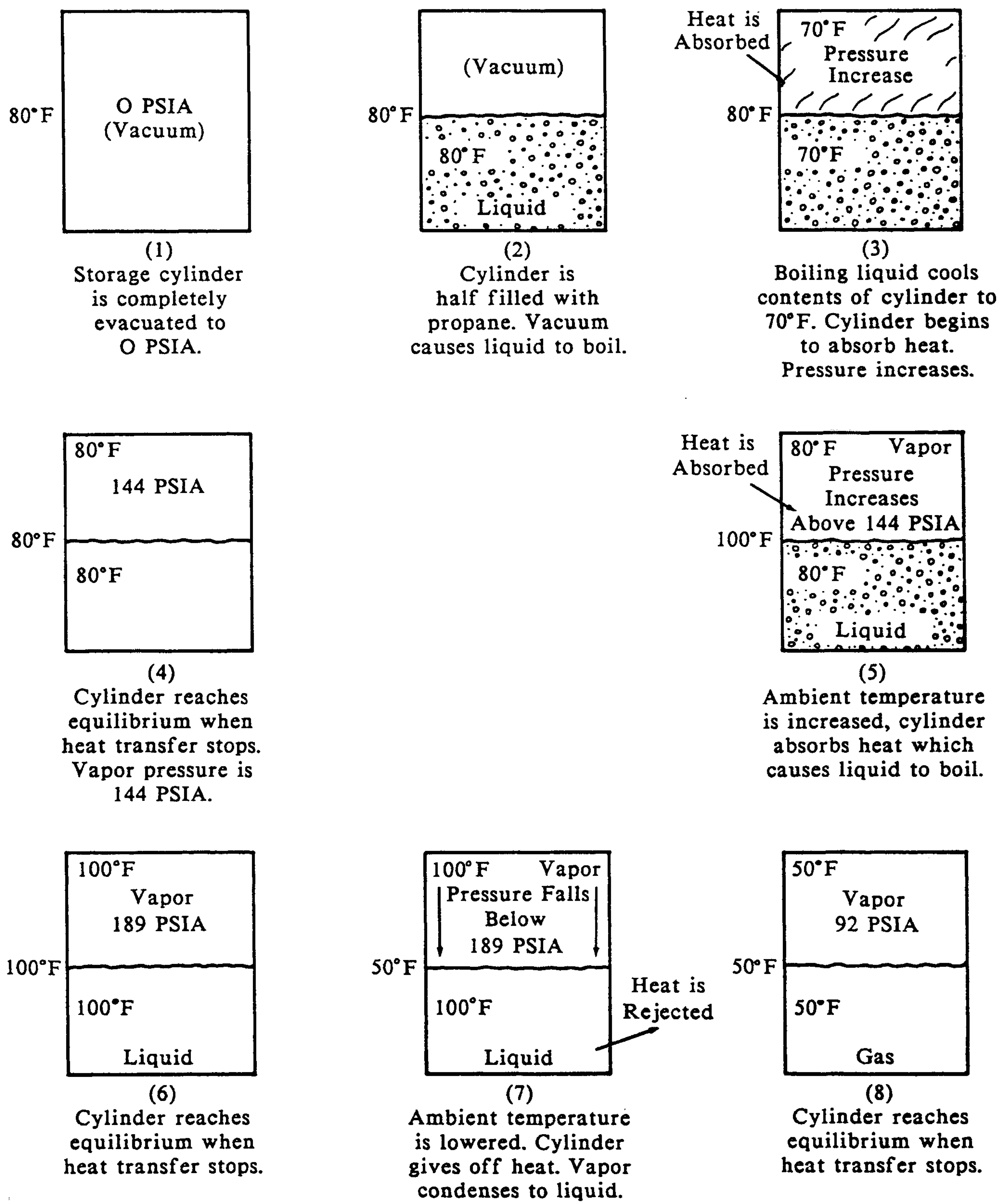
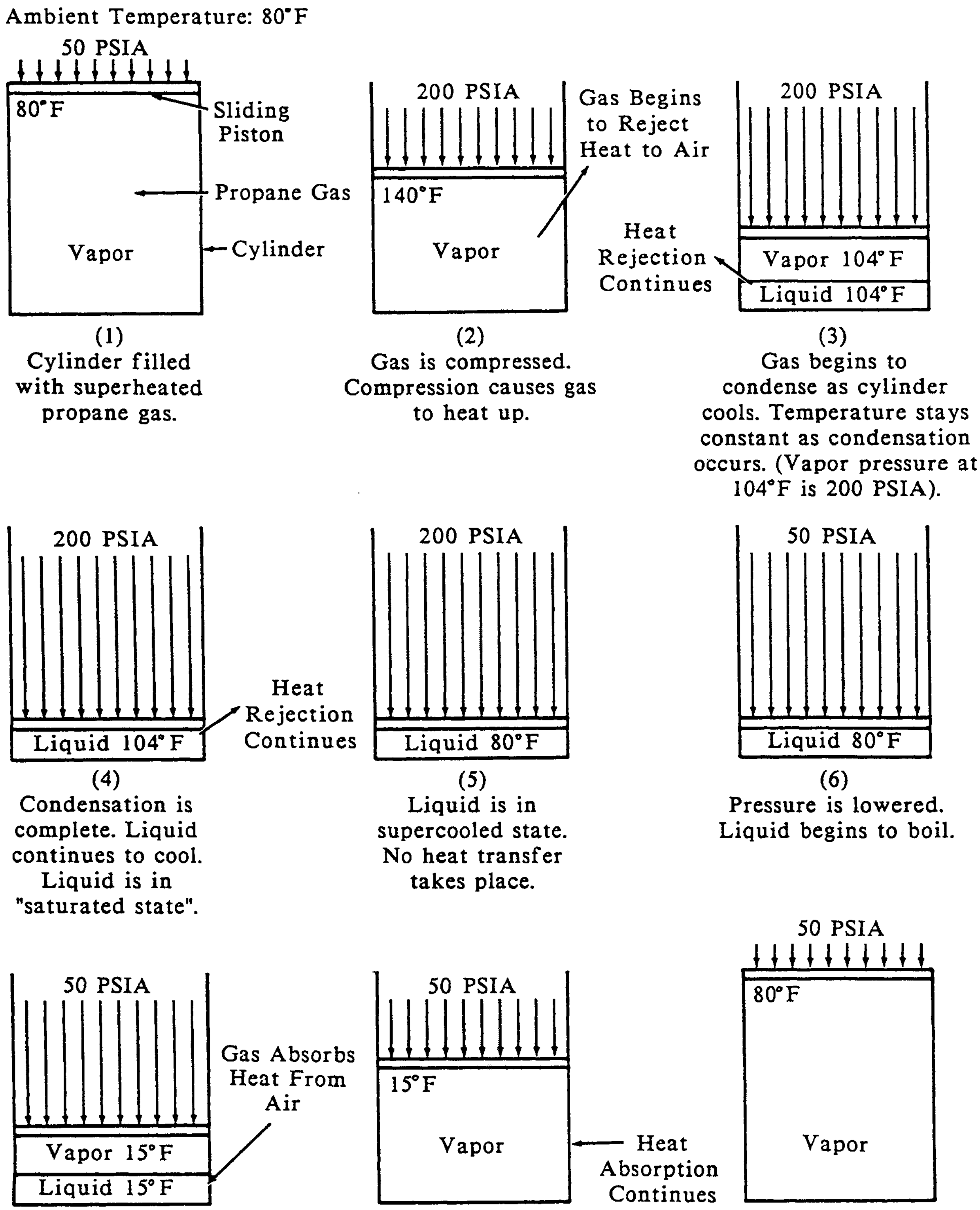


Figure 1.1E

The Effect Of Changes In Pressure On LP Gas



(1) Cylinder filled with superheated propane gas.

(2) Gas is compressed. Compression causes gas to heat up.

(3) Gas begins to condense as cylinder cools. Temperature stays constant as condensation occurs. (Vapor pressure at 104°F is 200 PSIA).

(4) Condensation is complete. Liquid continues to cool. Liquid is in "saturated state".

(5) Liquid is in supercooled state. No heat transfer takes place.

(6) Pressure is lowered. Liquid begins to boil.

(7) Vapor begins to form. Transformation of liquid to vapor causes cylinder to cool. (Vapor pressure at 15°F is 50 PSIA).

(8) Liquid is completely converted to gas. Gas is in "saturated state" at 15°F.

(9) Gas is superheated as it warms up to ambient temperature. Heat transfer ceases.

Figure 1.1F

Now we will reverse the process and see what happens. The pressure on the piston is lowered to 50 PSIA as shown in step 6. Figure 1.1A2 shows that at 80°F and 50 PSIA, propane should exist as a superheated vapor. This creates a situation similar to step 1 in example 1. The liquid will begin to boil and the energy for the phase change will come from the liquid. This will cause the liquid to cool down to 15°F as shown in step 7. Since the contents of the cylinder are now cooler than the surrounding atmosphere, the cylinder will absorb heat. The cylinder will absorb heat at 15° F until the liquid is completely converted to vapor as shown in step 8. Once the conversion to vapor is completed, the vapor will heat up to the ambient temperature of 80°F as shown in step 9. Step 9 is identical to step 1.

In both examples 1 and 2, you will note that a change of phase can only take place if there is heat transfer taking place. The temperature differences required to cause heat transfer are created two ways 1)Changing the internal pressure of the container and 2)Changing the external temperature around container.

As you will see as we continue our study, it is necessary to pay careful attention to changes in external temperature and internal pressure in any LP pump or compressor system because this is what causes unwanted phase changes which result in damage to the system.

(ΔP) Changes in Internal Pressure

and/or

(ΔT) Changes in External Temperature

↓

Result in

(ΔQ) Heat Transfer

↓

Which Results in
Change of Phase
For Part or All of
The Contents of a
Closed System

Figure 1.1G
The Pressure-Temperature Relation For Liquid Gases

CHAPTER 2
LP Gas Pumps

2.1 Liquid, Vapor and Pumps

The most important factor in LP gas pump design and installation is to keep the propane liquid from changing into vapor. Why is this so important? There are several answers to this question.

Vapor entering the pump displaces liquid which results in a lower liquid flow rate. This causes longer unloading times, wasted energy and increased wear on the pump.

You will remember from the first chapter that vapor is a relatively poor coolant and lubricant compared to liquid. Since LP gas pump design requires rubbing surfaces at the seals and vanes, the liquid must provide lubrication and cooling to these surfaces. More vapor results in less lubrication and cooling which in turn results in more rapid wear and failure.

Liquid/vapor mixtures result in unstable and uneven fluid flow. This causes the stresses on the pump to fluctuate and induce vibrations that result in rapid wear.

By limiting vapor formation to a small fraction of the liquid flow, highly reliable LP gas pump performance can be attained.

2.2 Vapor Formation In Suction Piping

All vapor formation in the suction piping of LP gas pumps may be traced to two sources 1)Heat transfer into the piping from an external source which causes externally driven boiling. 2)Internal pressure drops within the piping which cause internally driven boiling.

Heat transfer should be taken into consideration whenever there is a large difference between night and day temperatures. During the day, when most LP gas pumps are operated, the atmosphere will heat up more quickly than the liquid propane in the storage tank and piping. This causes heat transfer from the air to the propane in the piping. The radiative heat of the sun causes further heating. To minimize the amount of heat transfer, the surface area should be minimized by keeping the suction piping as short as possible. Painting the tank and piping white also minimizes heat transfer by reflecting rather than absorbing the sun's rays. Placing the pump and suction piping in the shade of the storage tank is helpful.

Pressure drops that cause vapor to be present in the suction piping can be traced to three sources 1)Changes in elevation 2)Friction and 3) Vapor entrainment.

The pressure at the suction to an LP gas pump equals the vapor pressure in the tank minus the pressure drop through the suction piping plus the "suction head". The suction head is the additional pressure created by the weight of the propane above the pump suction. CORKEN recommends that the feed tank be placed four feet above the pump whenever possible. The "suction head" this creates helps counterbalance the effect of the pressure drop through the suction piping.

Friction is created whenever a fluid flows over a surface. In the piping to a LP gas pump, this friction causes energy stored in the form of pressure to be converted to heat. This results in lowering the pressure of the liquid. Two factors determine how much frictional pressure drop will take place 1)The velocity of the liquid and 2) The turbulence of the liquid.

The amount of friction created by fluid flow through a pipe is proportional to the square of the velocity. In other words, the frictional pressure drop at 2 ft/sec will be four times greater than at 1 ft/sec through the same pipe. Larger diameter pipe results in slower liquid velocities and lower pressure drops. Restrictions in the piping will result in higher velocities and pressure drops. These restrictions may be caused by strainers, excess flow valves or block valves. Fittings should be chosen that result in the minimum amount of restriction. For example, ball valves are preferred to globe valves.

Turbulence is the amount of internal agitation in a fluid. The more turbulent the liquid is as it flows through the pipe, the greater the amount of friction and the higher the pressure drop. Turbulence is caused by restrictions in the piping (valves, strainers, etc.) and bends in the piping. Turbulence producing fittings should be kept at least ten pipe diameters from the pump suction for the smoothest pump operation.

The ideal LPG pump has suction piping designed to prevent the liquid pressure from falling below the boiling pressure (vapor pressure) at any point in the suction piping. If liquid pressure falls below vapor pressure, internally driven boiling occurs. Figure 2.2A shows the amount of vapor that will be present at the pump suction due to internally driven boiling. For example, a pump on a 90^{o} F day with a suction pressure 9 psi below vapor pressure will be pumping 10% vapor and 90% liquid. Vapor formation will increase with lower temperatures and higher pressure drops. The amounts shown in Figure 2.2A are minimum amounts. Since internally-driven boiling causes externally driven boiling due to refrigeration of the liquid, the actual amount of vapor formation will be even higher.

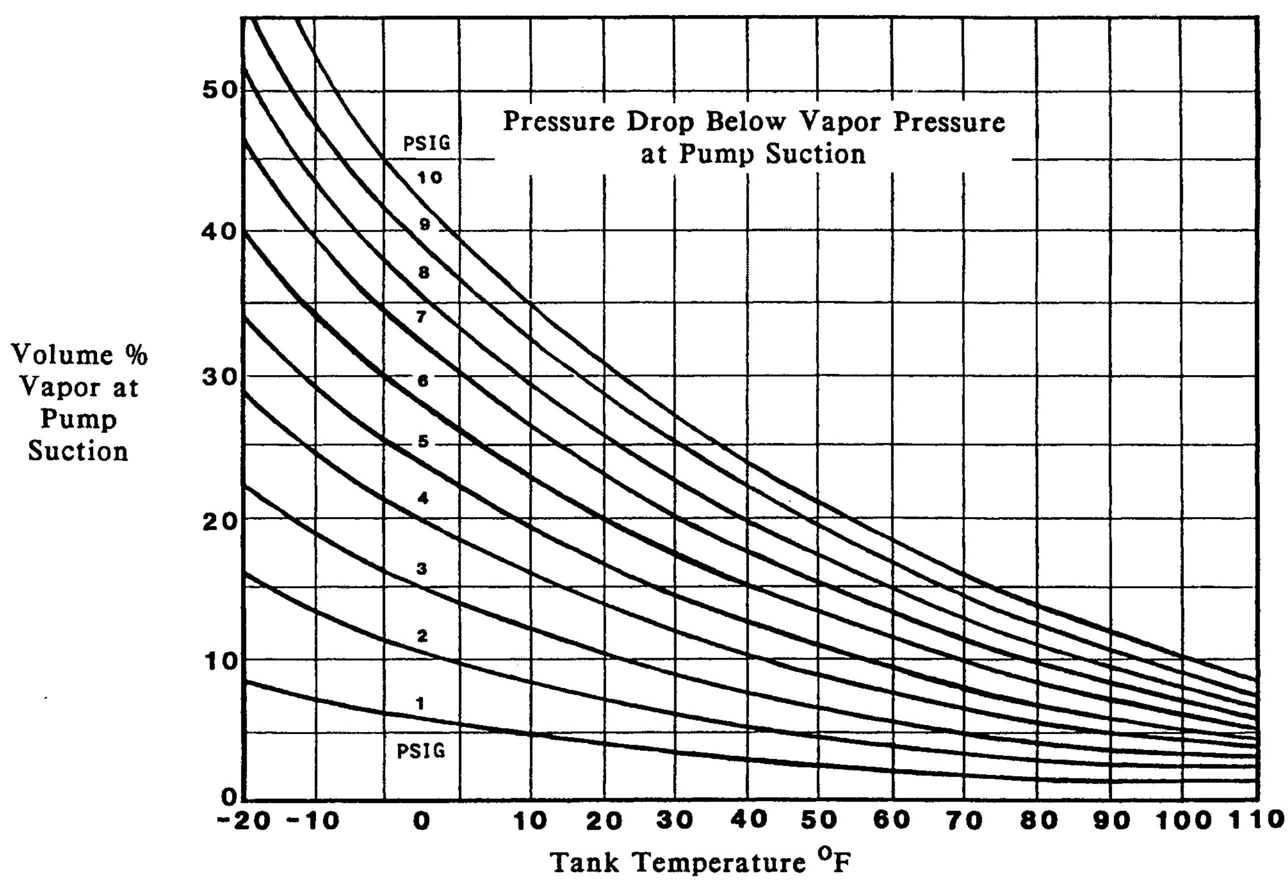


Figure 2.2A
Vaporization of Propane By Internally Driven Boiling

Internally driven boiling can be prevented in suction piping by providing sufficient static head on each restrictive device to cancel out the pressure drop through that device. 4.5 ft. of LPG creates about 1 psi of static pressure, so 4.5 ft. of static head can cancel out the effect of a 1 psi pressure drop as long as it is placed before the point of the pressure drop. Static head after the point of the pressure drop can reverse some of the boiling but more head is required to suppress boiling after a restriction than prevent it before a restriction.

Designing an LPG pump installation that prevents vaporization in the suction piping under all operating conditions is rather impractical and expensive, primarily because of the excess flow valves. Safety regulations require all inlets and outlets from LPG tanks to be equipped with excess flow valves (EFV's). The EFV closes automatically when an unusually large amount of liquid or vapor flows out of the tank due to a hose pull-out or ruptured line. Although EFV manufactures have gone to considerable lengths to minimize pressure drops through these devices, the pressure drops are still large enough to be significant. For example, if the pressure drop through an EFV is 1 psi, then at least 4.5 ft. of LP would be required in the tank to cancel out the pressure drop through the EFV. Whenever this tank operates with a lower liquid level than 4.5 ft., vaporization due to internally driven boiling will occur. It is obviously impractical to maintain a high enough liquid level in a tank at all times to prevent vaporization at the EFV since the tank must be refilled more frequently - which costs money. Placing tanks higher up in the air is also expensive since more money must be spent on foundations, supports and piping. These problems have popularized the use of regenerative turbine and sliding vane pumps. These pumps can move boiling liquid that contains some vapor and still give reliable operation.

Vapor which is formed in the feed tank and then drawn into the pump is called entrained vapor. Vapor entrainment is caused by a drop in the internal pressure of the feed tank. As the pump draws liquid out of the feed tank, the vapor space expands causing the tank pressure to drop. This causes the liquid to boil into vapor to bring the vapor pressure back up. Unfortunately, the boiling takes place at the bottom of the tank. This is exactly the point where it is most likely to be pulled into the suction piping. To maintain the vapor entrainment at a low enough level to protect the pump, no more than 2 to 3% of the tank volume should be removed per minute. For underground tanks this should be lowered still further to 1 to 2% of the tank volume per minute. This will also prevent the formation of a whirlpool that would substantially increase the amount of vapor entrainment.

The best method to minimize entrainment of vapor in the feed tank is with a vapor return line. The vapor return line connects the feed tank's vapor space to the vapor space of the tank being filled. As liquid is removed from the feed tank, it is replaced by vapor from the fill tank. This way the liquid in the feed tank does not need to boil to maintain the vapor pressure. See Figures 2.2B and 2.2C. Unfortunately in many areas, local authorities do not allow vapor return lines to be used on systems with meters. When a return line is used, some of the vapor in the customer's tank goes back in the supplier's tank. While techniques exist to calibrate the meter to compensate for this lost vapor, these techniques are not allowed by regulatory authorities in some areas.

Since vapor formation in suction piping cannot be eliminated economically, the LPG industry has been forced to balance out costs related to wear and tear on the pump with installation and operation costs. Therefore LPG pumps need to meet two important criteria: 1) The pump must not cause any significant vapor formation in addition to the vapor already formed by the suction piping. 2) The pump must be able to handle some vapor in the liquid and still give reliable service.

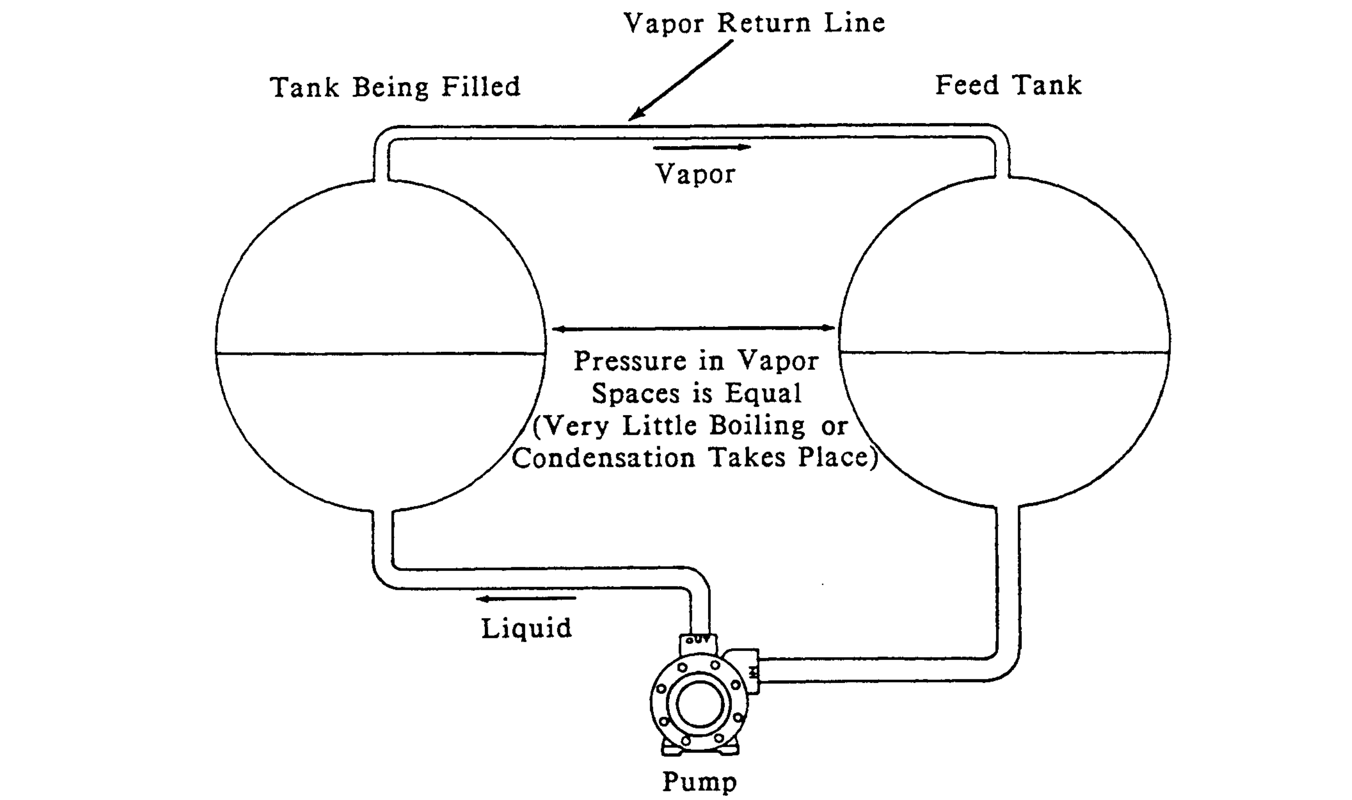


Figure 2.2B Pumping System With Vapor Return Line

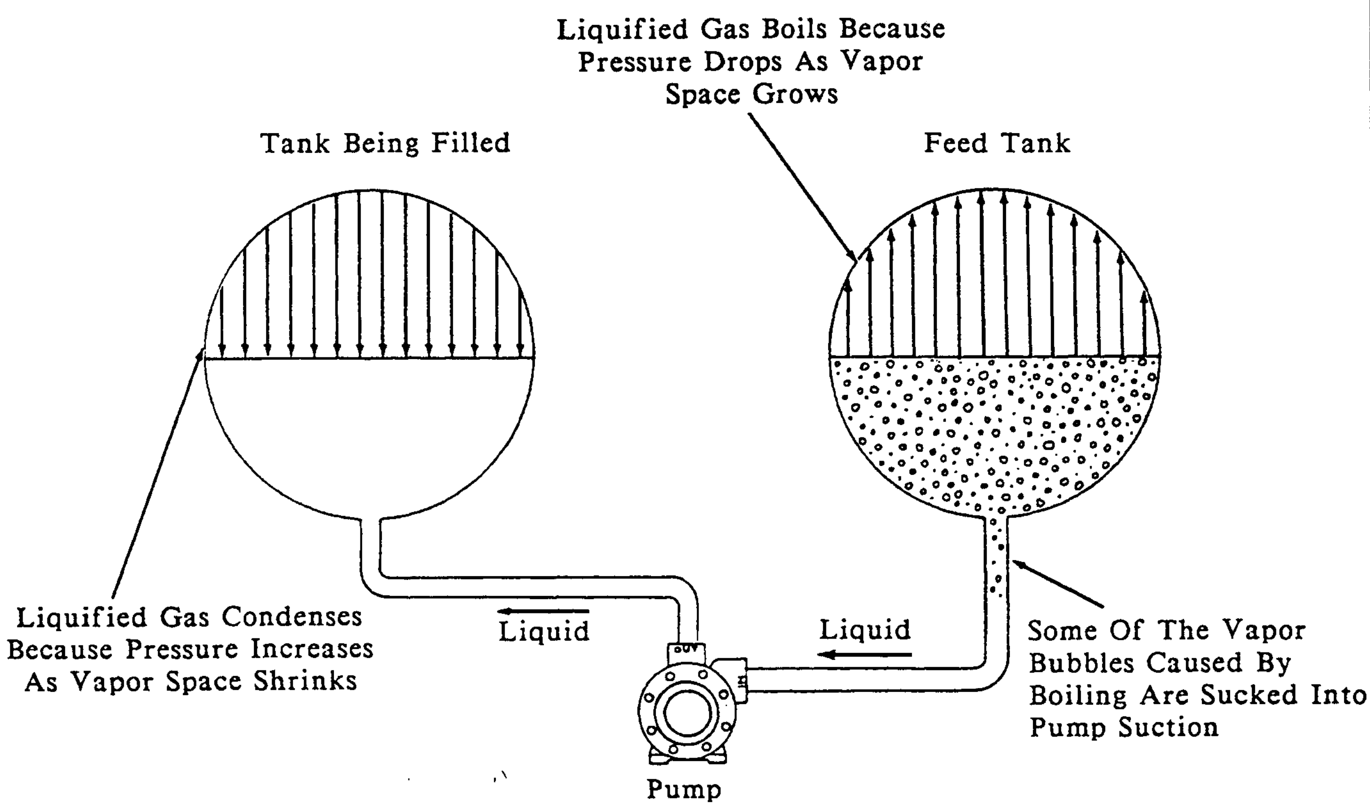


Figure 2.2C Pumping System Without Vapor Return Line

The question "How much vapor formation is too much?" is difficult to answer. More vapor means faster wear. However, wearing the pump out faster may be cheaper than building an ideal installation. In most cases the wisest thing to do is follow the pump installation instructions in Appendix Z400. These instructions have been based on 30 years of experience and will result in installations that are economical but limit vapor formation to a low enough level to allow very reliable operation. Whenever a departure from these recommendations is considered, careful consideration should be given to how the changes would affect vapor formation in the suction piping.

Figure 2.2A shows that much larger amounts of vapor formation occur on cold days than hot days for the same pressure drop. This explains why loading rates in LP bulk plants are lower on cold days. It is very important to understand that the lower flow rate is not caused by the pump but by the suction piping.

Probably the most frequently overlooked fact concerning LPG pumps is that they do not cause significant vaporization and they don't cavitate significantly (this will be examined in more depth in Section 2.9). The regenerative turbine and sliding vane pumps play a virtually passive role in vapor formation. If they are fed liquid, they pump liquid. If they are fed vapor, they pump vapor. Vaporization in LP pumping systems is almost entirely related to suction piping, not the pump.

2.3 Design of LP Gas Pumps

Pumps with positive displacement performance characteristics that rotate (rather than reciprocate) are the overwhelming favorite of the LP gas industry. These pumps have dominated the market because they best meet the two criteria we discussed earlier 1)The pump does not cause significant vaporization of LPG and 2)The pump is able to move some vapor without being damaged. To understand why these pumps meet these criteria so well, it is helpful to understand why the more common, conventional designs perform so poorly.

The most common kind of liquid pump is the centrifugal pump. The centrifugal pump draws fluid into its chamber by means of an impeller that scoops up the fluid, accelerates it and throws it into a restriction at the discharge called a volute. The kinetic energy (energy of motion) imparted to the liquid by the impeller is converted to potential energy (energy from pressure) in the volute. Because the liquid is accelerated by the impeller, the liquid must enter the pump at a high velocity. This results in a large pressure drop at the pump suction. This pressure drop results in high vapor formation and cavitation of liquified gas. The vapor formation and cavitation is too great for standard single-stage centrifugal pumps to be utilized for LPG transfer if the suction pressure is near or below vapor pressure as it is in most commercial applications.

Another common pump, the piston pump, is not suitable for pumping liquid LP gas from storage tanks. Piston pumps (same as reciprocating pumps) belong to the positive displacement group with rotating positive displacement pumps. Positive displacement pumps handle liquid in finite "bites" such as the volume of the cylinder in a piston pump. The liquid is forced out of the pump by displacing it with a piston. In a piston pump, the flow of fluid into and out of the cylinder is restricted by suction and discharge valves. These restrictions cause pressure drops that result in an unacceptably large amount of vapor formation on LP gas liquid pumped from storage.

Rotating pumps with positive displacement performance characteristics pressurize fluid without the acceleration required by centrifugal pumps. They have large unrestricted suction ports. The rotary motion results in smooth flow instead of the pulsating flow of a reciprocating pump. Since the pump is positive displacement, it can move vapor as well as liquid. These properties uniquely suit these pumps to liquified gas transfer.

Rotating pumps with positive displacement performance characteristics for LP gas can be separated into three different families 1)Vane pumps, 2)Regenerative turbine pumps and 3)Gear pumps. The regenerative turbine pump is similar to the centrifugal pump in many aspects but its performance characteristics are essentially identical to a positive displacement pump (this will be discussed in more detail in Section 2.5). CORKEN manufactures vane pumps and regenerative turbine pumps.

2.4 Sliding Vane Pumps

The sliding vane pump is the most popular type of pump in the LP gas industry for generating high flow rates (20 GPM or more). They combine low cost with high reliability and easy maintenance. The operating principle is simple. A slotted rotor is eccentrically supported in a cycloidal cam. The rotor is placed close to the wall of the cam so a crescent shaped cavity is formed. The rotor is sealed into the cam by two sideplates. The clearance between the rotor and sideplates is 8 to 10 thousandths of an inch depending on the model. Blades* slide in and out of the rotor slots to seal off a volume between the rotor, cam and sideplate. Liquid enters the crescent shaped pumping chamber through holes in the cam. The blades sweep the fluid to the opposite side of the crescent where it is squeezed through discharge holes of the cam as the blade approaches the point of the crescent. (Figure 2.4A).

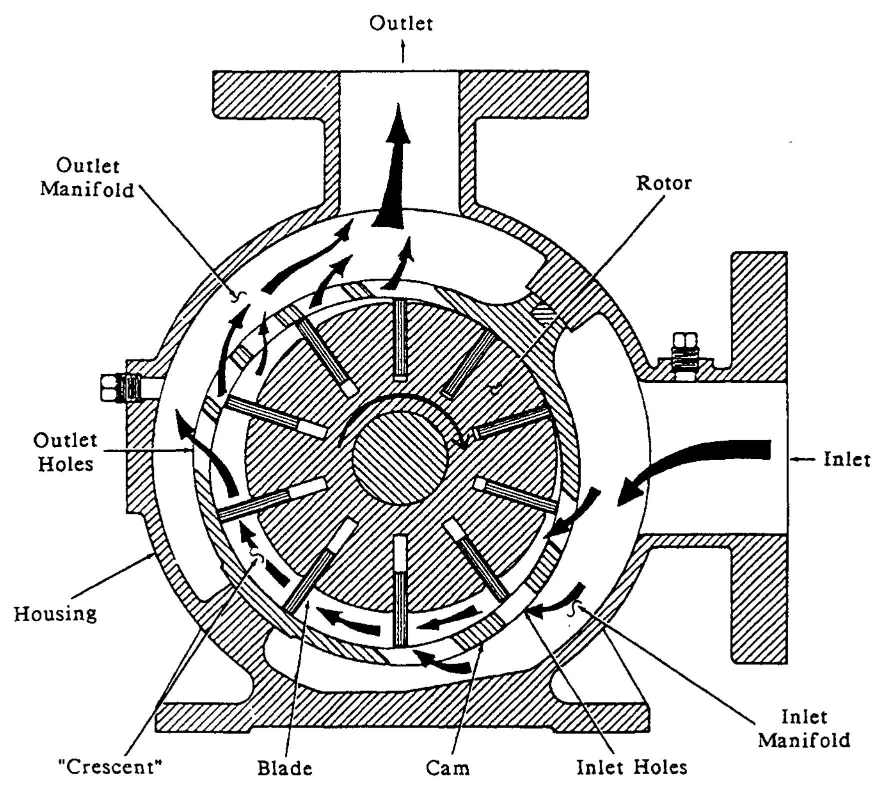


Figure 2.4A Vane Pump Construction

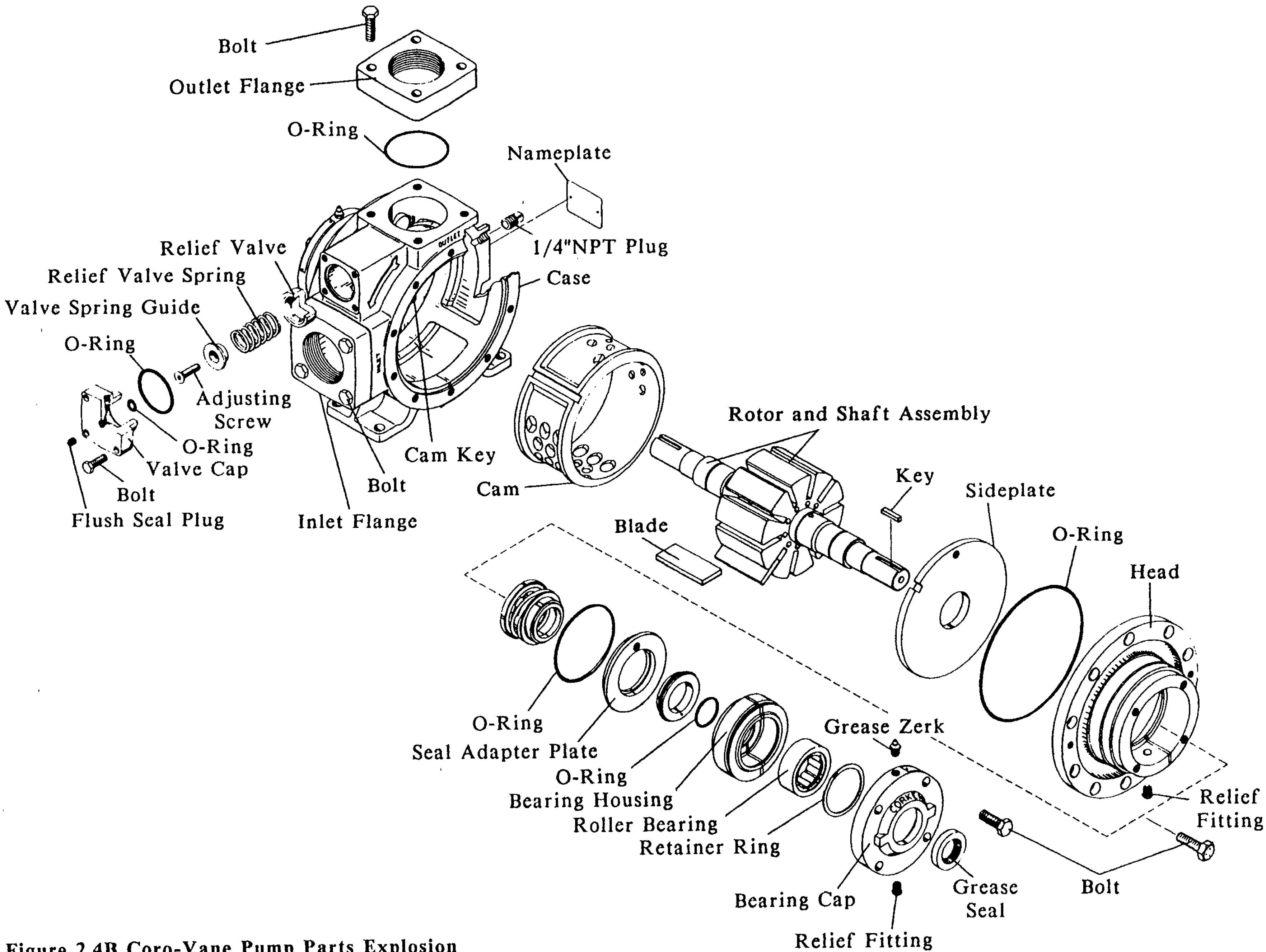


Figure 2.4B Coro-Vane Pump Parts Explosion

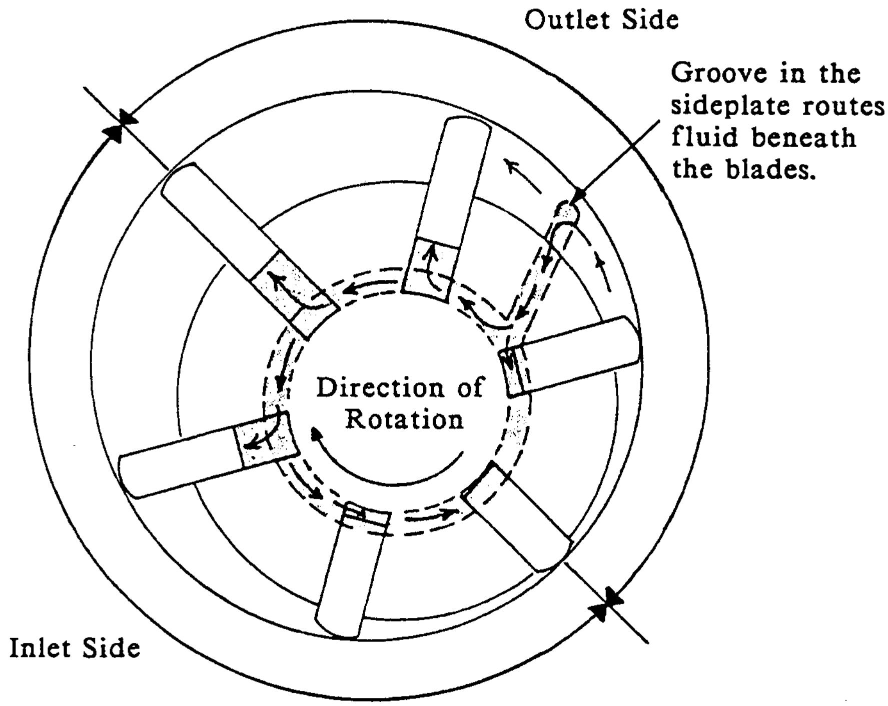


Figure 2.4C Hydraulic Actuation

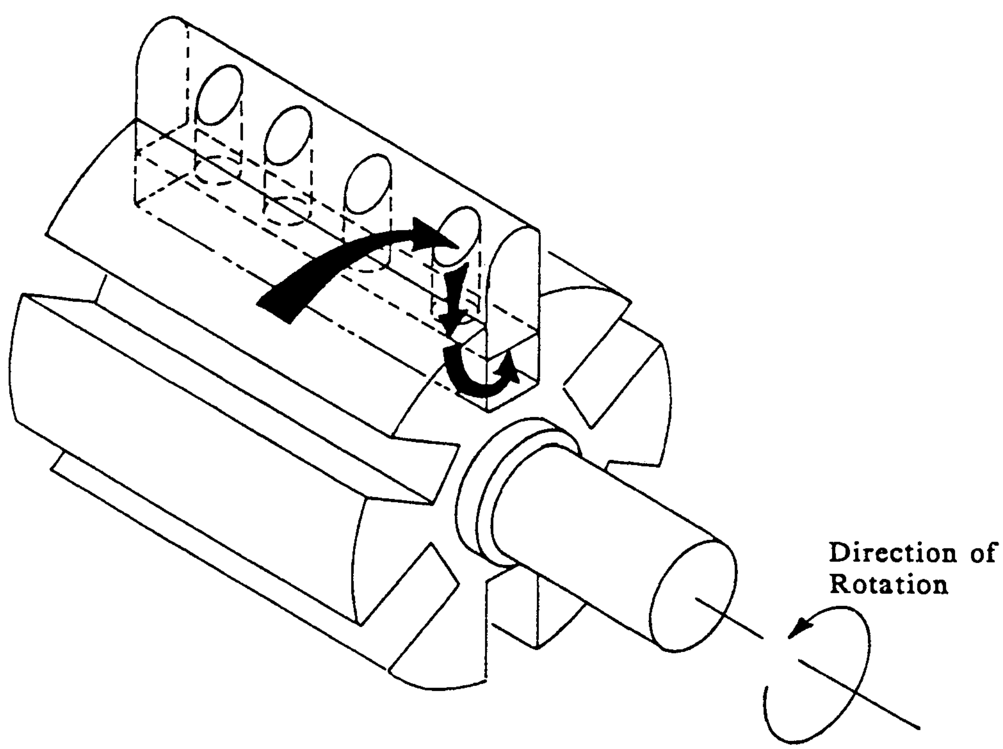


Figure 2.4D Hydraulically Balanced Blades

For a vane pump to function properly, the blade must always firmly contact the cam wall to form a tight seal. Centrifugal force provides some force to actuate the blade but this force is not adequate by itself. Hydraulic forces exerted by the liquid being pumped tend to push the blades back into the rotor. Special design features must be incorporated into the pump to counteract these forces. This is generally done by routing discharge pressure under the blade via slots in the sideplates or holes in the blade.

Coro-Vane LPG/Ammonia pump housings and rotors are fabricated from ductile iron, an advanced cast iron which combines high strength with low cost. Blades are either a special fiber filled nylon (not used on ammonia) or polyphenylene sulfide. Some fluids such as ammonia cause nylon blades to swell; the polyphenylene sulfide blades do not swell in ammonia and similar fluids. CORKEN Coro-Vane pumps contain no copper parts so they may be used in ammonia service.

The rotor is solidly supported on both ends by roller bearings. Inboard mechanical seals are used on both sides of the rotor for positive leakage control. The pumps are designed to operate at speeds from 400 to 1000 RPM.

CORKEN manufactures four sizes of vane pumps that cover flow rates from 20 GPM to 350 GPM. Typical applications include cylinder filling, loading and unloading of bobtail trucks, and loading and unloading of large transports. Coro-Vane pumps are selected based on the flow rate and differential pressure required. The proper speed and horsepower for the pump may be read from the pump curves in the CORKEN Sales Manual. Coro-Vane pumps may be direct or V-belt driven by either an electric motor or gasoline engine. Coro-Vane truck pumps may be driven off the truck's engine by a power take-off(PTO). Truck pumps come with a drive shaft extending from both sides of the pump to allow the pump to be driven by the PTO regardless of which side of the engine the PTO is mounted on.

Occasionally it is necessary to operate Coro-Vane pumps with motors exceeding 20 HP. In these cases the pump should be driven through a gear reducer or low speed motor (400 to 1000 RPM). Using a V-belt drive for motor sizes 25 HP and greater will result in excessive bending stresses in the driveshaft.

Some Coro-Vane pumps come with an internal relief valve for added protection. This valve relieves pressure from the pump discharge back to the suction. The function of the valve is to prevent the differential pressure across the pump from exceeding the rated limit. This protects the blades and helps keep the motor from overloading. (Note - All PD pumps must have an external back-to-tank relief valve in addition to any internal relief valve supplied with the pump. UL requires all LP gas pumping systems to have an external bypass valve).

To maintain the pump's efficiency, the clearance between the rotor and sideplates must be very small. Coro-Vane pumps have a "floating" rotor that utilizes hydraulic forces to center the rotor and prevent rotor-to-side plate contact. This design eliminates the troublesome assembly and difficult adjustment procedures a fixed rotor design requires.

Coro-Vane truck pumps are usually supplied with an optional thrust absorber. A PTO shaft can create some thrust load that tends to push the rotor against the sideplate in some cases. The thrust absorber is a fixed shaft that fits over the rotor shaft. The rotor shaft telescopes into the thrust absorber shaft and is still able to float. The thrust absorber passes on the rotary force of the PTO to the rotor shaft while supporting the axial thrust force transmitted in the PTO.

The Coro-Vane pump roller bearings are grease lubricated. To prevent over-greasing the bearing, a grease relief is installed in the bearing cover.

*The words "blade" and "vane" are used interchangeably for discussing sliding vane pumps.

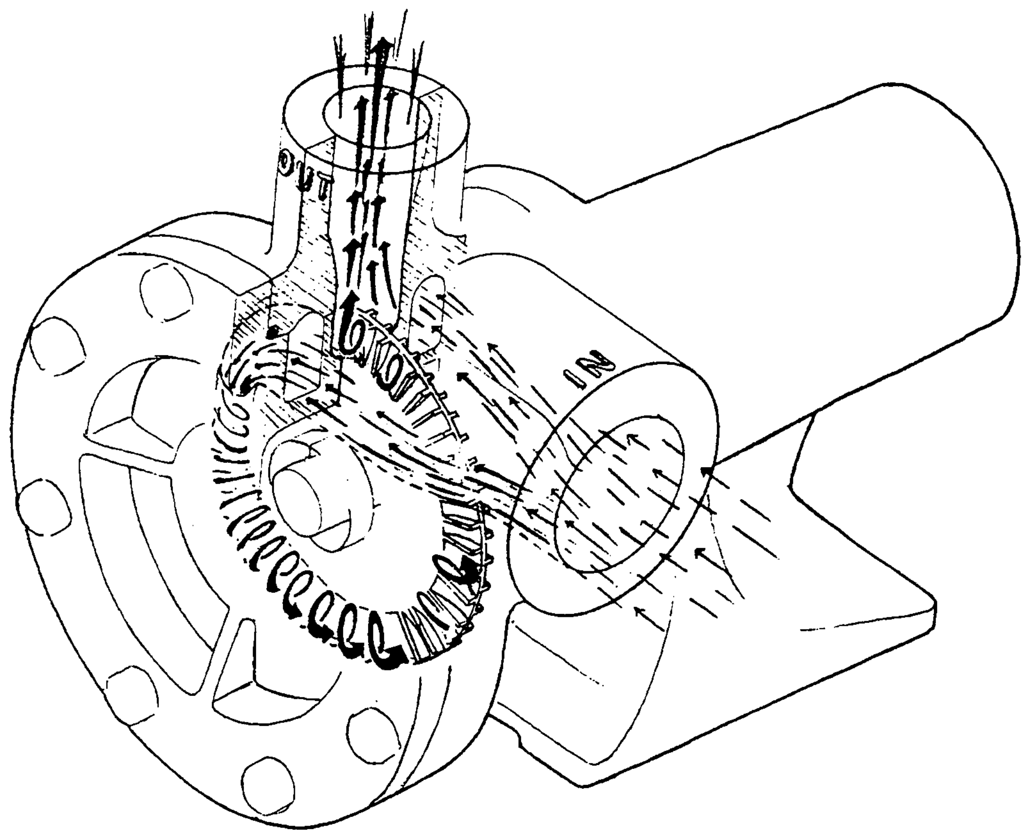


Figure 2.5A Coro-Flo Pump

2.5 Regenerative Turbine Pumps

The regenerative turbine (RT) pump has acquired a well-deserved reputation as the most dependable LP gas pump on the market. Pump lives extending beyond 25 years are not at all unusual, even with regular daily usage.

The operating principles of the RT pump are rather subtle compared to other pumps. From a mechanical viewpoint the regenerative turbine pump is a centrifugal pump. However, the performance characteristics of the pump correspond to a positive displacement pump. An RT pump pressurizes fluid the same way as a centrifugal pump. It accelerates the fluid to convert kinetic energy to potential energy. The RT pump differs from the centrifugal pump because it breaks the acceleration/pressurization process into dozens of separate steps. The fluid is slightly accelerated and slightly pressurized with each step.

As fluid enters the pump, it is picked up by the impeller and begins to make a spiraling motion around the circumference of each side of the impeller (See Figure 2.5A). Each spiral represents an acceleration/ pressurization cycle. The impeller has teeth cut on both sides of its edge. The impeller spins at high speed (3600 RPM for 60 HZ motors, 2880 for 50 HZ motors) in a very close fitting casing.

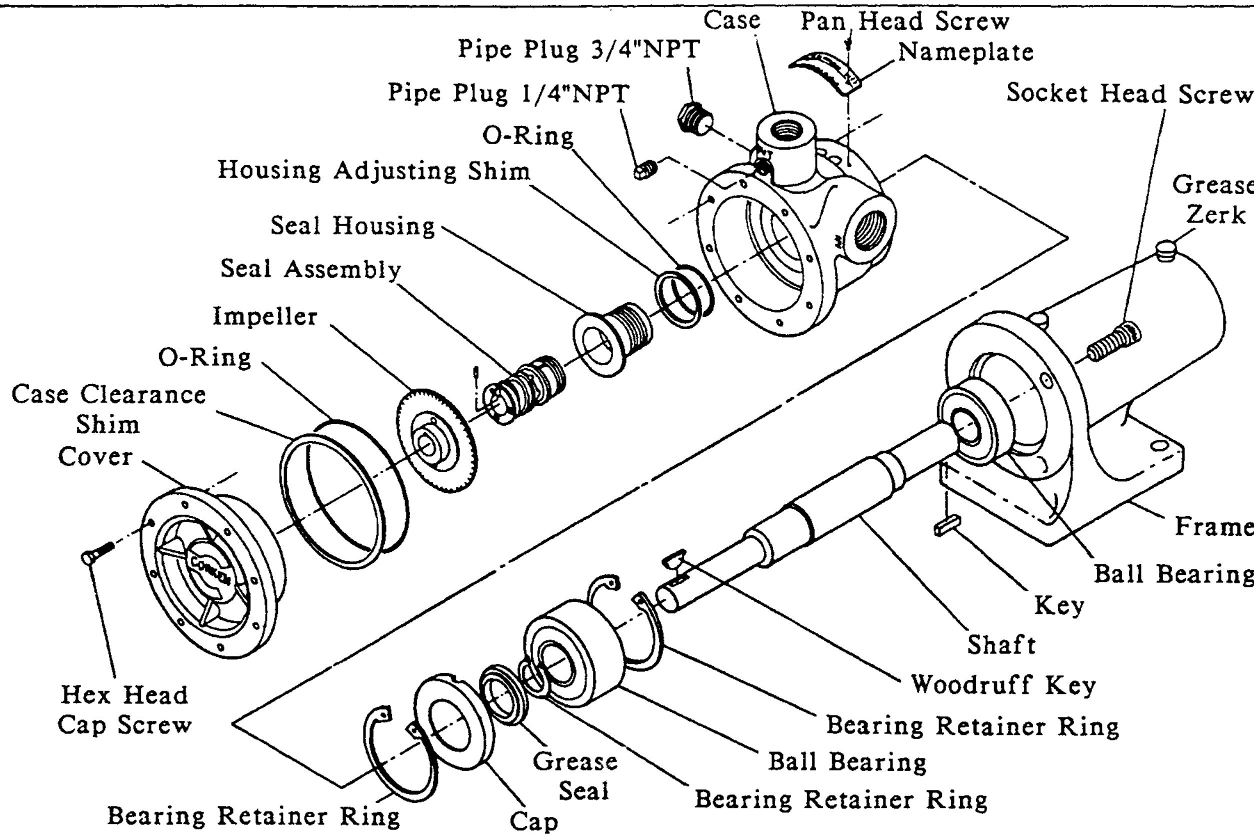


Figure 2.5B "F" Model Coro-Flo Pump Parts Explosion

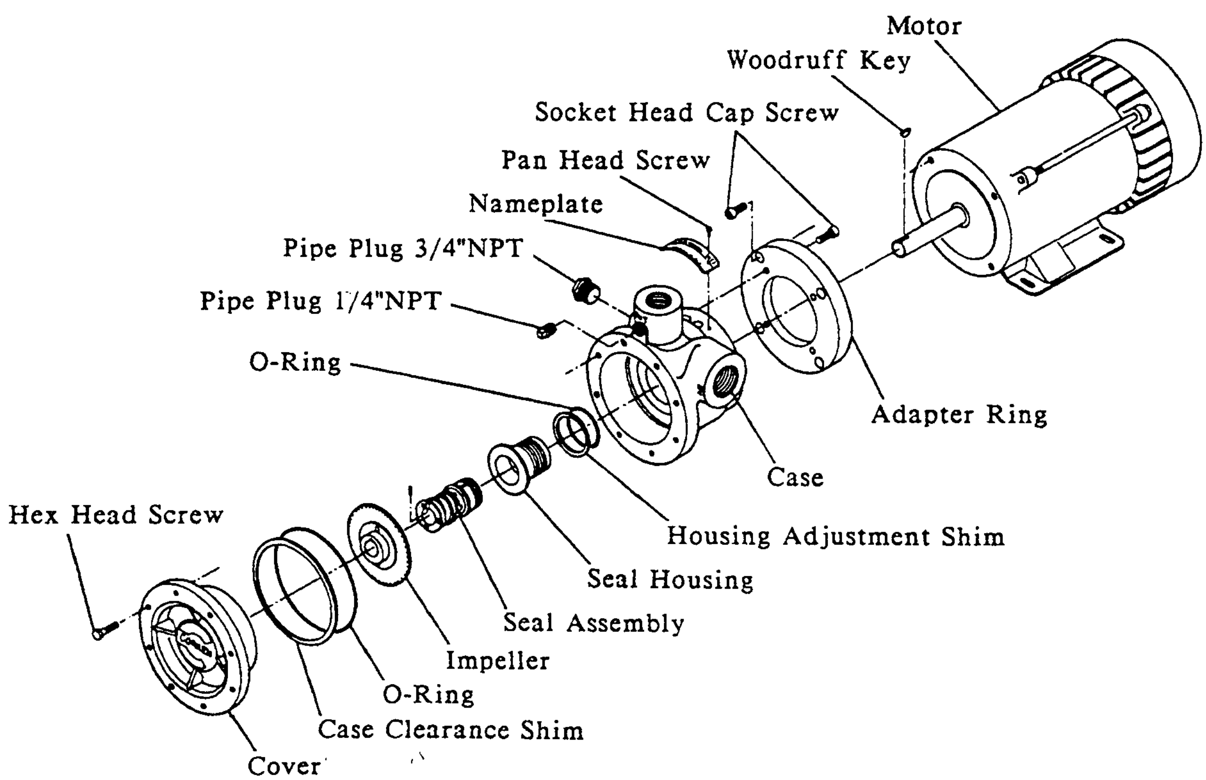


Figure 2.5C "C" Model Coro-Flo Pump Parts Explosion

Because the fluid is only accelerated to a speed slightly above the speed at the pump suction, the pressure drop and vapor formation in the pump suction is very low. The close tolerances between impeller and casing are so tight that very little slippage can take place past the teeth. The tight fit makes the pump perform much like a positive displacement pump which allows it to move some vapor.

The mechanical design of the RT pump closely resembles a typical centrifugal pump. The lightweight impeller allows an overhung impeller design to be used. This design requires only one mechanical seal to seal off the pumping chamber. The impeller is designed to float on the shaft so hydraulic forces in the pump may perfectly center the impeller to prevent metal-to-metal contact between the impeller and casing. The CORKEN Coro-Flo pump impeller is actually easier to install than a centrifugal pump impeller, in spite of the tight fit, because of the floating impeller design.

The CORKEN Coro-Flo Regenerative Turbine is available in six different sizes and is suitable for being direct driven by either a 3600 or 2880 RPM motor. If a slower speed motor must be used, a V-belt drive may be used to run the pump at 3600 RPM. The flow rates range from 1 to 35 GPM with differential pressures up to 150 PSI. Pumps may be selected using the curves in the Sales Manual.

The Coro-Flo pump casing is made of ductile iron. Propane pumps use a bronze impeller with steel shaft and aluminum seal sleeve. For NH3, the bronze impeller must be replaced with an iron impeller. The pump may be purchased with all the steel parts replaced with stainless steel for handling corrosive fluids.

Frame mounted or "F" type Coro-Flo pumps (Figure 2.5B) may be driven with a flexible coupling by motors as large as 10 HP. For propane bottle filling applications, CORKEN has developed the "C" model pump (Figure 2.5C). This compact design mounts the pump directly on the motor. A common shaft is shared by the motor and the pump. "C" model Coro-Flo pumps are equipped with 3/4 through 3 HP motors depending on the pump size.

The Coro-Flo pump has earned a reputation for extremely high reliability in bottle filling applications. When properly installed, a regenerative turbine pump will nearly always outlast a vane pump by eliminating the problem of vane wear. Regenerative turbines are usually the best choice for low horsepower (10 HP or less) applications where reliability is more important than energy efficiency. On high horsepower applications, the improved energy efficiency of vane pumps offsets their shorter service life.

2.6 Mechanical Seals for LP Gas Pumps

Of all the components of an LP gas pump, the mechanical seal is the most crucial. The mechanical seal must be properly designed, installed and maintained to control leakage to an absolute minimum.

Pump shaft seals are used to seal rotating components against stationary ones. To do this, a seal must be formed across a rotating surface contacted by a stationary surface. In a mechanical seal this is done by sealing a rotating seal face against the shaft and sealing a stationary face or "seal seat" against the pump casing. The seal faces are highly polished and almost perfectly flat so that when they contact each other only a minute amount of leakage can pass across the contacting surfaces (See Figure 2.6A). One of these surfaces is usually made of carbon while the other seal face is made of a metallic or ceramic material. This combination of materials results in very low friction at the rubbing surfaces of the seal face. CORKEN has found that a rotating carbon face against a stationary cast iron seat results in very economical and reliable service on LP gas and ammonia pumps. CORKEN provides several material options for the Coro-Flo pump seal (See Sales Manual for more information on material options.

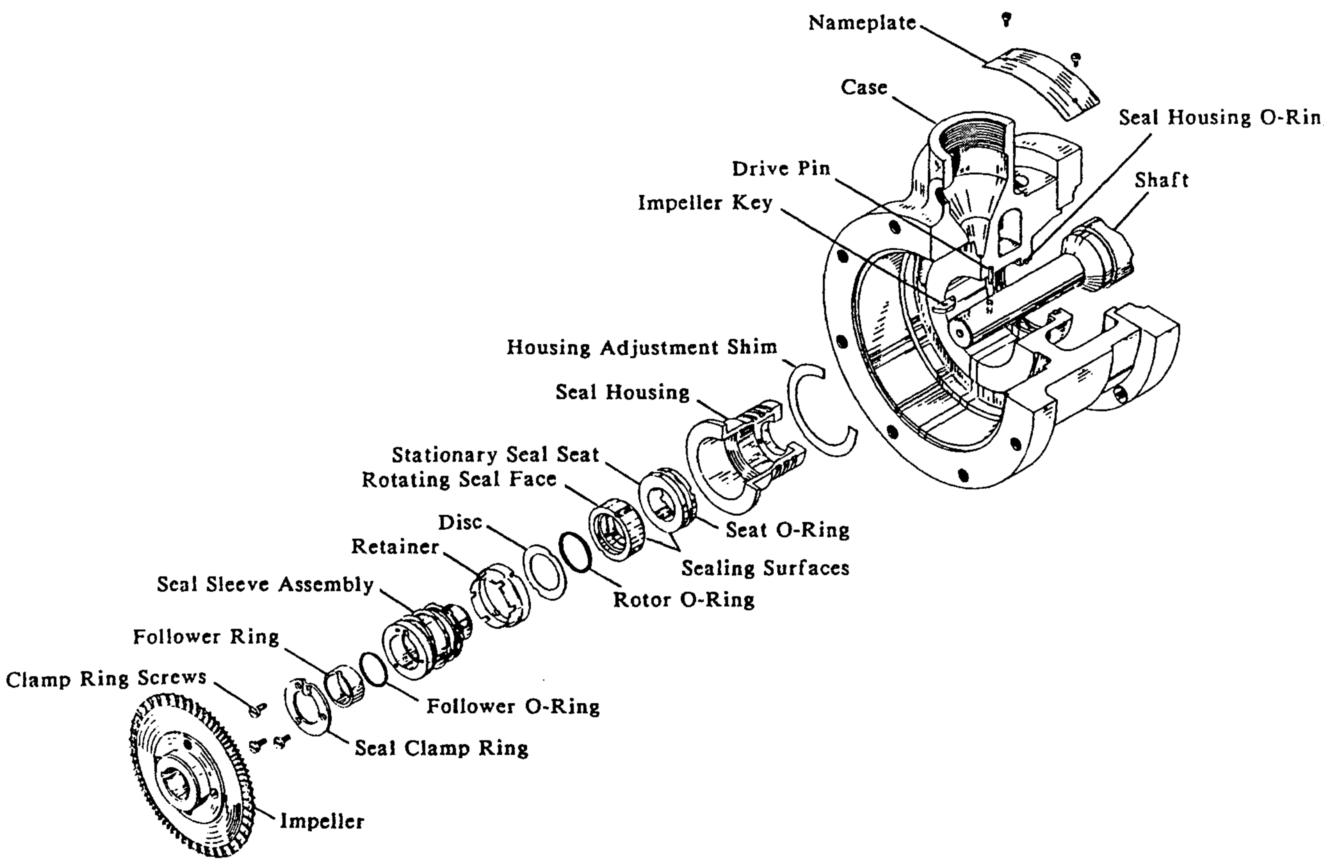


Figure 2.6A Coro-Flo Pump Mechanical Seal

Although the seal faces are extremely smooth, microscopic imperfections still exist. The seal between the two polished faces is completed by the fluid being pumped. The fluid fills in microscopic imperfections and forms a lubricating film between the two faces. This lubricant film reduces friction to a point where frictional heating of the seal becomes insignificant. While a small amount of fluid does leak across the seal faces, a good seal will limit leakage to such a minute amount that it is undetectable.

Serious seal leakage can usually be traced to two sources 1)Leakage through the contacting seal faces 2)Leakage past the O-rings sealing the faces to the pump shaft or casing.

Leakage at seal faces can result from:

1)Misalignment of the seal faces. The seal faces must be perfectly parallel to each other in order to seal. If one of the seal faces is slightly cocked out of parallel, a gap will result between the two faces. Seal face misalignment on CORKEN pumps may be easily avoided by making sure all the guide pins are aligned and the seal seats are completely pressed into the seal housing (Coro-Flo) or the seal seat retainer (Coro-Vane).

2)Damage to the seal faces. Any scratch or abrasion on the seal face will result in leakage. Scratches are usually caused by careless installation or pumping a liquid contaminated with abrasive particles. Seal faces may also be damaged by excessive frictional heat caused from running the pump dry. Dry running causes the liquid film between the seal faces to evaporate which results in greatly increased friction. Damage to the seal faces can usually be detected by visual inspection. Both seal faces should be replaced even if only one of them appears to be damaged.

Leakage past the O-rings can result from:

1)Damaged or worn O-rings. O-rings provide a low cost, reliable and easily installed sealing gasket. However, for an O-ring to seal, it must be in near-perfect condition. Any cut, pinch or abrasion on the O-ring will probably result in leakage. Because of their low cost, it is wise to completely replace the O-rings when opening a pump for seal repairs.

2)Degradation of the O-ring material. The elasticity and strength of an O-ring can be adversely affected by corrosive chemicals, excessive heat or excessive cold (as a result the O-ring can lose its sealing power because it is softened, hardened, swollen or shrunk by the heat or chemical action of the pumpage). Proper material selection is important to achieve maximum seal life. Buna N has been found to be the best material for commercial LP gas and ammonia applications. Teflon, Viton, Ethylene-Propylene and Neoprene O-rings are also available for more corrosive liquids. The most common cause of material degradation is excessive heating caused by running the pump dry.

3)Improperly seated O-rings. It is necessary to create a differential pressure across the O-ring to "seat" it in the groove and form a tight seal. The best way to seat the O-ring is to pressurize it with vapor before opening the liquid line. When a new pump seal is suddenly exposed to liquid before being pressurized with vapor, the following can happen: liquid leaks past the O-ring, flashes to vapor which refrigerates the O-ring and causes it to stiffen and fail to form a good seal.

The life of a seal is unpredictable. Most seals will last many years, but there are many ways an operator can shorten their life. Anything that causes the pump to run dry will damage the seal. This includes such things as forgetting to disengage the PTO on truck pumps and driving off with the pump turning. Special care should be taken not to continue pump operation after the supply tank is empty. This explains why transport trucks are notoriously rough on seals. Never operate the liquified gas pump with a closed inlet line because the liquid will flash immediately into a vapor and the pump will run dry.

Some preventative action can be taken to help seal life. When a pump must be removed from service, fill it with a light oil or kerosene while in storage. In a pump that has been in operation on a liquified gas, the solvent action of the fluid generally removes any protective oil film so pumps removed from service can rust up. Whenever it is possible and safe, the pump should be left pressurized during periods when the system is shut down. This can generally be done with a slightly "cracked" vapor valve.

No mechanical seal is inherently "bubble tight". The very nature of a mechanical seal, which requires a fluid film separating the two seal faces, assures that there will always be some product escaping at this point. This is generally extremely minor, but it would be foolish to leave a group of propane trucks in an enclosed building without making sure that all the tank valves are tightly closed. It should always be kept in mind that a mechanical seal does not eliminate leakage - it only controls leakage.

2.7 Bypass Valves and Bypass Piping

All LPG pumps require an external bypass valve for safe and efficient operation.* The function of the bypass is to internally relieve excessive differential pressures in the pumping system to protect the pump, piping and system components without opening any hydrostatic relief valves to atmosphere. The design of a bypass valve is similar to a relief valve except the discharge from the bypass valve is returned to the suction tank instead of to atmosphere. The inlet to the bypass valve is connected to the discharge piping as close to the pump as possible (see Figure 2.7A). The valve opens whenever the differential pressure across the pump exceeds the set pressure of the valve. LPG pumps require bypassed liquid to be returned to the suction tank in order to dissipate the frictional heat the liquid picks up in the pump. If LPG is internally bypassed in the pump, the same liquid is recirculated until the frictional heat causes it to boil. Some vane pumps are equipped with internal relief valves but these are only provided as a secondary device in case the external bypass line is accidentally blocked. An internal bypass valve will protect the system from over pressure, but when the bypassed liquid flashes to vapor, the pump will quickly experience extreme wear.

An external bypass can perform several essential protective functions in an LPG pumping system. These functions include:

1)Protecting the pump from excessive differential pressure. Excessive differential pressure results in undesirable stresses on the blades, vanes, shafts and bearings. The UL power pump code requires differential pressure be limited to 125 PSIG.

2)Protect the system from excessive pressure. If the pump overpressurizes the LPG in the discharge line, the relief valves could vent LPG to atmosphere.

3)Prevent motor overload and optimize energy efficiency. Differential pressure is roughly proportional to pump motor horsepower. The bypass valve can limit power required by the pump to prevent overloading the motor. The bypass valve can be adjusted to prevent the pump from generating more differential pressure than the application requires. This results in lower energy consumption when the system operates on full bypass.

4)(Regenerative Turbine Pumps Only) Prevent regenerative turbine pumps from operating at differential pressures that may result in flashing. The flow rate of RT pumps declines as differential pressure increases. At low flow rates, the liquid flow is not sufficient to dissipate the frictional heat generated by the pump. This causes the LPG in the pump to vaporize and vapor lock the system. Limiting differential pressure prevents vapor locking.

CORKEN manufactures three basic types of bypass valves to provide the ideal bypassing capabilities for each type of pump and application. These three types are the B166, T166 and B177 bypass valves.

*NFPA58 requires external by-pass for all LPG pumps.

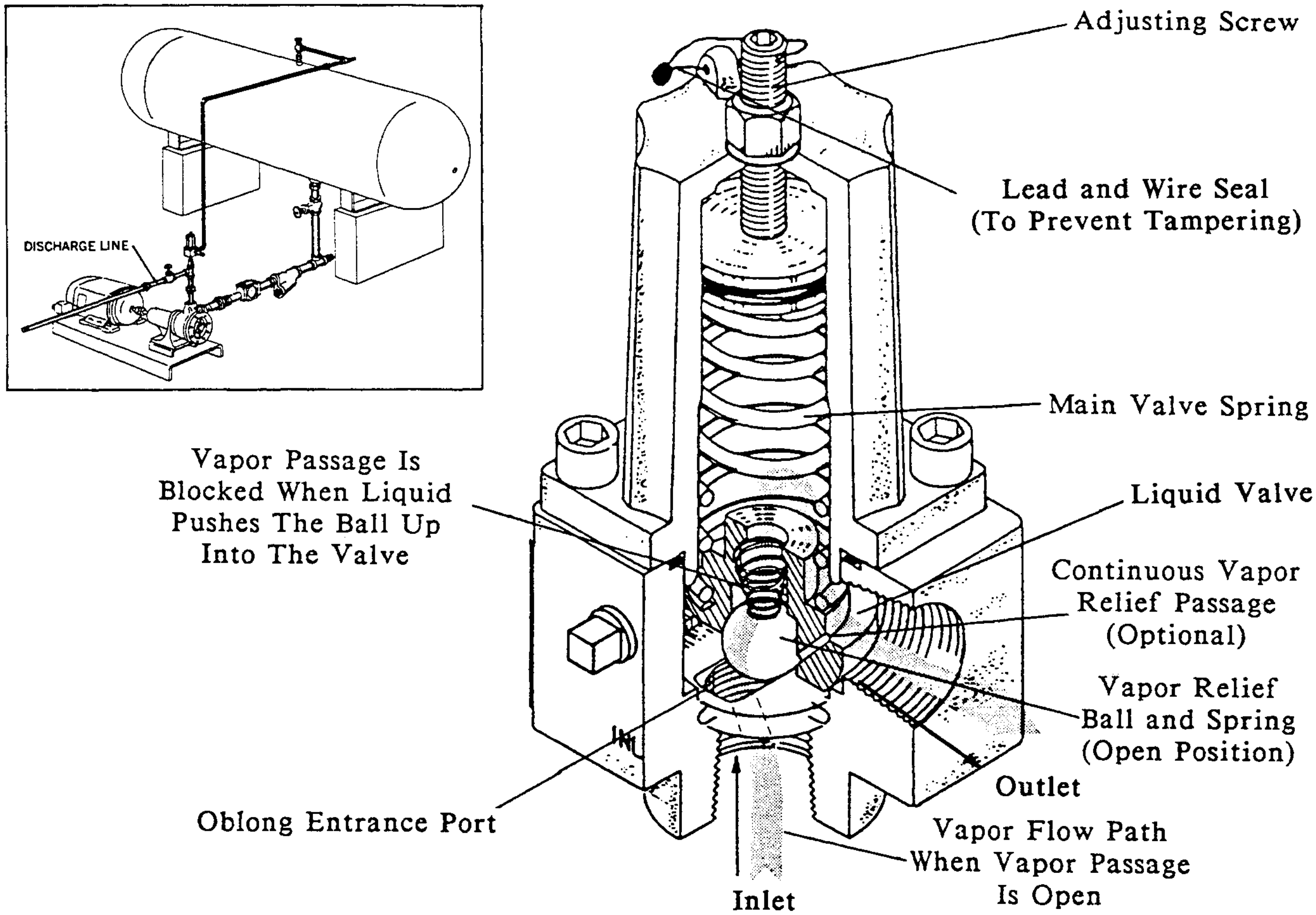


Figure 2.7A B166 By-Pass Valve Construction

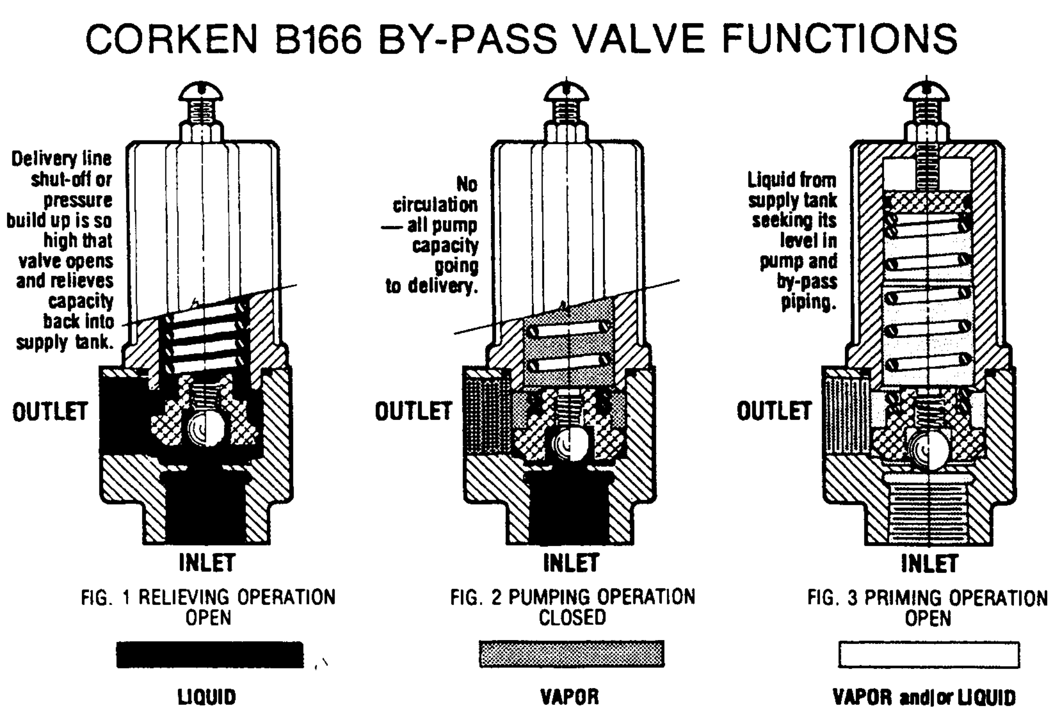


Figure 2.7B By-Pass Valve Operation

B166 Bypass Valve.

The B166 is designed specifically for use with the Coro-Flo regenerative turbine pump. Its primary function is to prevent vapor locking.

RT pumps can pressurize gas vapor but their vapor handling capabilities are considerably less than those of vane pumps. For this reason, it is important to provide RT pumps with a bypass system that allows vapor present in the pump suction during priming to be easily returned to the vapor section or suction tank. To provide the easiest possible route for vapor to be returned to the suction tank, the B166 is supplied with a vapor relief valve (See Figure 2.7A & B) The vapor relief valve is contained in the liquid valve but relieves in the opposite direction. The vapor relief valve remains open after start-up until the system is primed and there is enough liquid flow to cause the vapor relief valve to close (Figure 2.7B, Frame B). The liquid valve only opens when the differential pressure exceeds the set pressure.

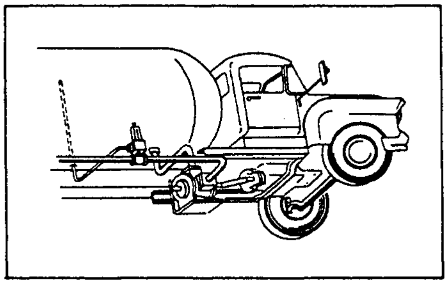
On installations with poor suction conditions, such as underground tanks, extra vapor elimination capabilities are highly desirable. For these applications, the continuous vapor relief passage option should be specified (See Figure 2.7A). This extra passage helps eliminate vapor build- up even if the vapor relief valve is closed. For additional information on underground tank installations see appendix D.

To adjust the B166, back the set screw out until there is no pressure on the spring. Next, increase the compression on the spring by turning in the set screw while operating the pump on full bypass (i.e. with discharge shut-off). Continue to increase the compression on the spring until one of the following three things occur 1)The differential pressure is sufficient for the application. 2)Differential pressure is at 125 PSIG. 3)Differential pressure does not increase when compression on the spring is increased. If number 3 occurs first, the liquid is flashing in the pump. In this case, back out the set screw until it is 5 to 15 PSIG below the flash pressure. When the proper setting is made, install the lead and wire seal to prevent tampering.

T166 Bypass Valves.

The T166 is a modified version of the B166. The T166 is specifically designed for use with 522 & 722 truck pumps. Truck pumps have extremely poor suction conditions so the pump is forced to handle large quantities of vapor. If this vapor is fed to the discharge tank, it must be compressed & recondensed as the tank fills which results on additional strain in the pump. The T166 is equipped with a large continuous vapor relief passage instead of the vapor relief valve found in the B166 (See Figure 2.7C). This passage vents a large part of the vapor present at the pump discharge back into the suction tank. It also bypasses some liquid back to the feed tank. Ideally, the T166 should be piped into the vapor section as shown in Figure 2.7C. This "spray" type connection results in some of the bypass liquid vaporizing which helps maintain the vapor pressure when the truck tank is being emptied without a vapor return line.

To adjust the T166, back out the set screw until there is no pressure on the spring. Next, turn in the screw while the pump is operating on full bypass (Discharge is closed). Increase the compression until the differential pressure is between 100 and 110 PSI. The internal relief valve on Coro-Vane pumps is set at 125 PSID. If the pressure setting of the internal relief valve has been changed, make sure the external bypass valve is set to relieve at a differential pressure 10 to 20 PSID less than the internal bypass valve.



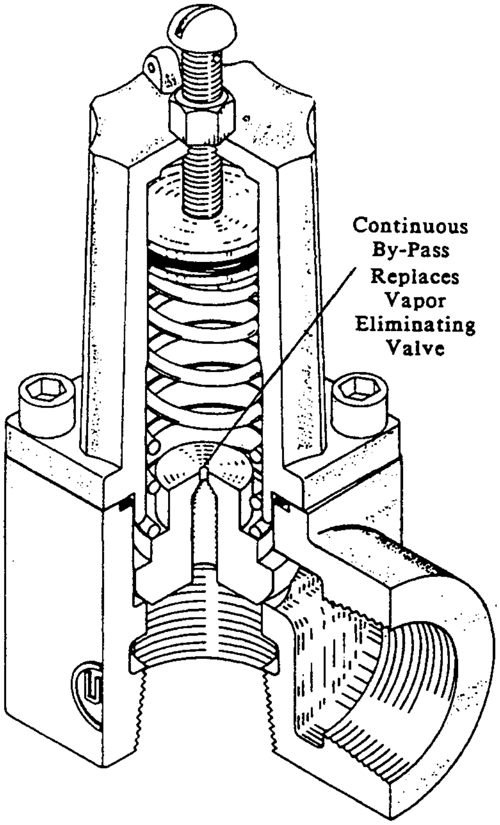
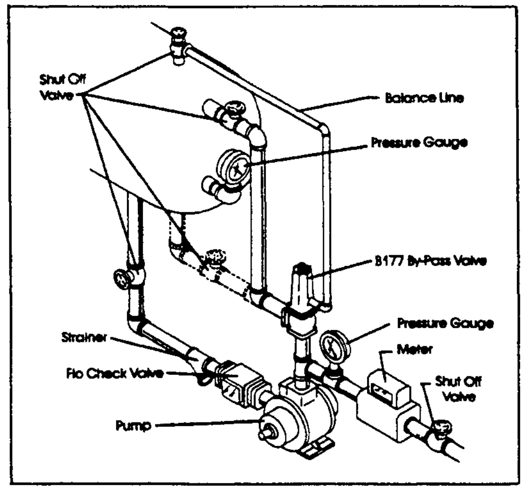


Figure 2.7C
The T166 By-Pass Valve



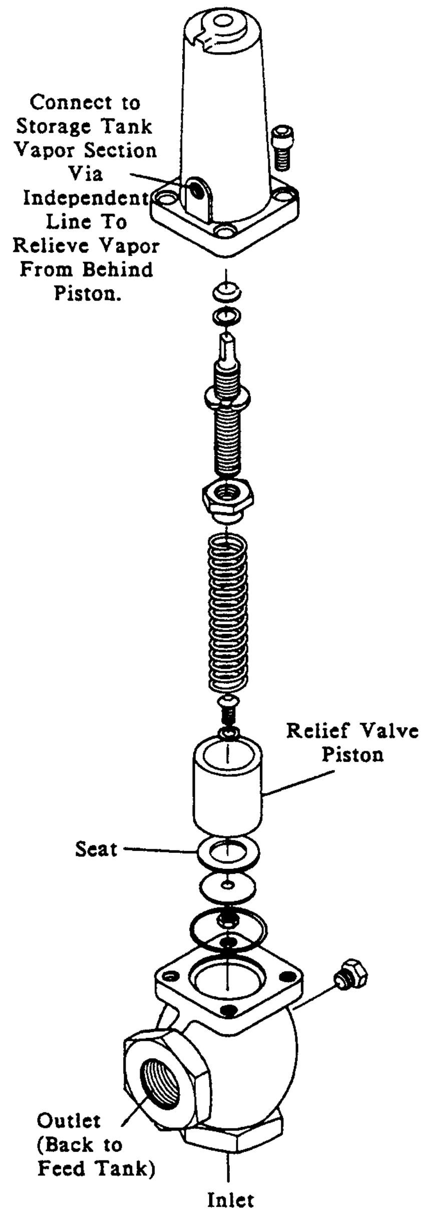


Figure 2.7D
CORKEN B177 By-Pass Valve

B177 Bypass Valve.

The B177 is designed for stationary Coro-Vane pump installations and the larger Coro-Vane truck pumps (1022 & 1522). The bonnet of the B177 is isolated from the bypass line, so a separate "vapor sensing line" must be connected from the bonnet of the B177 to the vapor section of the feed tank. This connection is essential to insure the bypass valve functions according to the real differential pressure across the pump. The discharge from the bypass valve may be run to the liquid space of the suction tank since the discharge line is not required to sense vapor pressure as it is on the B166 and T166. However, it is recommended to return the bypass line to the vapor section of the storage tank wherever possible. When the bypassed liquid is sprayed into the vapor section, part of the liquid will vaporize which helps to maintain the tank pressure as the tank is emptied.

The adjustment screw on the B177 decreases the set pressure when it is screwed in (this is the opposite of the B166 and T166). On trucks, the B177 may be adjusted the same as the T166 (just remember the set screw directions are opposite). On electric motor driven installations of Coro-Vane pumps, the bypass valve is usually adjusted according to motor amperage. This allows the pump to generate the maximum amount of pressure without overloading the motor. For this type of adjustment, attach an ammeter to one of the motor leads and relieve the force on the spring by turning in the set screw. Next, while operating the pump on full bypass, turn out the set screw until the motor is running slightly below full load amperage. Never adjust the bypass valve to a set pressure over 125 PSIG.

The B177 comes in two basic sizes. The small size can be purchased with 1 1/4" or 1 1/2" connections and the large size can be purchased with 2" or 2 1/2" connections. The performance characteristics for all Corken bypass valves are shown in Figure 2.7E.

Proper spring selection is important to achieve optimum performance. Springs may be selected from the chart shown in Figure 2.7F. Always select the strongest possible spring. Stronger springs open and close more slowly and reduce the possibility of "valve chatter" (rapid opening and closing of the bypass valve).

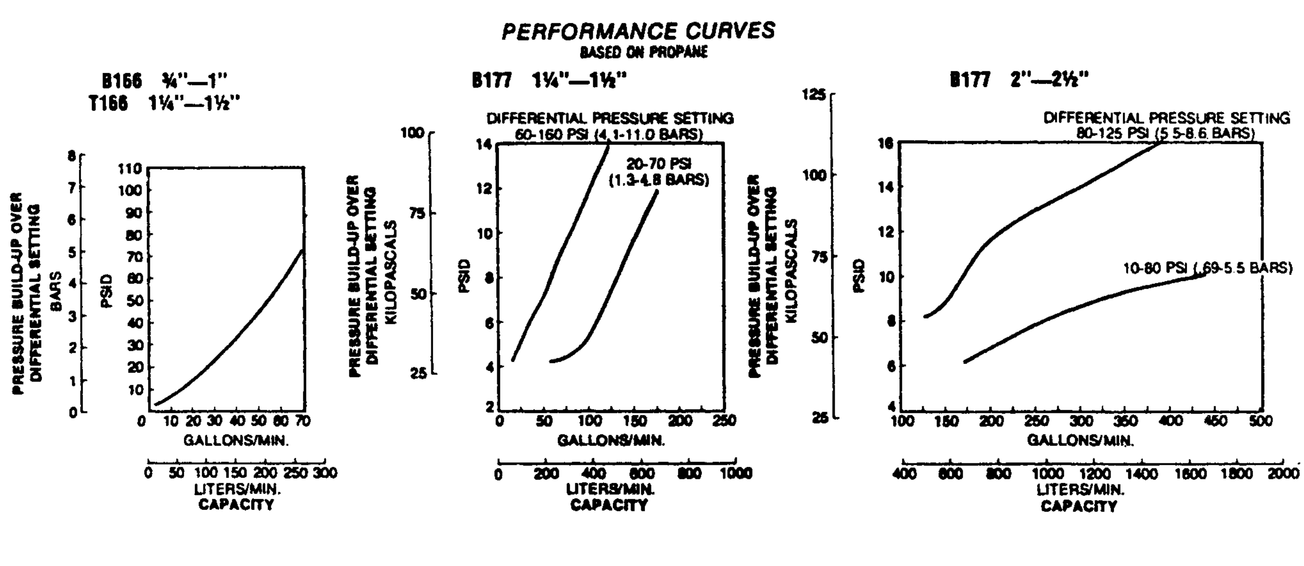


Figure 2.7E Capacity of CORKEN By-Pass Valves

SPRING SELECTION TABLE					
B166 & T166		B177 (1¼"-1½")		B177 (2"-2½")	
Spring No.	Differential Range PSID (Bars)	Spring No.	Differential Range, PSID (Bars)	Spring No.	Differential Range PSID (BARS)
1138	25-60 (1.7-4.1)	1817	20-70 (1.3-4.8)	1783	10-40 (.69-2.8)
1193	50-150 (3.4-10.3)	1818	60-100 (4.1-6.9)	1785	30-80 (2.1-5.5)
1193 & 1313	100-225 (6.9-15.5)	1819	80-160 (5.5-11.0)	1786	80-110 (5.5-7.6)
				1786-1	100-125 (6.9-8.6)

Figure 2.7F Spring Selection of CORKEN By-Pass Valves

2.8 LP Gas Pump Installation

CORKEN has published an easy-to-use handbook on LP gas pump installation (Pamphlet Z400). CORKEN strongly recommends that these procedures be used when installing any LP gas pump. The graphic illustrations in Z400 can be reduced to nine basic points:

1)Minimize the pressure drop in the suction piping. This results in the minimum amount of vapor formation up to the pump suction. To minimize the pressure drop, do the following: use the shortest length of pipe possible, use the minimum number of valves and fittings, use the minimum number of turns, use a suction pipe of larger diameter than the pump suction.

2)Provide up to four feet of positive suction head whenever possible. The static pressure of the liquid helps to counteract the pressure drop in the suction piping.

3) Minimize turbulence at the pump suction. Locate turbulence producing fittings such as strainers and elbows at least ten pipe diameters from the pump suction.

4) Install piping so buoyancy forces may help return vapors to the feed tank. Two types of forces act on vapor bubbles. Buoyancy forces tend to drive the bubbles upward while friction forces tend to drive the bubbles in the direction the liquid is flowing. A well designed piping system maximizes the effect of buoyancy forces and minimizes the effect of friction forces. This allows some of the vapor to escape back to the vapor space of the feed tank instead of being drawn into the pump suction. Install the pump directly beneath the tank, slope horizontal piping down towards the pump, use a large suction line and minimize restrictions.

5) Use an eccentric reducer with the flat end up to reduce the suction pipe down to the suction nozzle size. Vapor can collect in the upper section of a concentric reducer that can cause "slug flow". Slug flow is caused when liquid and vapor flow in alternating "slugs".

6) When two pumps are installed in parallel, make sure that one pump will not starve the other. The best way to do this is to feed each pump with a separate line from the feed tank.

7)Use special installation procedures when installing above ground pumps on underground tanks. Locate the pump as close to the tank as possible to minimize pressure drop and vapor formation. Use a smaller diameter pipe than the pump suction (opposite of recommended practice of above ground pumps). This helps the pump to maintain a stronger suction lift to prevent vapor locking. Use a foot valve to seal off the bottom of the dip tube when the pump is not operating. This holds liquid inside the tube and reduces the time required for the pump to prime. Eliminate all extraneous fittings in the pump suction and bury the tank as shallow as possible.

8)When pumping into a long discharge line, place a soft seat check valve immediately after the bypass valve. When the pump is not operating, vapor will form in the discharge line. The check valve isolates the pump from this vapor so that the pump will remain submerged in liquid. Starting the pump when it is filled with liquid allows the pump to quickly reprime the system. Starting the pump when it is filled with vapor results in substantial wear and tear on the pump since it must purge the vapor from the system in order to prime. The CORKEN Flo-Check valve is an excellent check valve for this application (see Section 4.2 for more details). Hard seat valves are not recommended because they allow substantial vapor leakage back into the pump.

9)Always connect the line off the vapor eliminator on the meter back to the vapor section of the feed tank. Connecting this line to the bypass line can result in liquid blocking the vapor eliminator.

2.9 Cavitation

The primary concern in the design of many pumping systems for low vapor pressure liquids such as water is the avoidance of Cavitation. Cavitation of low vapor pressure liquids can be avoided by following a relatively precise set of engineering procedures. (Since these procedures are not really relevant to LPG system design they will not be reviewed here. Interested readers can find a thorough review in any standard handbook on conventional pumps). These procedures determine how much pressure (net positive suction head required or NPSHR) is required at the pump suction to prevent liquid from boiling in the pump. Unfortunately, these methods become extremely imprecise for high vapor pressure liquids such as LPG. A good deal of time and effort is regularly wasted by engineers worrying about LPG pump cavitation that would be better spent examining the topics discussed earlier in this booklet, especially minimization of boiling in the suction piping.

The discussion of cavitation is complicated by lack of a widely accepted definition. For the purpose of this discussion, boiling and cavitation are going to be defined as opposites. Boiling is the formation of vapor from liquid. Cavitation will be defined as the violent collapse of vapor bubbles due to rapid pressurization. Cavitation requires boiling to occur first but the presence of boiling does not necessarily mean cavitation is inevitable. Liquid must be boiled under conditions where the vapor bubbles formed will collapse violently if the cavitation is to be noticed.

Any liquid, regardless of its vapor pressure or temperature, can be boiled by subjecting it to a low enough pressure. Cold water can be boiled without the addition of heat if it is subjected to a deep vacuum. This type of boiling allows very serious cavitation to occur when the liquid is repressurized. Figure 2.9A demonstrates the process. In position "A" the cylinder is filled with cold water and pressurized by a piston held in place by a crankshaft. If the crankshaft is rapidly rotated to position "B", a vacuum is created that will boil the cold water. The vapor bubbles formed are composed of very low density vapor. In fact, the bubbles are really closer to being vacuum pockets than vapor bubbles. These types of bubbles or "cavities" are what create serious cavitation. If the crankshaft in Figure 2.9A is rotated rapidly and continuously, bubbles will be formed and collapsed. The more rapid the rotation, the more violent the collapse. Violent cavitation results in high impact stresses as the bubbles collapse. These stresses can actually erode metal surfaces when sufficiently strong.

The cavitation process described above occurs in low vapor pressure liquid pumps when they are fed with liquid at or below the boiling pressure. The pressure drop created in the suction nozzle creates bubbles similar to position "B" in Figure 2.9A. When the bubbles recollapse in the pump discharge the results can cause noise, vibration and rapid wear and erosion of wetted surfaces.

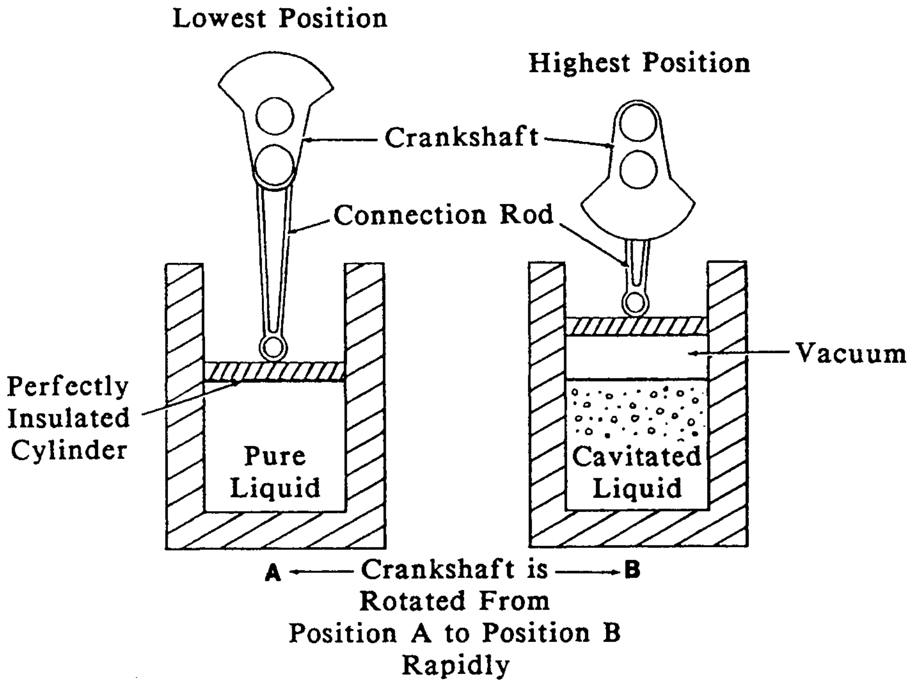


Figure 2.9A

From a purely theoretical point of view it can be said that rotary vane and regenerative turbine pumps may cavitate when fed LPG at or below its boiling pressure. However, the collapse of any vapor bubbles at the pump discharge lacks the destructive violence encountered with low vapor pressure liquids. The pressure drops within these pumps are very low, so very little additional vapor is formed. The pressure drop in the suction nozzle and the pressure increase in the pumping chamber are relatively gradual, so any collapse that does occur is less violent. Probably the most important factor is that LPG vapor bubbles are relatively dense so they collapse more slowly than the bubbles in low vapor pressure liquids if they collapse at all.

For practical purposes, it can be said rotary vane and regenerative turbine pumps do not cavitate because practical experience shows these pumps don't fail due to vapor bubble collapse. The failures of these pumps primarily result from excessive friction caused by feeding the pump an excessive amount of vapor. It is impossible for enough LPG boiling to occur in only the pump itself to cause any damage. When enough vapor formation occurs to cause damage, it takes place in the suction piping, not the pump.

The most important point of the discussion is that the design of LPG pumping systems should be done according to the methods discussed in this manual. Conventional techniques for analyzing pumping systems are designed for handling liquids that are above their boiling pressure. LPG pump and pump installation techniques are designed to handle high vapor pressure liquids at or below their boiling pressure.

2.10 Selecting LP Gas Pumps

Selecting CORKEN pumps for LP gas and NH3 applications is simple. The only information required to make the selection is the flow rate and differential pressure required. For most LP gas applications the required differential pressure is primarily determined by the frictional losses and elevation changes in the piping. For more information on calculating pressure drops in LP gas piping, see Appendix C.

Coro-Flo Pumps

Coro-Flo pumps are suitable for flows as high as 35 GPM for some pressure conditions. The Coro-Flo pump is usually direct driven at 3600 RPM in countries with 60 cycle electric power or at 2880 RPM in countries with 50 cycle power. Although the Coro-Flo regenerative turbine pump has performance characteristics of a positive displacement pump, the pump does obey the "affinity laws" of centrifugal pumps as well. These laws are: 1)The flow is proportional to RPM, 2)The pressure that can be generated is proportional to the square of the RPM. In many cases it is desirable to V-belt drive the Coro-Flo in 50 cycle countries so the pump can be operated at 3600 RPM to produce more pressure.

Coro-Flo pumps may be selected from either Figure 2.10A or 2.10B, depending on speed. To determine the performance of a specific pump, locate the maximum desired differential pressure (Outlet pressure minus inlet pressure) on the y-axis (vertical axis) on the left side of the chart. The example for the F9 in Figure 2.10A shows how to determine the flow (GPM) and power requirement (HP) from the differential pressure. At a differential pressure of 50 PSI, the pump will product a flow of 4.5 GPM (x-axis) and it will require .75HP (y-axis on the right). The horsepower is determined by the intersection of the flow (vertical line) and the HP line (slanted line sloping down to the right).

Pumps can seldom be selected that will product precisely the flow and pressure desired. For this reason, the exact differential pressure desired should be used to read the chart. A pump should then be selected that produces a larger than desired flow. The best way to do this is start with the F9 and check the flow for each size until a large enough pump is found. In order to achieve the desired flow, the bypass valve can be adjusted to return any excess capacity back to the feed tank.

If a large enough Coro-Flo pump is not available, use a Coro-Vane pump instead.

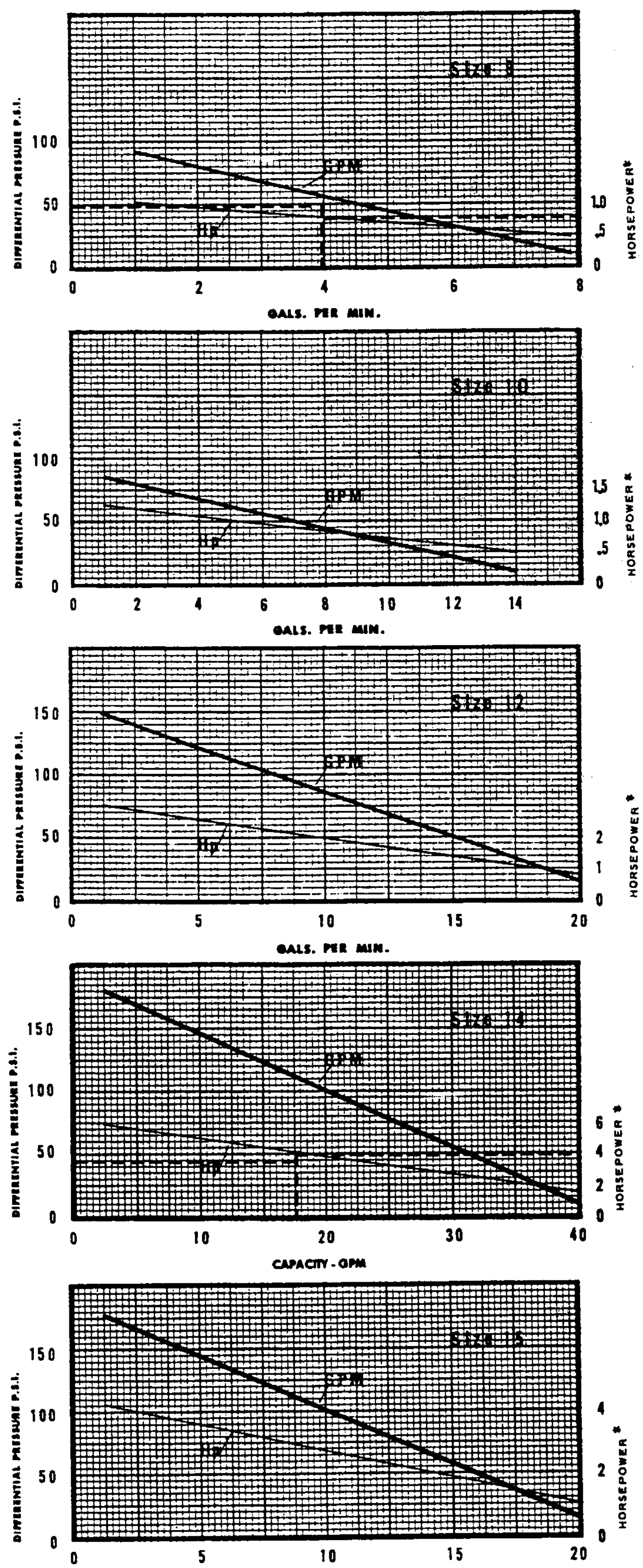
Coro-Vane Pumps

Coro-Vane pumps can generate flow rates of up to 350 GPM. Vane pumps are true positive displacement pumps so the pump may produce up to the maximum differential pressure of 125 PSIG at any speed, i.e. the pressure producing capabilities of the pump are completely independent of operating speed.

Coro-Vane pumps may be operated at speeds between 400 and 1000 RPM. The most practical V-belt and sheave combinations for this speed range fall at 420, 520, 640, 780 & 950 RPM. Figures 2.10C, D and E show the performance of the 521, 1021 & 1521 pumps for each of the standard speeds. To choose the desired speed for a particular pump, start with the lowest speed and determine the flow and power requirement at the desired differential pressure. For example, for a differential pressure of 60 PSI on the 521 operating at 420 RPM, the flow rate will be 30 GPM and the pump will require 2.5 BHP. If the flow is not high enough, proceed to the next higher speed. Continue to proceed to higher speeds until a speed is selected that results in a flow higher than is required. The excess flow is returned to the feed tank by the bypass valve.

Curves Based Upon LPG, Ammonia and Similar Products

3450 RPM

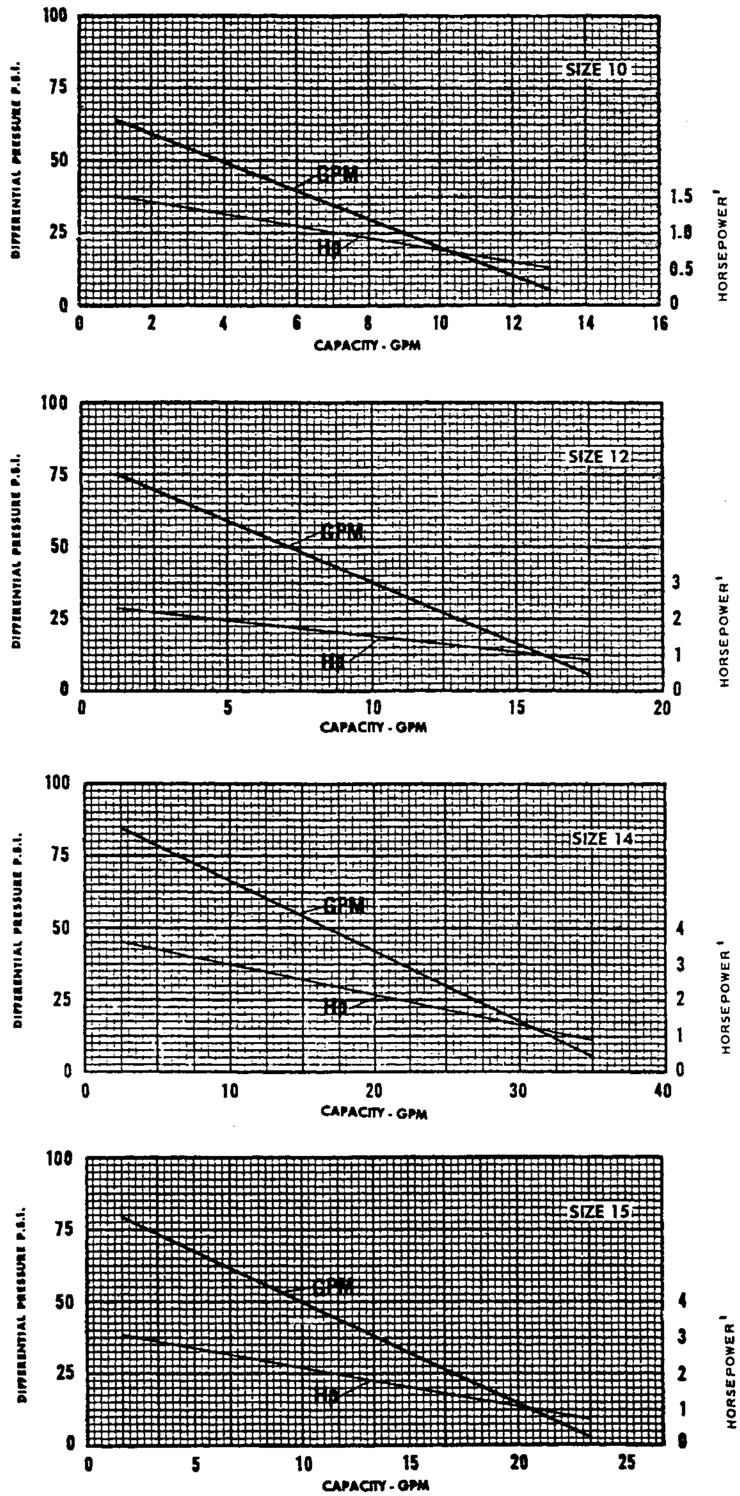


CAPACITY - GPM

*TO DETERMINE HORSEPOWER WHEN PUMPING AMMONIA, MULTIPLY CURVE HORSEPOWER READING BY 1.2.

Figure 2.10A Characteristic Curves Coro-Flo Pumps

Curves Based Upon LPG, Ammonia and Similar Products



[1] TO DETERMINE HORSEPOWER WHEN PUMPING AMMONIA, MULTIPLY CURVE HORSEPOWER READING BY 1.2.

Figure 2.10B Characteristic Curves Coro-Flo Pumps 2880 RPM

Curves Based Upon LPG, Ammonia and Similar Products

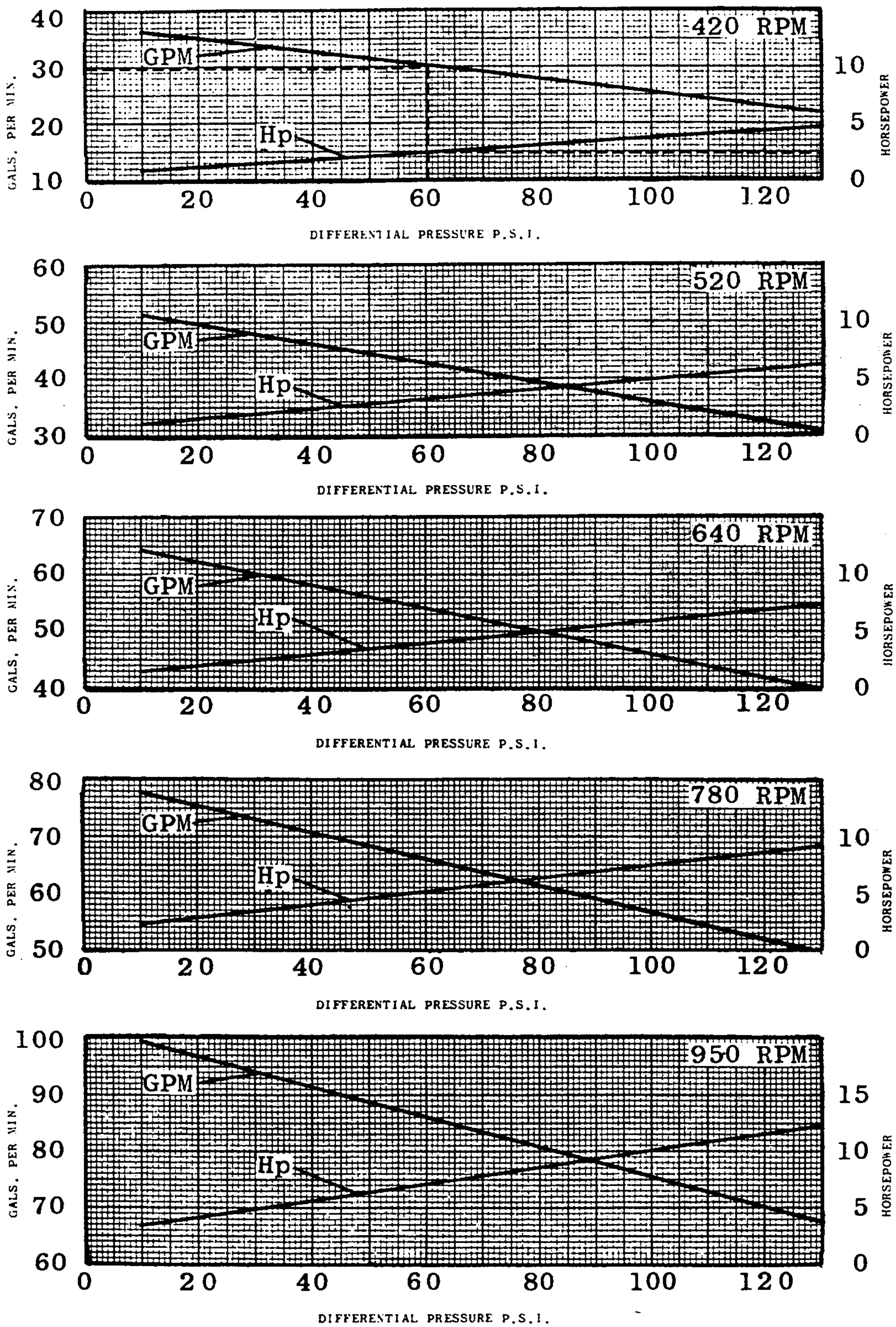


Figure 2.10C Characteristic Curves Coro-Vane Stationary Pumps Model 521

Curves Based Upon LPG, Ammonia and Similar Products

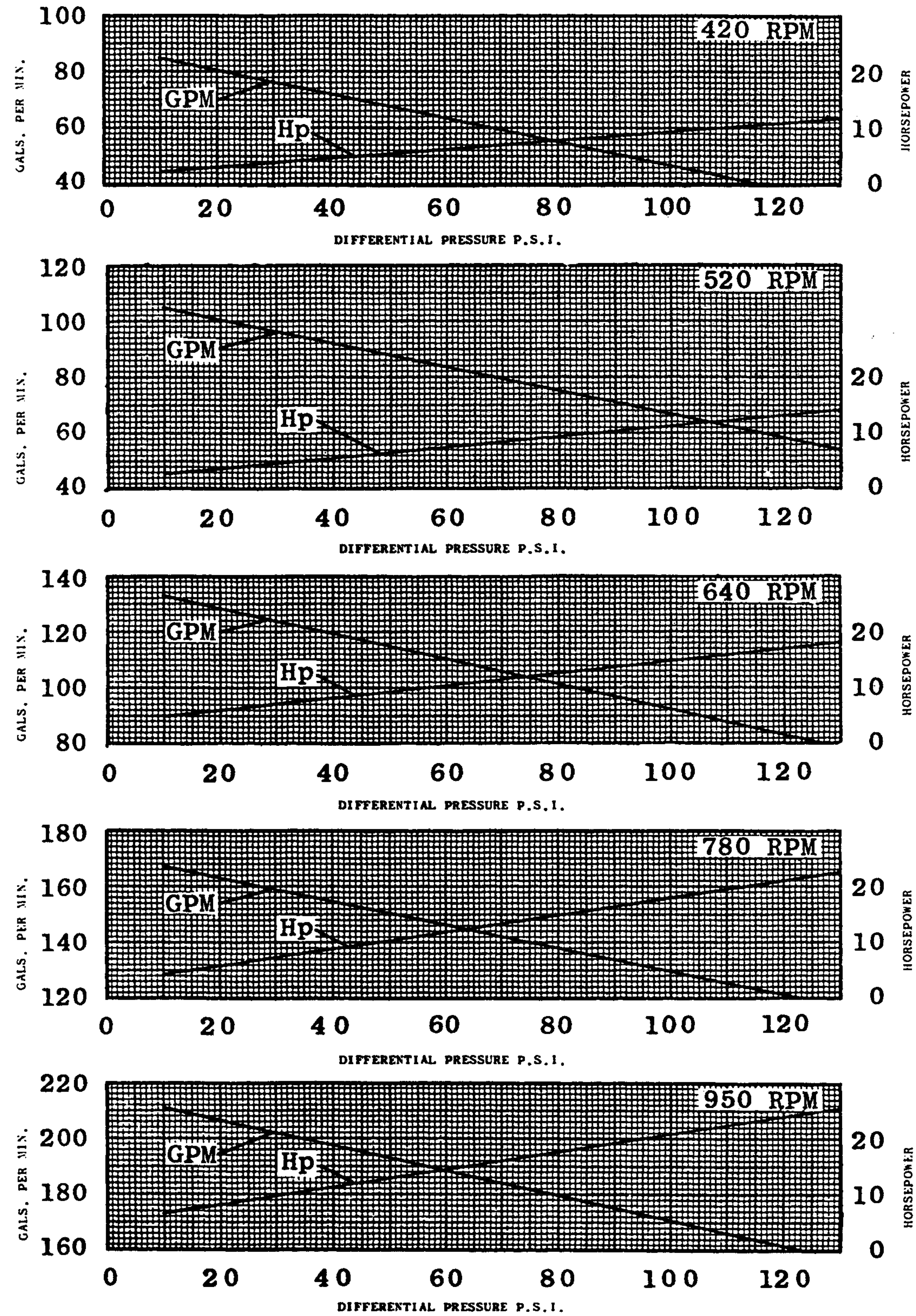


Figure 2.10D Characteristic Curves Coro-Vane Stationary Pumps Model 1021

Curves Based Upon LPG, Ammonia and Similar Products

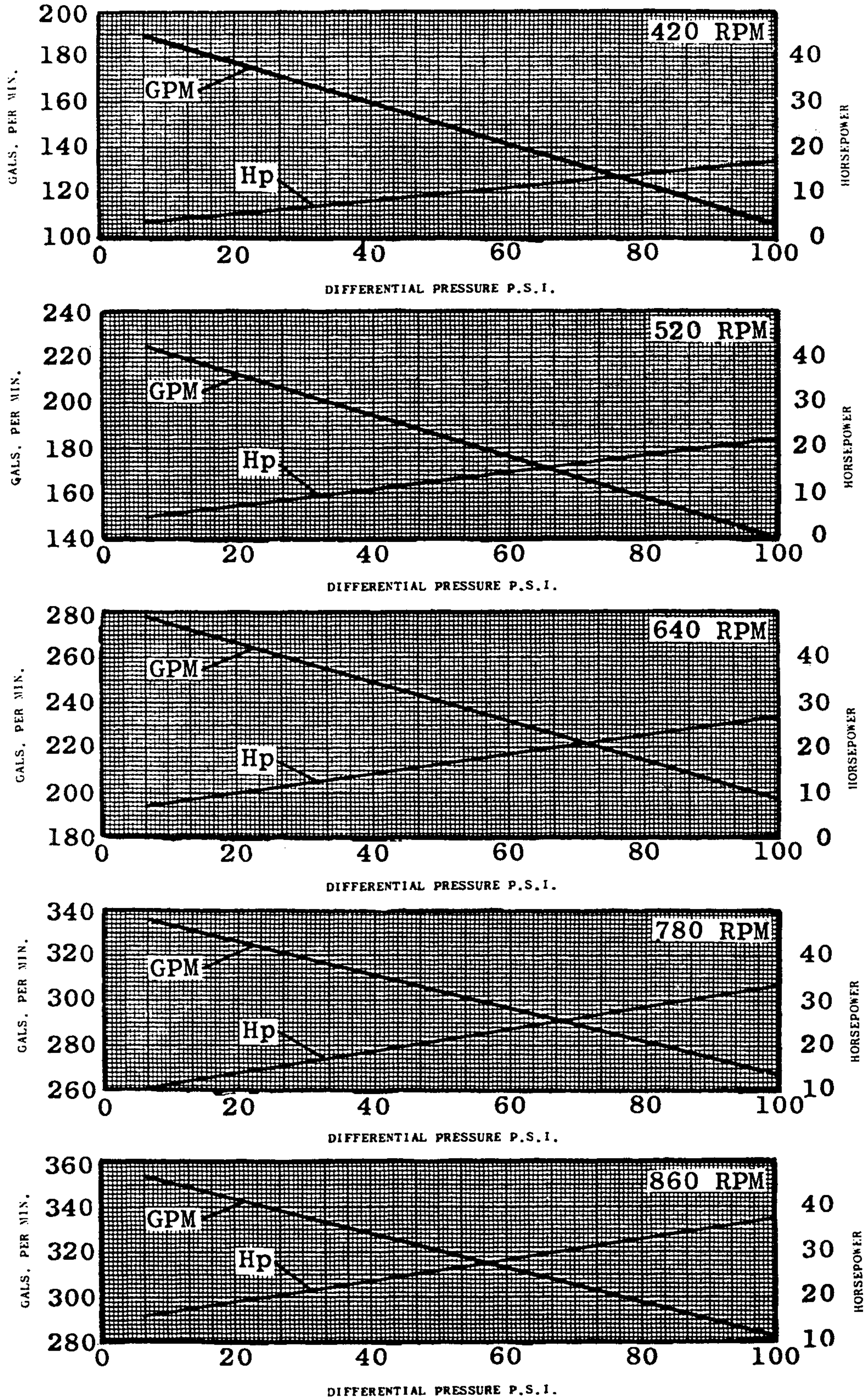


Figure 2.10E Characteristic Curves Coro-Vane Stationary Pumps Model 1521

CHAPTER 3

LP Gas Compressors

3.1 Moving Liquid With Vapor

The most flexible method for moving liquid propane is with a compressor, a device designed to handle vapor and only vapor. How is this done? You will remember from the first chapter that any fluid, vapor or gas, may be moved by creating a different pressure between two points. A compressor may be used to create a pressure difference between the vapor spaces of two tanks. If the liquid spaces of the two tanks are connected, the pressure difference exerted by vapor will cause the liquid to begin flowing from the higher pressure tank to the lower pressure tank (See Figure 3.1A).

You will also remember that changes in internal pressure of a propane tank will result in condensation and boiling. Condensation and boiling will tend to negate the pressure difference created by the compressor. Liquid transfer using a compressor works because vapor may be moved more quickly than it boils off and condenses. The flow rate induced will equal the volume of gas discharged from the compressor if a large enough compressor is chosen to make the effect of boiling and condensation negligible. The pressure increase through the compressor will equal the pressure decrease due to friction in the liquid piping. Years of experience have shown that piping designed to create a pressure drop of 30 PSI or less works best. Higher pressure drops result in more condensation and boiling and reduced flow rates due to reduced discharge volume.

Compressors may also be used to evacuate tanks. High pressure propane vapor in a large tank has substantial economic value that makes it worth recovering. Tanks that must be unloaded through a dip tube (such as most railroad tank cars) leave a small liquid puddle in the tank when liquid transfer is complete. A compressor can be used to reduce the pressure in the tank to boil the puddle into recoverable vapor. The vapor recondenses when it is fed into the liquid section of another propane tank (See Figure 3.1B).

CORKEN LP gas transfer compressors are the standard of the industry. Models 91, 290, and 490 are popular for truck unloading and unloading small railroad cars. The model 690 is suitable for unloading large railroad tank cars. CORKEN horizontal compressors and 891 vertical compressors are used for unloading barges or several railroad tank cars at a time.

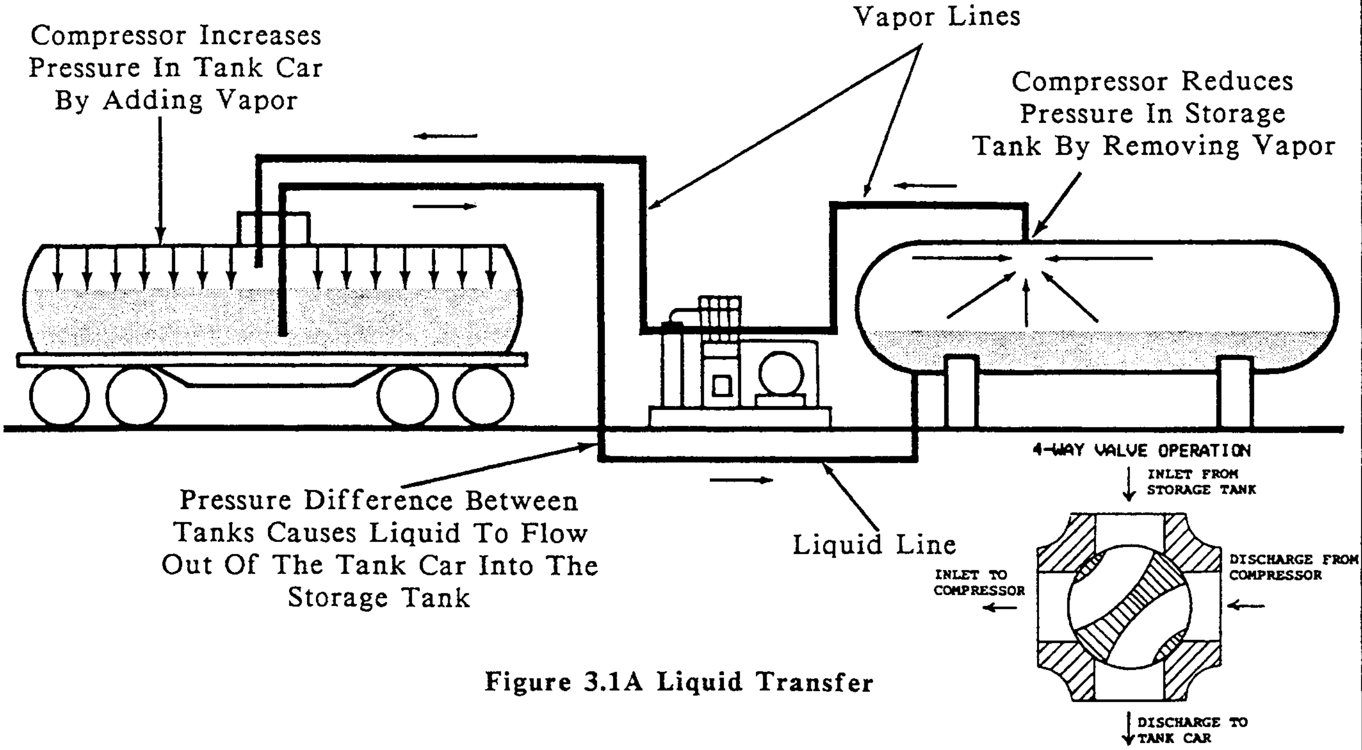


Figure 3.1A Liquid Transfer

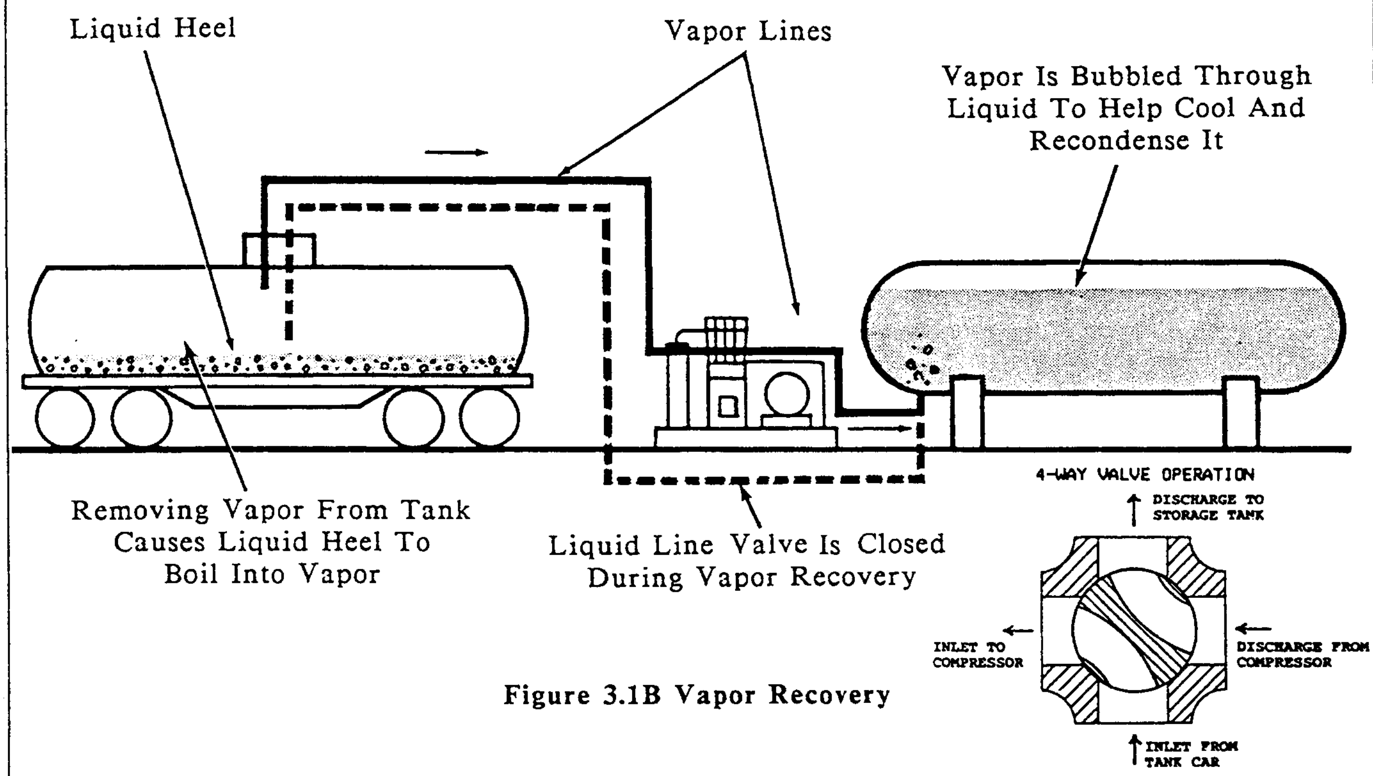


Figure 3.1B Vapor Recovery

Compressor size and speed selection is a highly inexact process with complex interactions of a number of different variables such as ambient temperature, pressure drops in liquid line and vapor suction line, solar radiation, precipitation, size of the tanks and the surface area of the tank and piping. With this many variables, the exact performance of the compressor cannot be precisely calculated. CORKEN's Compressor Selection Tables (VE200, VE201, and VE202) are a fast and easy method to make an approximate selection for butane, propane and ammonia compressors. These charts show flows for different CORKEN compressors run at different speeds with a maximum tank temperature of 100°F and 80°F with a 30 PSI pressure drop in the piping. In only the most extreme temperature conditions will tank temperatures exceed 100°F. A large tank heats up and cools down much more slowly than the surrounding atmosphere. Although temperatures may frequently exceed 100°F on hot summer afternoons, tank temperatures will seldom rise this high. Therefore, the horsepower values shown in the charts are very conservative and may be lowered for milder climates. Your local CORKEN distributor is usually the best source of information for ideal motor sizes for the climate in your region. CORKEN can also supply a computer analysis showing the horsepower required for different tank temperatures.

If it is important that unloading operations must be completed in a certain amount of time, a more complex analysis is required. When such an analysis is required, contact CORKEN so a factory application engineer may thoroughly review the problem. By inputting the tank size, pressure drops, model number, speed and gas into a special computer program, CORKEN's application engineers can determine how the machine will perform over a wide temperature range with reasonable accuracy. Such an analysis is shown in Figure 3.1C. This analysis is divided into three parts that clearly demonstrate how temperature affects flow rates and vapor recovery time.

The highest liquid flow rates are achieved on hot days (Figure 3.1D). This is because the pressure drop in the piping remains relatively constant as the temperature changes while the vapor pressure swings over a wide pressure range. The vapor pressure of propane is 38 PSIA at 0°F and 215 PSIA at 110°F. The discharge pressure, P2, is the product vapor pressure plus the system differential pressure. In Figure 3.1C the 25 PSI pressure drop is added to the vapor pressure (V.P.) to yield the discharge pressure shown in column P2. You will notice that the compression ratio (the absolute inlet vapor pressure divided by the absolute discharge pressure) rises as the temperature falls. As the compression ratio rises with falling temperature,the gas passing through the compressor is squeezed into a smaller and smaller discharge volume. As the volume at the discharge of the compressor is reduced, the amount of liquid displaced by the vapor is also reduced.

When the liquid in a tank is unloaded through a dip tube, liquid transfer will cease when the liquid level falls beneath the bottom of this tube. The residual puddle is called a "liquid heel". By reversing the direction of vapor flow and blocking the liquid line as shown in Figure 3.1B, this liquid may be recovered. By withdrawing vapor out of the tank, the liquid will begin to boil into vapor to replace the vapor being removed. This process is called "boil-out". Boil-out is completed most rapidly on hot days (See Figure 3.1E). The high vapor pressure on hot days gives the gas a higher density than on cold days. It takes a larger quantity of liquid to replace a cubic foot of high density vapor than low density vapor.

When boil-out is completed a substantial amount of propane is left in the tank in a vapor state. This vapor is equivalent to a substantial amount of liquid propane of significant economic value. As a rule of thumb in the LP gas industry, propane tank cars should be evacuated to 40 PSIA. Alternately, a final evacuation pressure of 25 to 30% of original tank car pressure is a good value for most any liquid gas. Evacuation pressures lower than this will not pay for the energy required to run the compressor and generally should not be considered unless factors other than economics are being considered. The vapor recovery procedure requires the most time on hot days because the high initial vapor pressure requires more time to reduce (See Figure 3.1F). The recovered vapor should be bubbled up through the liquid section of the receiver tank to recondense the vapor to liquid. The maximum horsepower requirement for the compressor occurs when the tank has been evacuated to approximately 50% of full vapor pressure (See Figure 3.1G). Larger motors are required to do vapor recover in hot climates.

᾿ROPANE COMPRESSOR SELECTION TABLE

MARCH 1988
SUPERSEDES VE200G

SERVICE	CAPACITY GPM(1)	DISPLACEMENT CFM	COMPRESSOR MODEL	COMPRESSOR RPM	DRIVER SHEAVE SIZE P.D."(2) 1750RPM	DRIVER SHEAVE SIZE P.D."(2) 1460RPM	DRIVER HORSEPOWER: LIQUID TRANSFER AND RESIDUAL VAPOR RECOVERY 100°F	DRIVER HORSEPOWER: LIQUID TRANSFER AND RESIDUAL VAPOR RECOVERY 80°F	DRIVER HORSEPOWER: LIQUID TRANSFER WITHOUT RESIDUAL VAPOR RECOVERY 100°F	DRIVER HORSEPOWER: LIQUID TRANSFER WITHOUT RESIDUAL VAPOR RECOVERY 80°F	PIPING SIZE (3) VAPOR	PIPING SIZE (3) LIQUID
SMALL BULK PLANTS	23	4	91	400	A 3.0	A 3.6	5	3	3	3	3/4	1-1/4
	29	5	91	505	A 3.8	B 4.6	5	5	5	5	3/4	1-1/4
	34	6	91	590	B 4.6	B 5.6	5	5	5	5	1	1-1/4
	40	7	91	695	B 5.4	B 6.6	5	5	5	5	1	1-1/2
	39	7	290,291	345	A 3.0	A 3.6	3	3	3	3	1	1-1/2
UNLOADING SINGLE TANK CAR OR TRANSPORT	45	8	91	795	B 6.2	B 7.4	7-1/2	7-1/2	7-1/2	7-1/2	1	1-1/2
	44	8	290,291	390	A 3.4	B 4.0	5	3	3	3	1	1-1/2
	50	9	290,291	435	A 3.8	B 4.6	5	5	3	3	1	1-1/2
	56	10	290,291	490	B 4.4	B 5.2	5	5	5	5	1	2
	61	11	290,291	535	B 4.8	B 5.8	5	5	5	5	1	2
	66	12	290,291	580	B 5.2	B 6.2	7-1/2	5	5	5	1	2
	71	13	290,291	625	B 5.6	B 6.6	7-1/2	5	7-1/2	5	1-1/4	2
	79	14	290,291	695	B 6.2	B 7.4	7-1/2	7-1/2	7-1/2	7-1/2	1-1/4	2
	84	15	290,291	735	B 6.6	B 8.0	10	7-1/2	10	7-1/2	1-1/4	2-1/2
	84	15	490,491	345	A 3.0	A 3.6	7-1/2	7-1/2	5	5	1-1/4	2-1/2
	89	16	290,291	780	B 7.0	B 8.6	10	10	10	10	1-1/4	2-1/2
	89	16	490,491	370	A 3.2	A 3.8	7-1/2	7-1/2	7-1/2	5	1-1/4	2-1/2
UNLOADING TWO OR MORE TANK CARS AT ONE TIME, OR LARGE TRANSPORT WITH EXCESS FLOW VALVES OF ADEQUATE CAPACITY	95	17	490,491	390	A 3.4	B 4.0	7-1/2	7-1/2	7-1/2	7-1/2	1-1/4	3
	101	18	490,491	415	A 3.6	B 4.4	10	7-1/2	7-1/2	7-1/2	1-1/4	3
	106	19	490,491	435	A 3.8	B 4.6	10	7-1/2	7-1/2	7-1/2	1-1/4	3
	108	20	490,491	445	B 4.0	B 4.8	10	7-1/2	7-1/2	7-1/2	1-1/4	3
	114	21	490,491	470	B 4.2	B 5.0	10	7-1/2	7-1/2	7-1/2	1-1/4	3
	119	22	490,491	490	B 4.4	B 5.2	10	10	7-1/2	7-1/2	1-1/4	3
	125	23	490,491	515	B 4.6	B 5.6	10	10	10	7-1/2	1-1/4	3
	130	24	490,491	535	B 4.8	B 5.8	15	10	10	10	1-1/4	3
	136	25	490,491	560	B 5.0	B 6.0	15	10	10	10	1-1/4	3
	141	26	490,491	580	B 5.2	B 6.2	15	10	10	10	1-1/4	3
	147	27	490,491	605	B 5.4	B 6.4	15	10	15	10	1-1/4	3
	152	28	490,491	625	B 5.6	B 6.6	15	15	15	15	1-1/2	3
	158	29	490,491	650	B 5.8	B 7.0	15	15	15	15	1-1/2	3
	163	30	490,491	670	B 6.0		15	15	15	15	1-1/2	3
	163	30	690,691	400	B 4.4	B 5.2	15	15	10	10	1-1/2	3
	168	31	490,491	695	B 6.2	B 7.4	15	15	15	15	1-1/2	3
	171	31	690,691	420	B 4.6	B 5.6	15	15	10	10	1-1/2	3
	179	32	490,491	740	B 6.6	B 8.0	15	15	15	15	1-1/2	3
	178	32	690,691	440	B 4.8	B 5.8	15	15	10	10	1-1/2	3
	186	34	690,691	455	B 5.0	B 6.0	15	15	15	10	1-1/2	3
	193	35	690,691	475	B 5.2	B 6.2	15	15	15	10	1-1/2	3
	200	36	690,691	495	B 5.4	B 6.4	15	15	15	15	1-1/2	3
UNLOADING LARGE TANK CARS, MULITPLE VESSELS, BARGES OR TERMINALS	208	38	690,691	510	B 5.6	B 6.8	20	15	15	15	1-1/2	4
	215	39	690,691	530	B 5.8	B 7.0	20	15	15	15	1-1/2	4
	223	41	690,691	550	B 6.0	A 7.0	20	15	15	15	1-1/2	4
	230	42	690,691	565	B 6.2	B 7.4	20	15	15	15	2	4
	237	43	690,691	585	B 6.4	A 7.4	20	15	15	15	2	4
	245	45	690,691	605	B 6.6	B 8.0	20	15	15	15	2	4
	252	46	690,691	620	B 6.8		20	20	15	15	2	4
	260	47	690,691	640	B 7.0	A 8.2	20	20	20	15	2	4
	275	48	690,691	675	B 7.4	B 8.6	25	20	20	20	2	4
	297	54	690,691	730	B 8.0	B 9.4	25	20	20	20	2	4
	319	58	690,691	785	B 8.6		25	20	25	20	2	4
	334	60	690,691	820	TB9.0	A 10.6	30	25	25	20	2	4

Consult factory for compressors for higher flows.

᾿OTES:
(1) The capacities shown are based on 70°F, but will vary depending upon piping, fittings used, product being transferred and temperature. The factory can supply a detailed computer analysis if required.
(2) Driver sheaves: 91 - 2 belts; 290,291,490,491 - 3 belts; 690,691 - 4 belts.
(3) The piping sizes shown are considered minimum. If the length exceeds 100 ft., use the next larger size.

N-BUTANE COMPRESSOR SELECTION TABLE

MARCH 1988
SUPERSEDES VE201G

SERVICE	CAPACITY GPM(1)	DISPLACEMENT CFM	COMPRESSOR MODEL	COMPRESSOR RPM	DRIVER SHEAVE SIZE P.D."(2) 1750RPM	DRIVER SHEAVE SIZE P.D."(2) 1460RPM	DRIVER HORSEPOWER: LIQUID TRANSFER AND RESIDUAL VAPOR RECOVERY 100°F	DRIVER HORSEPOWER: LIQUID TRANSFER AND RESIDUAL VAPOR RECOVERY 80°F	DRIVER HORSEPOWER: LIQUID TRANSFER WITHOUT RESIDUAL VAPOR RECOVERY 100°F	DRIVER HORSEPOWER: LIQUID TRANSFER WITHOUT RESIDUAL VAPOR RECOVERY 80°F	PIPING SIZE (3) VAPOR	PIPING SIZE (3) LIQUID
SMALL BULK PLANTS	13	4	91	400	A 3.0	A 3.6	3	3	3	3	3/4	1-1/4
	17	5	91	505	A 3.8	B 4.6	3	3	3	3	3/4	1-1/4
	20	6	91	590	B 4.6	B 5.6	3	3	3	3	1	1-1/4
	24	7	91	695	B 5.4	B 6.6	5	5	5	5	1	1-1/2
	23	7	290,291	345	A 3.0	A 3.6	2	2	2	2	1	1-1/2
UNLOADING SINGLE TANK CAR OR TRANSPORT	27	8	91	795	B 6.2	B 7.4	5	5	5	5	1	1-1/2
	26	8	290,291	390	A 3.4	B 4.0	2	2	2	2	1	1-1/2
	30	9	290,291	435	A 3.8	B 4.6	3	3	3	3	1	1-1/2
	33	10	290,291	490	B 4.4	B 5.2	3	3	3	3	1	2
	36	11	290,291	535	B 4.8	B 5.8	3	3	3	3	1	2
	39	12	290,291	580	B 5.2	B 6.2	5	3	5	3	1	2
	42	13	290,291	625	B 5.6	B 6.6	5	5	5	5	1-1/4	2
	47	14	290,291	695	B 6.2	B 7.4	5	5	5	5	1-1/4	2
	50	15	290,291	735	B 6.6	B 8.0	5	5	5	5	1-1/4	2-1/2
	50	15	490,491	345	A 3.0	A 3.6	5	5	5	5	1-1/4	2-1/2
	53	16	290,291	780	B 7.0	B 8.6	7-1/2	5	7-1/2	5	1-1/4	2-1/2
	53	16	490,491	370	A 3.2	A 3.8	5	5	5	5	1-1/4	2-1/2
UNLOADING TWO OR MORE TANK CARS AT ONE TIME, OR LARGE TRANSPORT WITH EXCESS FLOW VALVES OF ADEQUATE CAPACITY	56	17	490,491	390	A 3.4	B 4.0	5	5	5	5	1-1/4	3
	60	18	490,491	415	A 3.6	B 4.4	5	5	5	5	1-1/4	3
	63	19	490,491	435	A 3.8	B 4.6	5	5	5	5	1-1/4	3
	65	20	490,491	445	B 4.0	B 4.8	5	5	5	5	1-1/4	3
	68	21	490,491	470	B 4.2	B 5.0	5	5	5	5	1-1/4	3
	71	22	490,491	490	B 4.4	B 5.2	7-1/2	5	7-1/2	5	1-1/4	3
	75	23	490,491	515	B 4.6	B 5.6	7-1/2	5	7-1/2	5	1-1/4	3
	77	24	490,491	535	B 4.8	B 5.8	7-1/2	7-1/2	7-1/2	7-1/2	1-1/4	3
	81	25	490,491	560	B 5.0	B 6.0	7-1/2	7-1/2	7-1/2	7-1/2	1-1/4	3
	84	26	490,491	580	B 5.2	B 6.2	7-1/2	7-1/2	7-1/2	7-1/2	1-1/4	3
	87	27	490,491	605	B 5.4	B 6.4	7-1/2	7-1/2	7-1/2	7-1/2	1-1/4	3
	91	28	490,491	625	B 5.6	B 6.6	7-1/2	7-1/2	7-1/2	7-1/2	1-1/2	3
	94	29	490,491	650	B 5.8	B 7.0	10	7-1/2	10	7-1/2	1-1/2	3
	97	30	490,491	670	B 6.0		10	7-1/2	10	7-1/2	1-1/2	3
	94	30	690,691	400	B 4.4	B 5.2	7-1/2	7-1/2	7-1/2	7-1/2	1-1/2	3
	100	31	490,491	695	B 6.2	B 7.4	10	7-1/2	10	7-1/2	1-1/2	3
	98	31	690,691	420	B 4.6	B 5.6	10	7-1/2	10	7-1/2	1-1/2	3
	107	32	490,491	740	B 6.6	B 8.0	10	10	10	10	1-1/2	3
	103	32	690,691	440	B 4.8	B 5.8	10	7-1/2	10	7-1/2	1-1/2	3
	110	33	490,491	760	B 6.8	B 8.0	10	10	10	10	1-1/2	3
	113	34	490,491	780	B 7.0	B 8.6	10	10	10	10	1-1/2	3
	107	34	690,691	455	B 5.0	B 6.0	10	10	10	10	1-1/2	3
	111	35	690,691	475	B 5.2	B 6.2	10	10	10	10	1-1/2	3
	119	36	490,491	825	B 7.4	B 8.6	15	10	15	10	1-1/2	3
	116	36	690,691	495	B 5.4	A 6.4	10	10	10	10	1-1/2	3
UNLOADING LARGE TANK CARS, MULITPLE VESSELS, BARGES OR TERMINALS	120	38	690,691	510	B 5.6	B 6.8	10	10	10	10	1-1/2	4
	124	39	690,691	530	B 5.8	B 7.0	10	10	10	10	1-1/2	4
	129	41	690,691	550	B 6.0	A 7.0	10	10	10	10	1-1/2	4
	133	42	690,691	565	B 6.2	B 7.4	10	10	10	10	2	4
	137	43	690,691	585	B 6.4	A 7.4	10	10	10	10	2	4
	142	45	690,691	605	B 6.6	B 8.0	15	10	15	10	2	4
	145	46	690,691	620	B 6.8		15	10	15	10	2	4
	150	47	690,691	640	B 7.0	A 8.2	15	10	15	10	2	4
	158	48	690,691	675	B 7.4	B 8.6	15	15	15	15	2	4
	171	54	690,691	730	B 8.0	B 9.4	15	15	15	15	2	4
	184	58	690,691	785	B 8.6		15	15	15	15	2	4
	193	60	690,691	820	TB9.0	A 10.6	15	15	15	15	2	4

Consult factory for compressors for higher flows.

NOTES:

(1) The capacities shown are based on 70°F, but will vary depending upon piping, fittings used, product being transferred and temperature. The factory can supply a detailed computer analysis if required.
(2) Driver sheaves: 91 - 2 belts; 290,291,490,491 - 3 belts; 690,691 - 4 belts.
(3) The piping sizes shown are considered minimum. If the length exceeds 100 ft., use the next larger size.

LPG-NH3 COMPRESSORS VE 202B

AMMONIA COMPRESSOR SELECTION TABLE

MARCH 1988
SUPERSEDES VE201G

SERVICE	CAPACITY GPM(1)	DISPLACEMENT CFM	COMPRESSOR		DRIVER SHEAVE SIZE P.D."(2)		DRIVER HORSEPOWER: LIQUID TRANSFER AND RESIDUAL VAPOR RECOVERY		DRIVER HORSEPOWER: LIQUID TRANSFER WITHOUT RESIDUAL VAPOR RECOVERY		PIPING SIZE (3)	
			MODEL	RPM	1750RPM	1460RPM	100°F	80°F	100°F	80°F	VAPOR	LIQUID
SMALL BULK PLANTS	23	4	91	400	A 3.0	A 3.6	5	3	3	3	3/4	1-1/4
	29	5	91	505	A 3.8	B 4.6	5	5	5	3	3/4	1-1/4
	34	6	91	590	B 4.6	B 5.6	5	5	5	5	1	1-1/4
	40	7	91	695	B 5.4	B 6.6	5	5	5	5	1	1-1/2
	43	7	290,291	345	A 3.0	A 3.6	5	3	3	3	1	1-1/2
UNLOADING SINGLE TANK CAR OR TRANSPORT	46	8	91	795	B 6.2	B 7.4	7-1/2	5	5	5	1	1-1/2
	45	8	290,291	390	A 3.4	B 4.0	5	3	3	3	1	1-1/2
	50	9	290,291	435	A 3.8	B 4.6	5	5	3	3	1	1-1/2
	56	10	290,291	490	B 4.4	B 5.2	5	5	5	3	1	2
	62	11	290,291	535	B 4.8	B 5.8	7-1/2	5	5	5	1	2
	67	12	290,291	580	B 5.2	B 6.2	7-1/2	5	5	5	1	2
	72	13	290,291	625	B 5.6	B 6.6	7-1/2	5	5	5	1-1/4	2
	80	14	290,291	695	B 6.2	B 7.4	7-1/2	7-1/2	7-1/2	5	1-1/4	2
	85	15	290,291	735	B 6.6	B 8.0	10	7-1/2	7-1/2	7-1/2	1-1/4	2-1/2
	85	15	490,491	345	A 3.0	A 3.6	7-1/2	7-1/2	5	5	1-1/4	2-1/2
	90	16	290,291	780	B 7.0	B 8.6	10	7-1/2	7-1/2	7-1/2	1-1/4	2-1/2
	90	16	490,491	370	A 3.2	A 3.8	10	7-1/2	5	5	1-1/4	2-1/2
UNLOADING TWO OR MORE TANK CARS AT ONE TIME, OR LARGE TRANSPORT WITH EXCESS FLOW VALVES OF ADEQUATE CAPACITY	96	17	490,491	390	A 3.4	B 4.0	10	7-1/2	5	5	1-1/4	3
	102	18	490,491	415	A 3.6	B 4.4	10	7-1/2	7-1/2	7-1/2	1-1/4	3
	107	19	490,491	435	A 3.8	B 4.6	10	7-1/2	7-1/2	7-1/2	1-1/4	3
	110	20	490,491	445	B 4.0	B 4.8	10	7-1/2	7-1/2	7-1/2	1-1/4	3
	115	21	490,491	470	B 4.2	B 5.0	10	7-1/2	7-1/2	7-1/2	1-1/4	3
	120	22	490,491	490	B 4.4	B 5.2	15	10	7-1/2	7-1/2	1-1/4	3
	126	23	490,491	515	B 4.6	B 5.6	15	10	7-1/2	7-1/2	1-1/4	3
	131	24	490,491	535	B 4.8	B 5.8	15	10	10	7-1/2	1-1/4	3
	138	25	490,491	560	B 5.0	B 6.0	15	10	10	7-1/2	1-1/4	3
	142	26	490,491	580	B 5.2	B 6.2	15	10	10	7-1/2	1-1/4	3
	148	27	490,491	605	B 5.4	B 6.4	15	10	10	10	1-1/4	3
	153	28	490,491	625	B 5.6	B 6.6	15	10	10	10	1-1/2	3
	160	29	490,491	650	B 5.8	B 7.0	15	15	10	10	1-1/2	3
	165	30	490,491	670	B 6.0		15	15	15	10	1-1/2	3
	165	30	690,691	400	B 4.4	B 5.2	15	15	10	10	1-1/2	3
	170	31	490,491	695	B 6.2	B 7.4	15	15	15	10	1-1/2	3
	173	31	690,691	420	B 4.6	B 5.6	15	15	10	10	1-1/2	3
	181	32	490,491	740	B 6.6	B 8.0	15	15	15	15	1-1/2	3
	180	32	690,691	440	B 4.8	B 5.8	15	15	10	10	1-1/2	3
	188	34	690,691	455	B 5.0	B 6.0	20	15	10	10	1-1/2	3
	195	35	690,691	475	B 5.2	B 6.2	20	15	10	10	1-1/2	3
	203	36	690,691	495	B 5.4	B 6.4	20	15	15	10	1-1/2	3
UNLOADING LARGE TANK CARS, MULITPLE VESSELS, BARGES OR TERMINALS	211	38	690,691	510	B 5.6	B 6.8	20	15	15	10	1-1/2	4
	218	39	690,691	530	B 5.8	B 7.0	20	15	15	15	1-1/2	4
	226	41	690,691	550	B 6.0	A 7.0	20	15	15	15	1-1/2	4
	233	42	690,691	565	B 6.2	B 7.4	20	15	15	15	2	4
	240	43	690,691	585	B 6.4	A 7.4	20	20	15	15	2	4
	248	45	690,691	605	B 6.6	B 8.0	20	20	15	15	2	4
	255	46	690,691	620	B 6.8		25	20	15	15	2	4
	263	47	690,691	640	B 7.0	A 8.2	25	20	15	15	2	4
	278	48	690,691	675	B 7.4	B 8.6	25	20	15	15	2	4
	301	54	690,691	730	B 8.0	B 9.4	25	20	20	15	2	4
	323	58	690,691	785	B 8.6		30	25	20	20	2	4
	338	60	690,691	820	TB9.0	A 10.6	30	25	20	20	2	4

Consult factory for compressors for higher flows.

NOTES:
(1) The capacities shown are based on 70°F, but will vary depending upon piping, fittings used, product being transferred and temperature. The factory can supply a detailed computer analysis if required.
(2) Driver sheaves: 91 - 2 belts; 290,291,490,491 - 3 belts; 690,691 - 4 belts.
(3) The piping sizes shown are considered minimum. If the length exceeds 100 ft., use the next larger size.

LIQUIFIED GAS TRANSFER COMPRESSOR WORKSHEET — CORKEN
TEST — REV. 2.5.88 — DAS 02-17-88
PROPANE
690 N=1.13 RPM= 825 PD=60.7 CFM MAWP=265 PSIA CRITICAL PRESSURE=619 PSIA CRITICAL TEMP=666 DEG R

LIQUID TRANSFER PHASE TANK VOLUME=33000 GALLONS 30 PSI DROP IN LIQ. TRANSFER SYSTEM MOLECULAR WEIGHT=44.1
TOTAL LIQUID VOLUME TO BE TRANSFERRED= 29618 GALLONS OR 89.8 % OF TOTAL TANK VOLUME TANK IS 90.0% FULL

T1 F	V.P. PSIA	P2 PSIA	T2 F	CR	VE %	GPM	ACFM IN	ACFM OUT	BHP	TIME MIN	LB/HR LIQUID	Z IN	Z OUT
0	38	68	32	1.8	85	216	51.8	28.9	12.3	137	55229	0.92	0.89
10	46	76	38	1.7	87	238	52.7	31.9	13.1	124	60864	0.91	0.88
20	55	85	45	1.5	88	258	53.4	34.5	13.9	115	65938	0.90	0.87
30	66	96	52	1.5	89	278	54.0	37.1	14.8	107	70841	0.89	0.86
40	78	108	59	1.4	90	294	54.4	39.3	15.6	101	75048	0.88	0.85
50	92	122	67	1.3	90	309	54.8	41.3	16.6	96	78903	0.86	0.83
60	107	137	75	1.3	91	322	55.1	43.0	17.5	92	82154	0.85	0.82
70	124	154	83	1.2	91	333	55.3	44.6	18.5	89	85064	0.83	0.80
80	144	174	92	1.2	91	344	55.5	46.0	19.6	86	87748	0.81	0.79
90	165	195	101	1.2	92	353	55.7	47.1	20.7	84	89966	0.80	0.77
100	189	219	110	1.2	92	360	55.8	48.2	21.9	82	91969	0.78	0.75
110	215	245	119	1.1	92	367	55.9	49.1	23.2	81	93687	0.76	0.73

BOIL-OFF PHASE HEEL VOL.=83 GAL. LIQ. OR 0.25% OF TOTAL TANK VOL. 10 PSI DROP IN VAPOR RECOVERY SYSTEM

T1							V.P				P2	
F	PSIA	PSIA	F		%		IN	VOLUME(FT3)	RATE(GPM)	MIN	IN	OUT
0	38	48	13	1.3	92	9.4	55.8	955	5	17	0.92	0.91
10	46	56	21	1.2	92	10.0	56.0	797	6	14	0.91	0.91
20	55	65	29	1.2	93	10.5	56.2	673	7	12	0.90	0.89
30	66	76	38	1.2	93	11.2	56.4	564	8	10	0.89	0.88
40	78	88	47	1.1	93	11.9	56.5	480	10	8	0.88	0.87
50	92	102	56	1.1	93	12.7	56.6	408	11	7	0.86	0.85
60	107	117	65	1.1	93	13.5	56.7	352	13	6	0.85	0.84
70	124	134	75	1.1	93	14.4	56.7	304	15	5	0.83	0.82
80	144	154	84	1.1	93	15.4	56.8	261	18	5	0.81	0.81
90	165	175	94	1.1	94	16.5	56.8	227	21	4	0.80	0.79
100	189	199	103	1.1	94	17.6	56.8	197	24	3	0.78	0.77
110	215	225	113	1.0	94	18.9	56.8	171	27	3	0.76	0.75

VAPOR RECOVERY PHASE 30 PSIA DESIRED EVACUATION PRESSURE 10 PSI DROP IN VAPOR RECOVERY SYSTEM

T1 F	V.P. PSIA	P2 PSIA	T2 F	VE(%) INIT	VE(%) FINAL	ACFM INIT	ACFM FINAL	Z IN INIT	Z IN FINAL	BHP MAX	P1 @ VE=0	P1 @ MAX BHP	TIME MIN	EQUIVALENT LIQUID (GAL) ACTUAL	RECOVERED	CLAIMABLE	TTL TIME HRS.
0	38	48	20	92	90	55	54	.92	.93	10.2	5	26	19	381	89	337	2.9
10	46	56	42	92	86	56	52	.91	.94	11.1	6	32	35	456	185	405	2.9
20	55	65	64	93	82	56	49	.90	.95	12.1	6	34	50	540	288	482	2.9
30	66	76	80	93	80	56	48	.89	.95	13.4	8	41	67	645	377	578	3.1
40	78	88	103	93	75	56	45	.88	.95	14.8	9	48	84	758	506	682	3.2
50	92	102	126	93	69	56	41	.86	.96	16.4	10	57	101	891	650	803	3.4
60	107	117	143	93	66	56	40	.85	.96	18.1	12	60	118	1034	781	937	3.6
70	124	134	166	93	60	56	36	.83	.96	20.0	13	70	137	1197	953	1088	3.9
80	144	154	188	93	53	56	32	.81	.96	22.3	15	82	158	1395	1153	1272	4.1
90	165	175	209	94	47	56	28	.80	.97	24.6	17	95	180	1604	1364	1466	4.5
100	189	199	234	94	37	56	22	.78	.97	27.3	20	99	206	1850	1619	1695	4.0
110	215	225	256	94	29	56	17	.76	.97	30.2	23	114	237	2123	1894	1948	5.3

ASSUMPTIONS FOR CALCULATIONS 1)PRESSURE DROPS REMAIN CONSTANT 2)INDUCED FLOW BASED ON ISOTHERMAL COMPRESSION 3)BHP AND TEMP. ARE BASED ON ADIABATIC COMPRESSION 4)COMPRESSIBILITY EFFECTS ARE CONSIDERED IN CALCULATIONS 5)HEAT TRANSFER IS SUFFICIENT TO MAINTAIN CONSTANT TANK TEMPERATURE DURING BOILOUT.

Figure 3.1C CORKEN Liquid Transfer Compressor Performance Analysis (Example)

Liquid Transfer Phase
Propane
690 at 825 RPM
30 PSI Pressure Drop

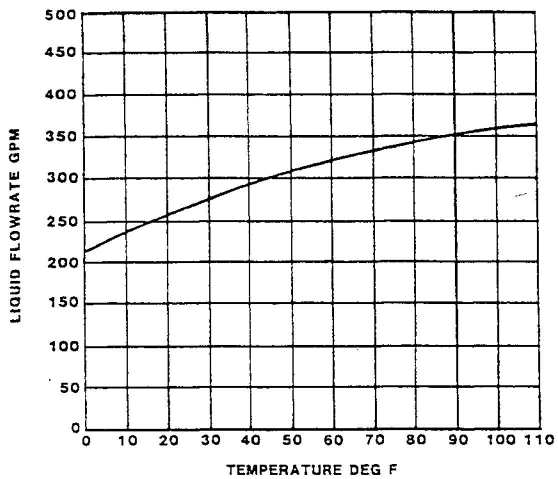


Figure 3.1D
Compressors Create Higher Flow Rates on Hotter Days

Boil-Out Phase
Propane
690 at 825 RPM
10 PSI Pressure Drop

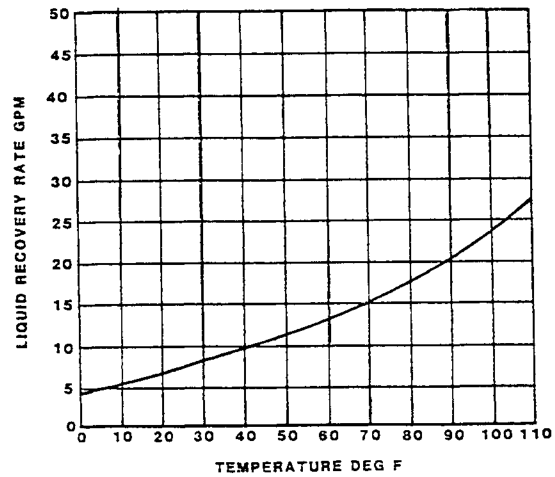


Figure 3.1E
"Liquid Heel" in Tank Cars Can Be Boiled Out More Rapidly on Hotter Days

Vapor Recovery Phase
Propane
690 at 825 RPM
Tank Volume = 33,000 gal.

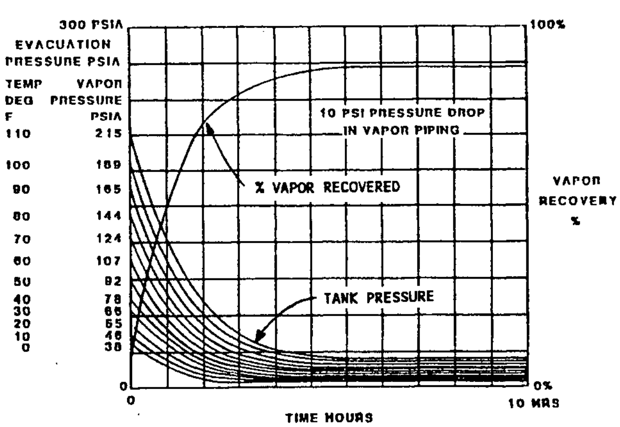


Figure 3.1F
Vapor Recovery Can Be Completed Most Rapidly on Cold Days Since Initial Vapor Pressure Is Lower

Vapor Recovery Phase
Propane
690 at 825 RPM

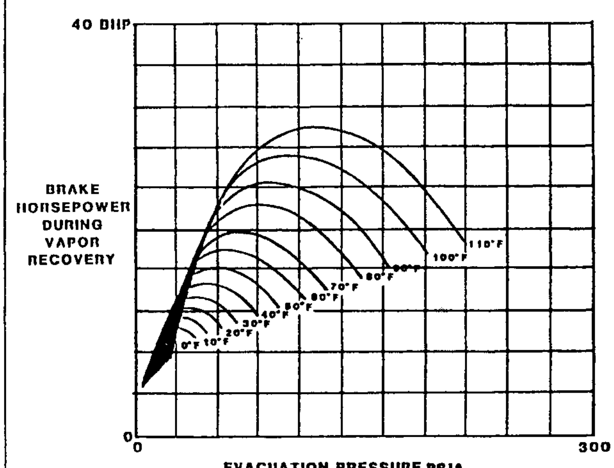


Figure 3.1G
Larger Motors Are Required For Vapor Recovery In Hot Climates

3.2 Pumps vs. Compressors

The total elimination of vapor formation in the suction piping of LP gas pumps is virtually impossible, regardless of the type of pump. This problem becomes especially difficult when the pump is fed by a negative suction head.

The safety regulations for LP gas storage and transport have created situations where LP must be transferred with negative suction heads. The most important example of this is the LP gas railroad tank car. All inlet and outlet connections for these tanks must be on top of the tank. This design minimizes the possibility of a rupture caused by shearing off a nozzle during a derailment. Some local regulatory authorities require LP gas tanks to be put underground. Railroad tank cars and underground pumps cannot rely on gravity to feed the pump. For this reason, pumps are not the most reliable method for unloading these types of tanks.

Compressors have completely dominated LP gas railroad tank car unloading and are frequently used for unloading underground tanks as well. Because of their flexibility and vapor recovery capabilities, they are also used in many truck loading and unloading operations in place of pumps.

The major criteria for choosing between a pump or a compressor may be summarized as follows:

Use a compressor when -

1)Liquid cannot be gravity fed to an unloading pump (negative suction head). Primary applications: railroad tank cars and underground tanks.

2)Vapor recovery is required or desired.

3)When plant has only one transfer device.

Use a liquid pump when -

1)Flooded, gravity fed suction is available.

2)Vapor recovery is not required.

3)Differential pressures above 30 PSI are required.

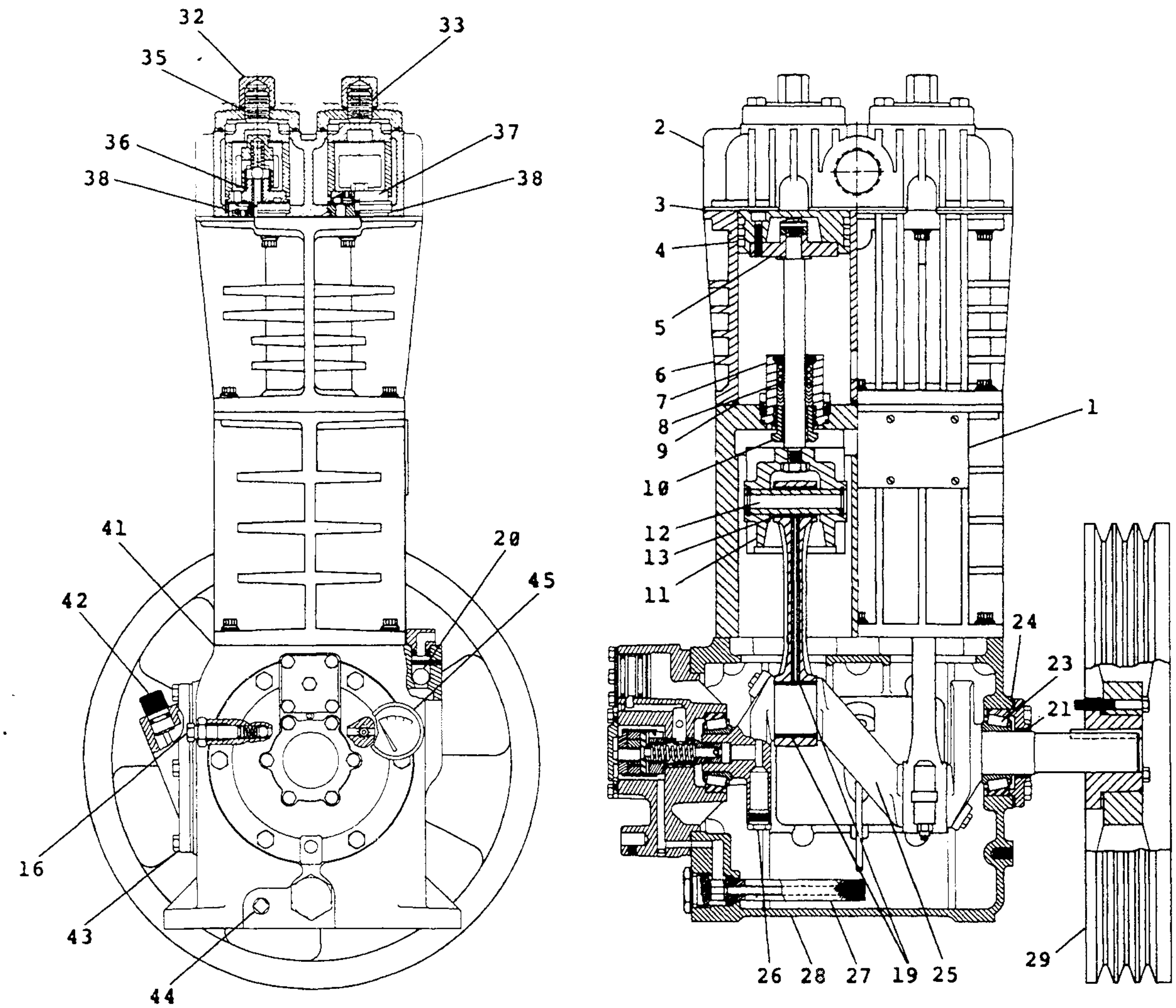
4)Liquid is to be metered.

5)Lower initial installation cost is required.

3.3 LP Gas Compressor Design

LP gas compressors are part of the reciprocating compressor family. Reciprocating compressors pull vapor into a cylinder through a suction valve by drawing back a piston to create a low pressure area in the cylinder. They pressurize the gas by pushing the piston back up into the cylinder to squeeze the gas out through the discharge valve. Figure 3.3A shows a cutaway of an LP gas compressor.

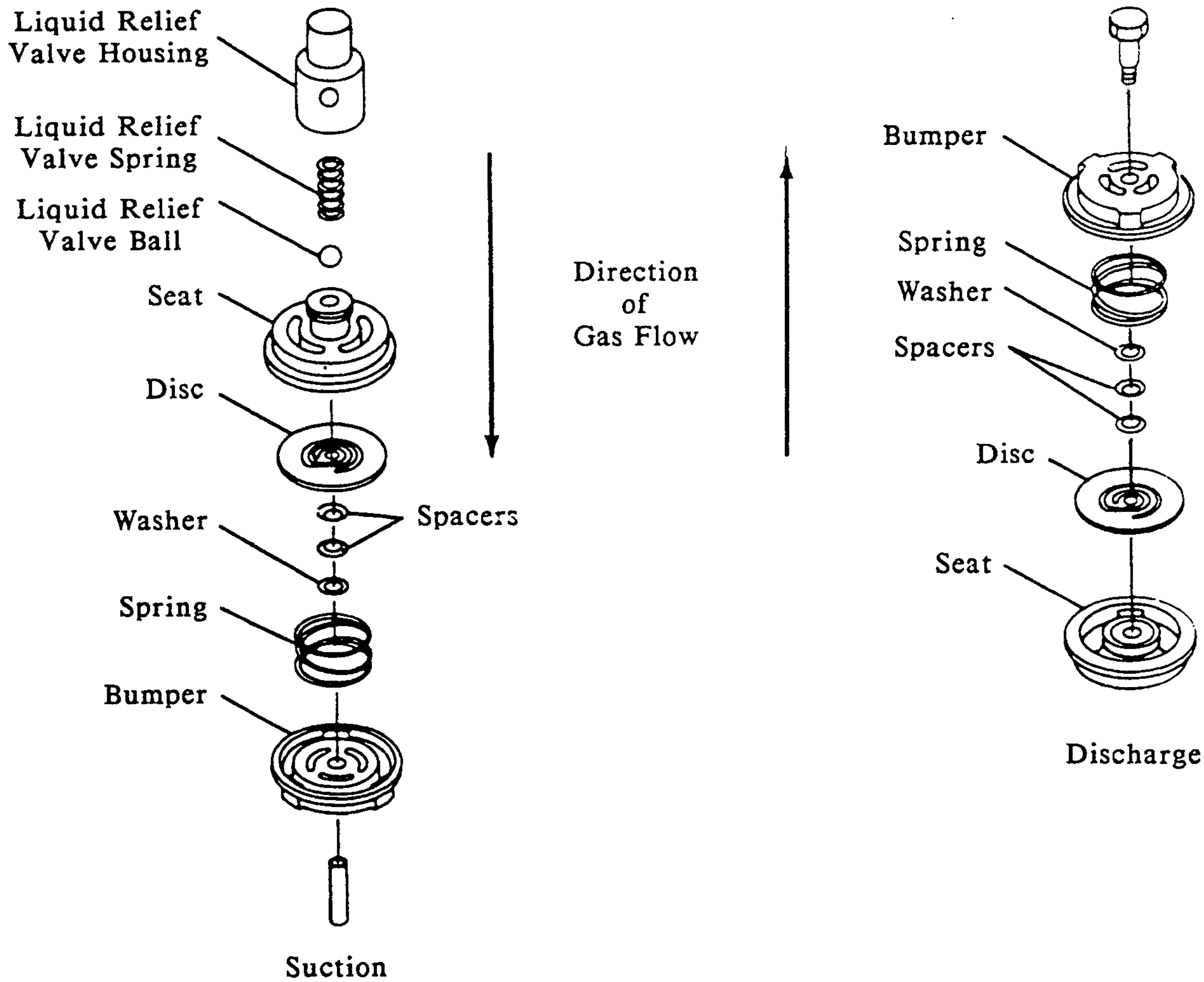
A compressor valve consists of four parts: a seat, bumper, disc and spring. The spring rests against a bumper and pushes the disc against the seat. The disc seals off the flow passage through the seat. If more pressure builds up on the seat side than the bumper side, the disc will be forced away from the seat and gas will flow through the valve (See Figure 3.3B).



Ref. No.	Part Name	Ref. No.	Part Name
1	Crosshead Guide Inspection Plate	25	Crankshaft
2	Cylinder Head	26	Crankshaft Plug
3	Cylinder Head Gasket	27	Filter Screen
4	Piston Rings and Expanders	28	Crankcase
5	Piston Assembly	29	Flywheel
6	Cylinder	30	Valve Screw Nut
7	Packing Box Assembly	31	Valve Cover Plate
8	Packing Set	32	Valve Cap
9	Cylinder Gasket	33	Valve Holddown Screw
10	Packing Adjusting Screw	34	Valve Cover Plate Gasket
11	Crosshead-Piston Rod Assembly	35	Valve Cap Gasket
12	Wrist Pin	36	Suction Valve Assembly
13	Wrist Pin Bushing	37	Discharge Valve Assembly
14	Crosshead Guide	38	Valve Gasket
15	Connecting Rod Assembly	39	Inlet Flange
16	Oil Relief Adjusting Screw	40	Outlet Flange
17	Oil Relief Valve	41	Crankcase Gasket
18	Oil Pump Assembly	42	Oil Level Bayonet
19	Connecting Rod Bearings	43	Crankcase Inspection Plate
20	Breather Valve Assembly	44	Oil Drain Plug
21	Oil Seal	45	Oil Pressure Gauge
22	Oil Circulating Ring	46	Cartridge Holddown Screw
23	Main Bearings	47	Piston Relief Valve
24	Bearing Adjustment Shims		

Note: These numbers are for general reference only and should not be used when ordering parts. Consult your Service Manual, Section E, for the correct part numbers for your Compressor Model.

Figure 3.3A CORKEN Liquified Gas Compressor



CORKEN Suction and Discharge Valves
For Size 390 and 490 Compressors

Figure 3.3B

The suction valves are also equipped with a small ball and spring relief valve (See Figure 3.3B) which is designed to relieve any condensation that takes place within the compressor cylinder. The liquid relief valve is not intended to relieve liquid that enters the cylinder through the suction valve (more on this later).

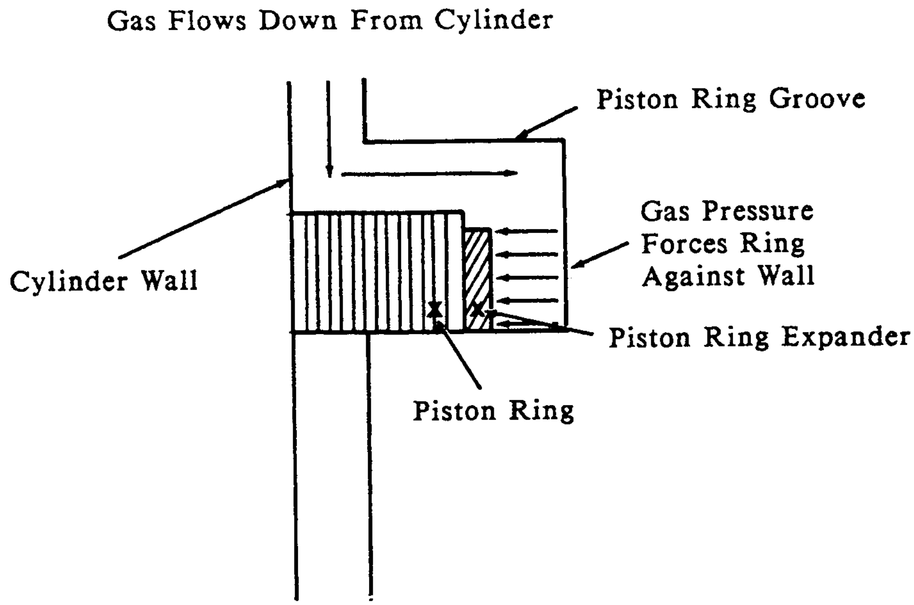


Figure 3.3C
(Not to Scale)

In order for compression to take place, the piston must be sealed against the wall. This seal is made with several piston rings. Since LP gas compressors must not be contaminated by lubricating oils, the piston ring must be made of a self lubricating material. CORKEN piston rings are usually made of glass-filled Teflon. Gas pressure in the cylinder is used to press the piston ring against the cylinder wall (See Figure 3.3C). Ring expanders are used to push the ring towards the cylinder wall so high pressure gas may flow behind the ring.

Piston rings form a good dynamic seal but they are not tight enough to seal all the pressure and gas inside the cylinder; an additional seal is required to do this. This seal is the piston rod packing. The piston rod packing is a seal that is located at the bottom of the cylinder. It is composed of several parts, the most important being the self-lubricating Teflon V-rings that tightly seal against the piston rod. A spring is included in the packing assembly which allows a slight amount of "float" to reduce friction. The rod packing also seals oil in the crankcase out of the compressor chamber to prevent contamination of the gas.

Most LP gas and ammonia compressors contain one set of piston rod packing per rod. One set of packing controls leakage and oil contamination of the vapor to a satisfactory level for most commercial LP gas/ammonia applications. When leakage and contamination must be held to an absolute minimum, two packing sets separated by a distance piece may be utilized. CORKEN manufactures vertical compressors in both the single and double packing set styles.

The crankcase converts rotary motion from the motor to reciprocating motion at the piston. All CORKEN compressors, except the 91, use an oil pump to pressure lubricate the bearings and wrist pins to assure long service life. The oil pump is a gear type that may be run in either direction; for this reason CORKEN compressors may be turned in either direction. CORKEN's vertical LP gas compressors are designed to run at 400 to 825 RPM.

3.4 Liquid Traps and Compressor Mounting

Compressors are designed to handle vapor and only vapor. While LP gas pumps are designed to handle small amounts of vapor, small amounts of liquid in a compressor usually result in major damage to the unit.

"Liquid slugging" is the term used to describe a compressor when it is accidentally turned into a liquid pump. The "liquid slug" occurs when the piston has pushed all the vapor out of the cylinder and encounters a wall of incompressible liquid. This results in immediate destruction in many cases, something like a car slamming into a brick wall at high speed.

To avoid the dangers of liquid slugging, some type of liquid removal device must be used on all LP gas compressors. LP gas is compressed at or close to its condensation temperature and frequently carries a fine entrained mist of liquid droplets. Vapor from a warm tank that is drawn through a cold pipe is prone to change to liquid before it reaches the compressor.

Liquid droplets suspended in the suction vapor are subjected to two types of forces: 1)Gravity and 2)Friction. The faster the vapor stream travels, the more friction force it has to pick up droplets of liquid. If the stream is slowed down, gravity is able to separate much of the liquid from the vapor. Liquid traps work on the principle of slowing down the speed of the vapor. The trap has a large diameter relative to the suction pipe which slows down the vapor. The liquid drops out into the bottom of the trap. In most cases this vapor will boil off into vapor as the system warms up. If the liquid level gets too high though, the trap must either block off the liquid line or stop the compressor so the trap may be drained.

Fewer precautions are necessary in installing LP gas compressors than LP gas pumps, however some installation rules need to be followed.*

1)Condensate will frequently form in the discharge and suction lines when the compressor is shut down. Install the piping so none of this liquid drains into the compressor.

2)Install the compressor as close to the tank being unloaded as possible using adequately sized piping (See Figure 3.1C for recommended pipe sizes). This minimizes the cooling of the discharge gas to result in the largest possible volume of gas reaching the tank.

3)Use adequately sized liquid piping so the overall system pressure drop does not exceed 30 PSI (See Figure 3.1C).

4)Securely bolt and grout baseplate to the foundation to minimize vibration.

*SEE "Important Instruction" manual VE100 for more information on correct compressor installation.

CORKEN offers three types of liquid traps for removal of entrained liquids. The simplest is a ball float trap. If the liquid level rises above the inlet, the ball floats will plug the compressor suction. The compressor creates a vacuum in the inlet piping and continues to operate until it is manually shut down by the operator. Before restarting the compressor, the trap must be drained and the vacuum-breaker valve opened to allow the ball float to drop back to the bottom of the trap. This type of trap is only appropriate for use where the compressor is kept under fairly close observation by the operator. Typically, this trap is only used in the LP-gas and agricultural ammonia business and is included in the -109 and -107 mountings.

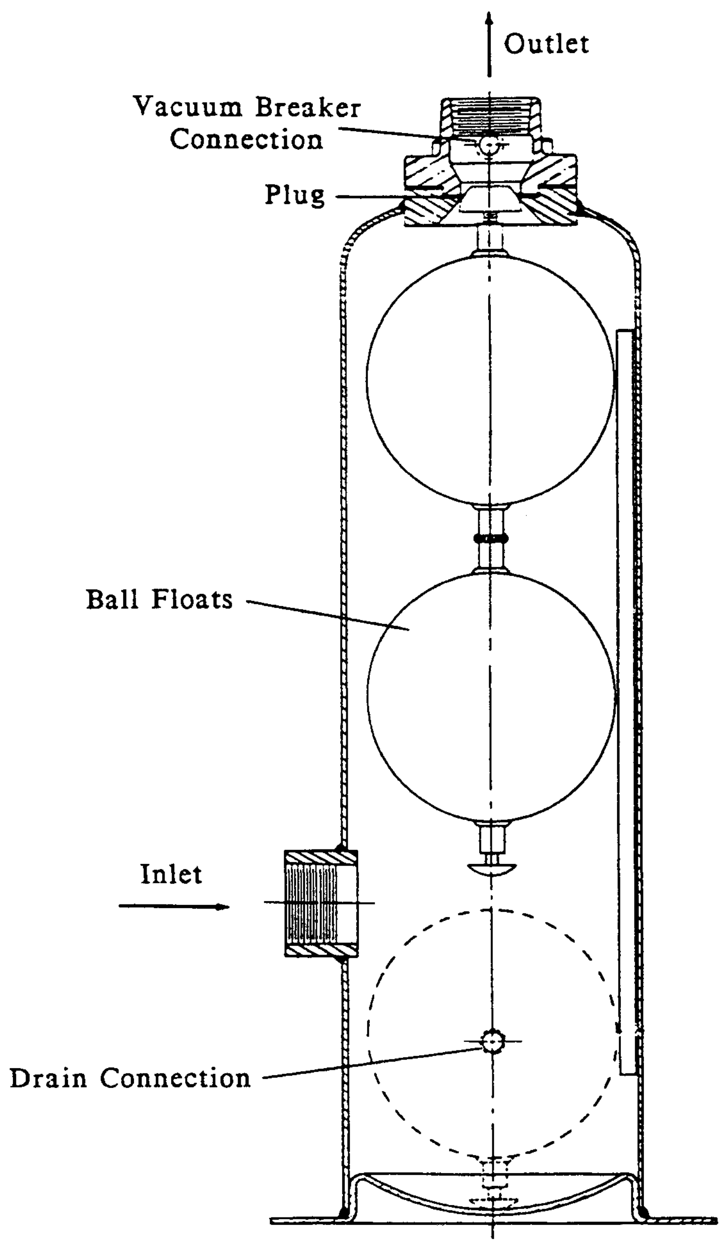


Figure 3.4A Ball Trap

When a more fool-proof form of protection is required because the unit may not be continuously monitored, an automatic trap is recommended. The automatic trap replaces ball floats with electrical float switches. If the liquid level should rise to too high a level, the level switch will open to disconnect the power to the motor starter which will stop the compressor. This design insures the machine will be protected even when it is not under close observation. This trap is standard in the -109A and -107A mounting configurations.

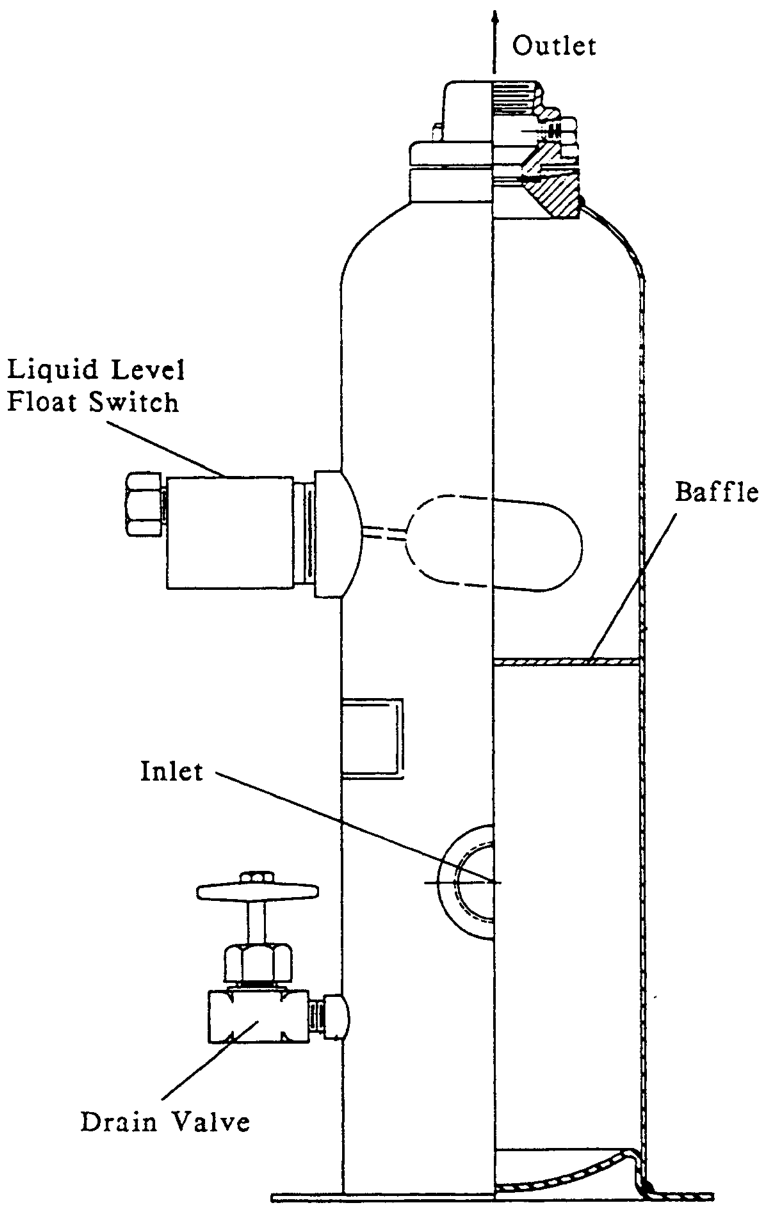


Figure 3.4B Automatic Liquid Trap

CORKEN's most sophisticated trap provides the most thorough liquid separation. This trap is larger than the other two traps and is ASME code stamped. It contains two level switches, one for alarm and one for shutdown. In some cases the alarm switch is used to activate a dump valve (not included with trap) or sound an alarm for the trap to be manually drained by the operator. This trap also contains a demister pad. A demister pad is a mesh of interwoven wire that is extremely effective at disentraining fine liquid mists. The ASME code trap is standard in the -109B and -107B mounting configurations.

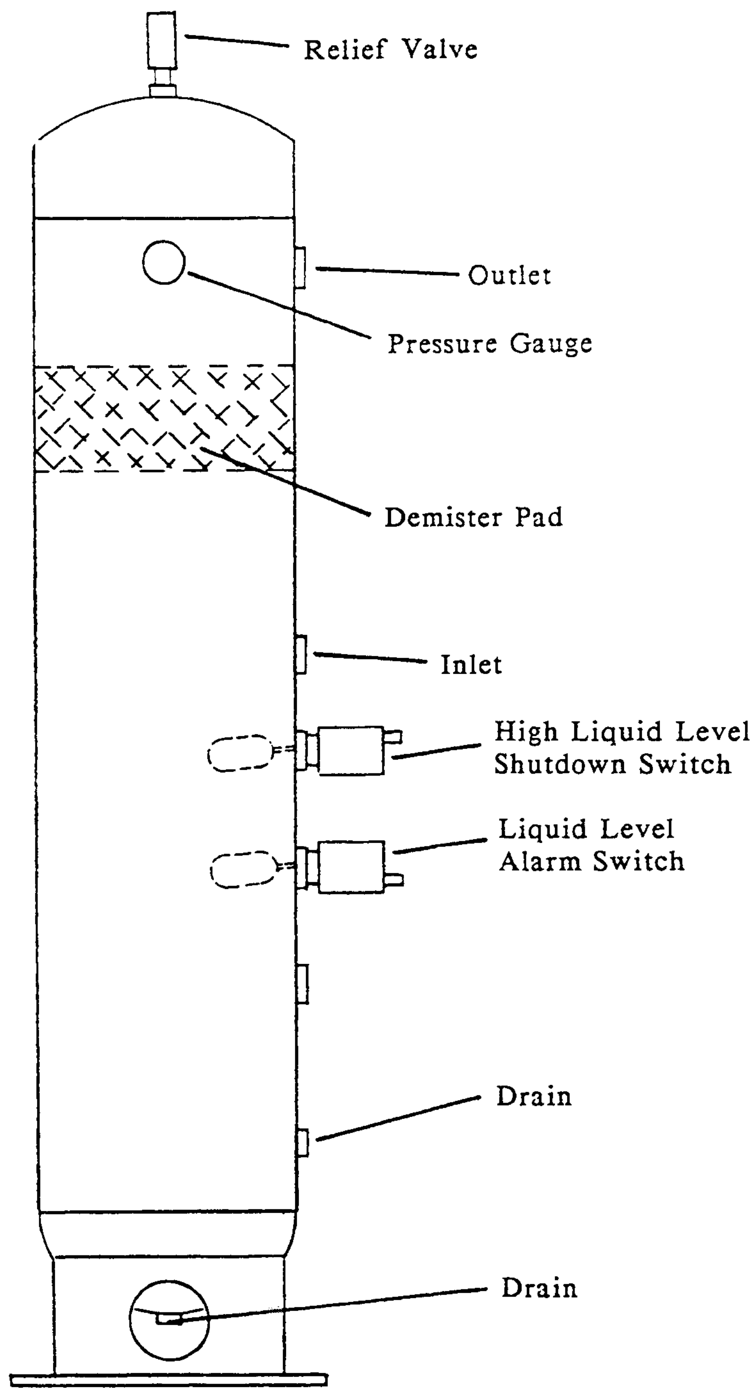


Figure 3.4C ASME Automatic Trap

Any of CORKEN's three types of liquid traps can be purchased as part of a -109 or -107 type package. The -109 package includes the compressor mounted on a steel baseplate with pressure gauges, V-belt drive, beltguard, motorbase, interconnecting piping and one of the three liquid traps already described. The 109 mounting uses the ball trap (Figure 3.4A); the 109A uses the automatic trap (Figure 3.4B) and the 109B uses the ASME automatic trap(Figure 3.4C). The -107 package includes all the features of the -109 package as well as a strainer, a relief valve, and piping connecting the suction and discharge connections to a four-way valve. The four-way valve allows the suction and discharge lines to be reversed when switching from liquid transfer to vapor recovery. The 107 and 107A are the most commonly used mounting configurations for LP gas applications. The -109 mounting is for liquid transfer only.

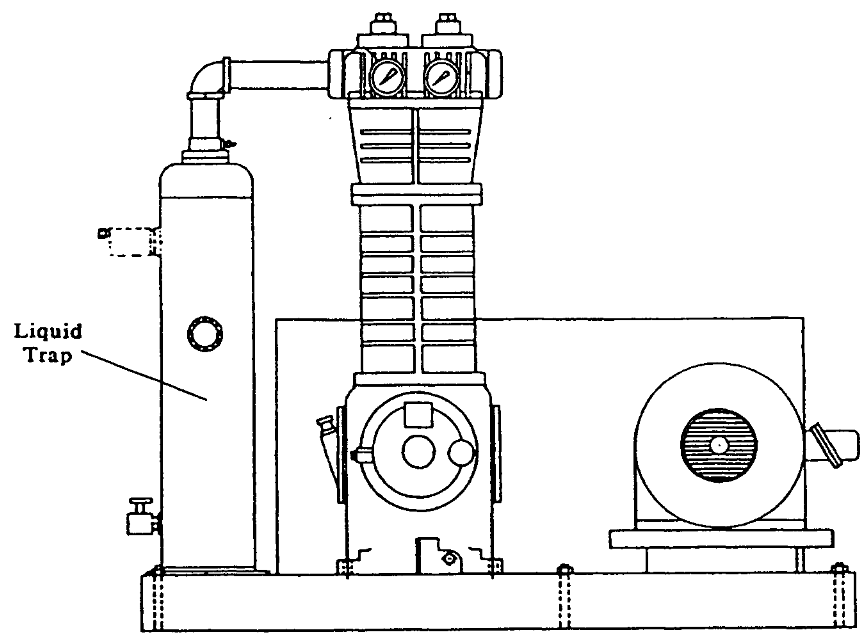


Figure 3.4D 109 Mounting

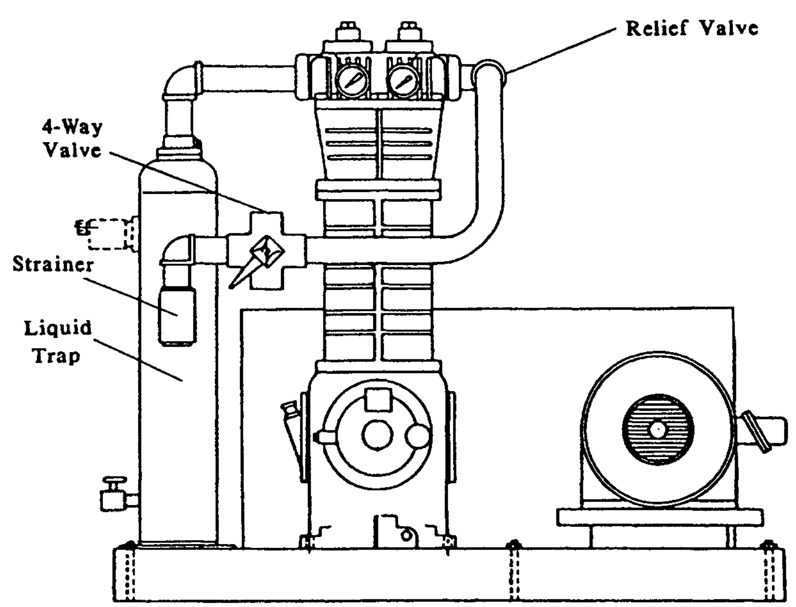
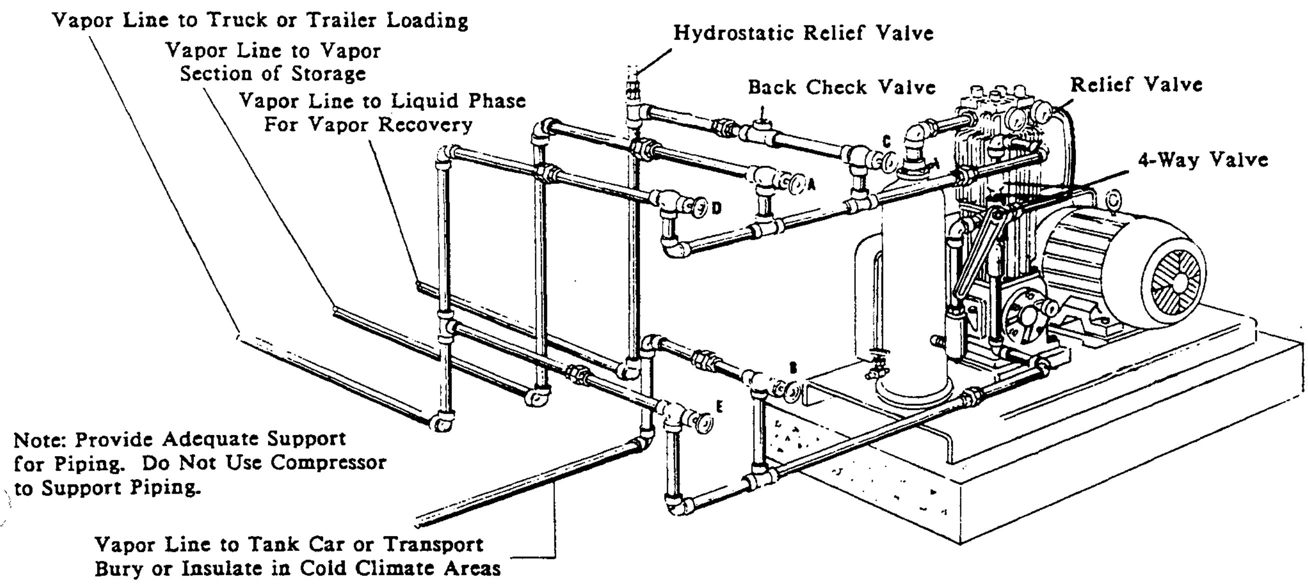
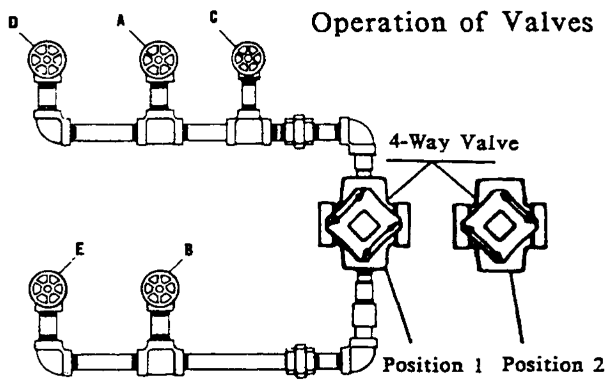


Figure 3.4E -107 Mounting

107 style compressor units are typically mounted using either the five-valve or three-valve style manifold shown in Figures 3.4F and 3.4G. The three-valve manifold is for installation of compressors to be used for unloading operations only. The five-valve manifold can be used for both loading and unloading. The five-valve manifold system is most typically used to unload railroad tank cars in storage and also load bobtails from storage. Always make sure you have a check valve on any vapor lines running into the liquid section. This will prevent liquid from backing into the compressor when it is not operating.



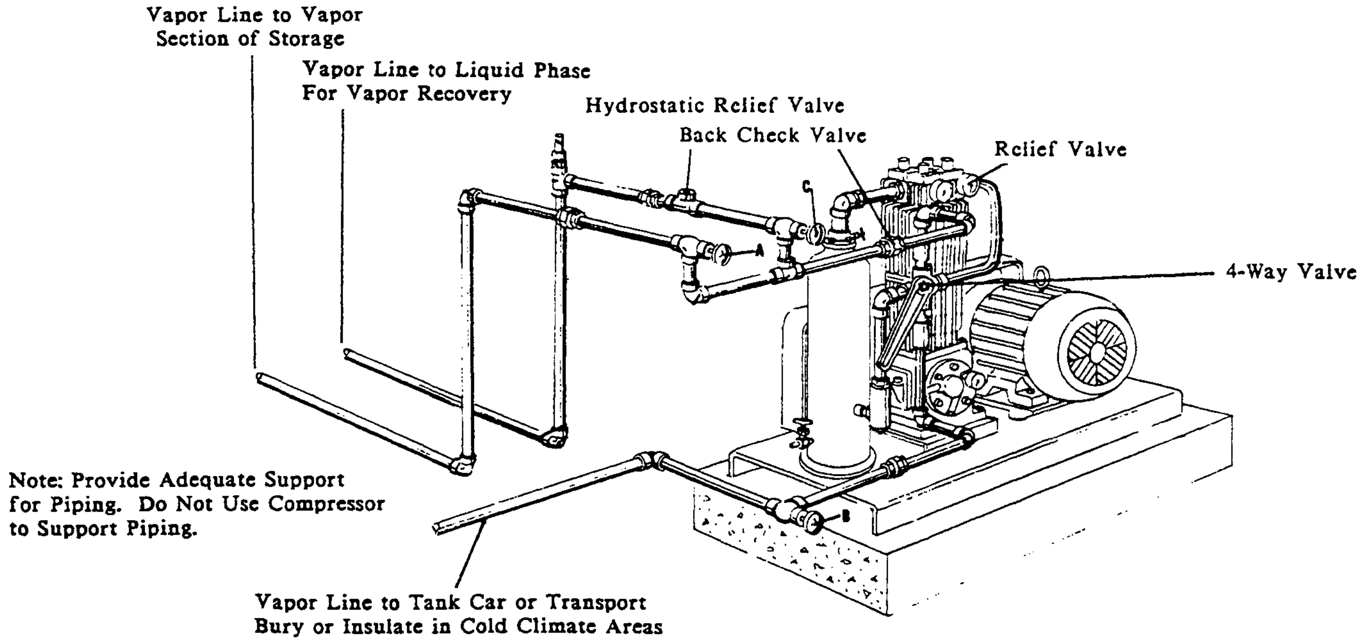
Operation of Valves



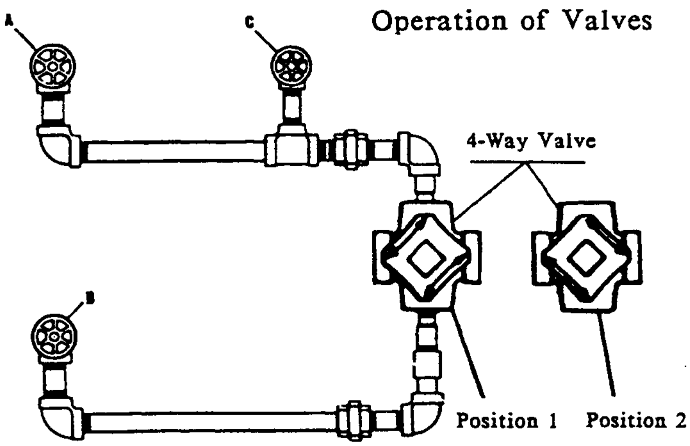
SERVICE TO PERFORM	VALVE POSITION					
	4-Way	A	B	C	D	E
1. Unload Tank Car into Storage Tank	Position - One	Open	Open	Close	Close	Close
2. Recover Vapors from Tank Car into Storage Tank	Position Two	Close	Open	Open	Close	Close
3. Unload Transport or Truck into Storage Tank	Position One	Open	Close	Close	Close	Open
4. Recover Vapors from Transport or Truck into Storage Tank	Position Two	Close	Close	Open	Close	Open
5. Load Truck or Field Tank from Storage Tank	Position Two	Open	Close	Close	Close	Open
6. Load Truck or Field Tank from Tank Car	Position One	Close	Open	Close	Open	Close
7. Equalize Between Tank Car and Storage Tank without using Vapor Pump	---	Open	Open	Close	Open	Open
8. Equalize Between Truck or Field Tank and Storage Tank without using Vapor Pump	---	Open	Close	Close	Open	Close

Five Valve Manifold Piping System

Figure 3.4F



Operation of Valves



SERVICE TO PERFORM	VALVE POSITION			
	4-Way	A	B	C
1. Unload Tank Car into Storage Tank	Position One	Open	Open	Close
2. Recover Vapors from Tank Car into Storage Tank	Position Two	Close	Open	Open

Three Valve Manifold Piping System

Figure 3.4G

3.5 Scavenger Systems

Scavenger systems are growing more popular all the time as more emphasis is placed on safety, pollution reduction, cost reduction and energy conservation. A scavenger system is useful whenever LP gas (or any liquified gas) must be cleared from hoses, tanks, bottles or piping. Without a scavenger, clearing operations would typically be performed by simply venting the gas to the atmosphere. Venting gas to the atmosphere results in increased fire hazard, increased pollution and wasted energy.

The design of a scavenger system is quite simple. A compressor is activated whenever the pressure in a special receiver tank rises to a point slightly above atmospheric pressure. Any items in a bulk plant that require evacuation are connected to this receiver tank. By drawing vapor out of the tank, a relatively low pressure may be maintained in the tank which in turn draws liquid and vapor LP out of the items connected to it.

A two-stage compressor is used to draw vapor out of the receiver in order to maintain it at a relatively low pressure. The compressor is controlled by a pressure switch which starts up the unit whenever the suction pressure rises above its set point (typically around 5 PSIG).

Typically a two-stage compressor is used because it is capable of handling higher compression ratios than the single-stage units used for liquid transfer operations. Reliable operation at high compression ratios is crucial during summer months because high vapor pressure in the storage tank results in high compression ratios (10 or more) across the scavenger compressor (atmospheric pressure to 200 PSIG or more). Using a single-stage compressor for scavenger operations would result in over heating and extremely poor volumetric efficiency in many situations.

CORKEN has designed a very compact scavenger unit for small bulk plants (See Figure 3.5A). This design uses the CORKEN model 190 two-stage compressor in a -109 mounting configuration mounted on a 60 gallon tank. This way the hot gas from the compressor discharge can be used to help vaporize any liquid propane remaining in the bottom of the tank (See Figure 3.5A). The discharge vapor is fed back to the main bulk storage tank after it exits the cooling pipe through the receiver tank. The discharge vapor recondenses into liquid after being "bubbled" through the liquid in the main storage tank.

For large bulk plants CORKEN can custom design scavenger systems with higher capacities using larger CORKEN compressors.

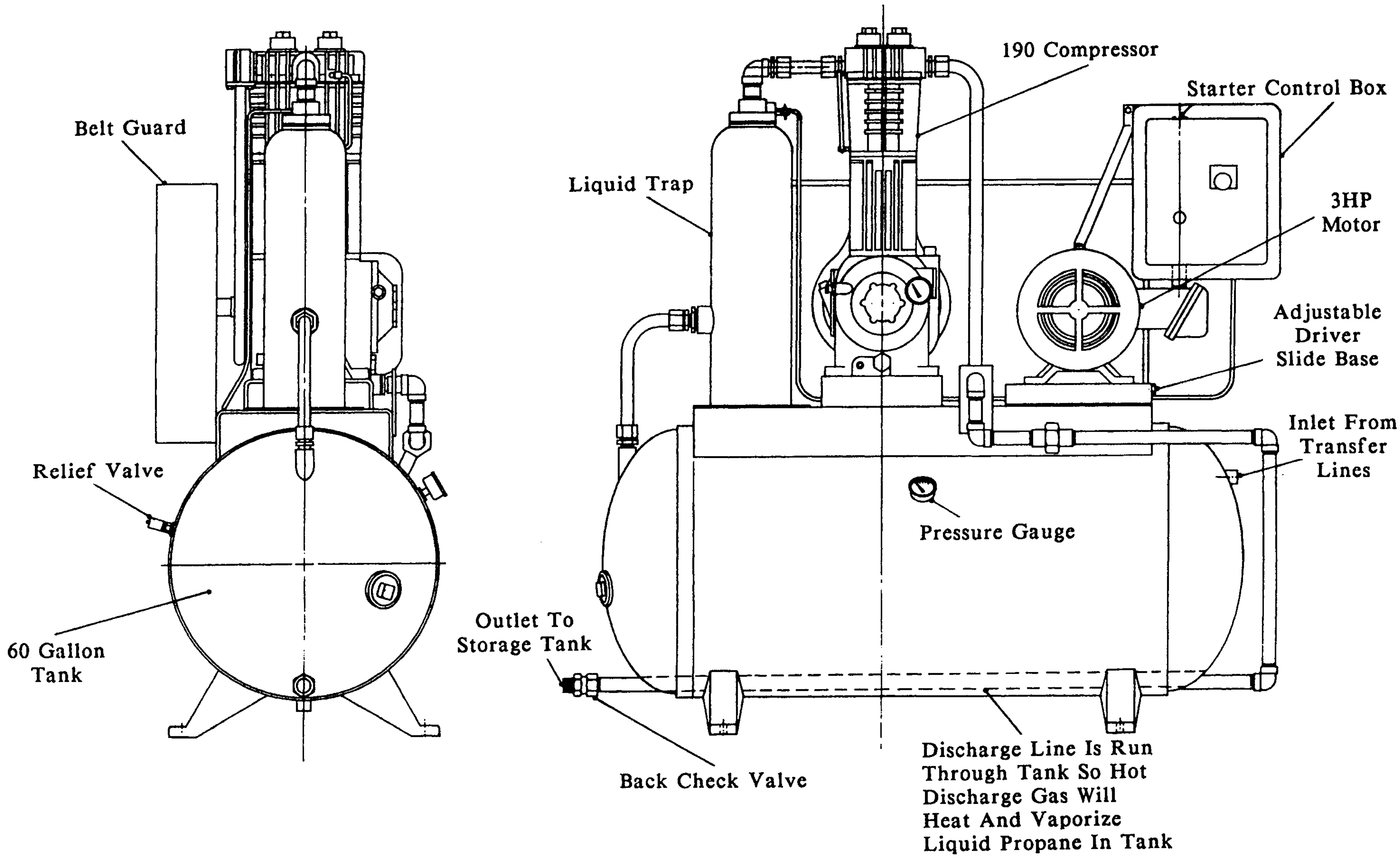


Figure 3.5A CORKEN Gas Scavenger

CHAPTER 4
Accessories

4.1 The Coro-Jet Ejector

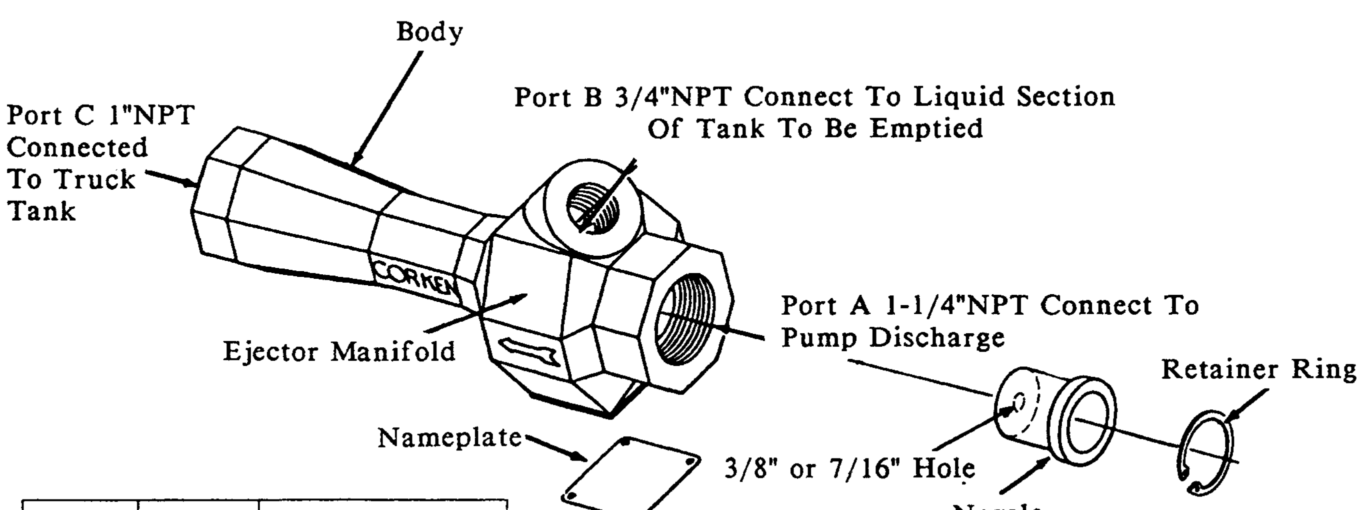
The newest member of the CORKEN family of LP gas equipment is the Coro-Jet Ejector.* Until the introduction of the Coro-Jet, the evacuation of small stationary tanks with bob-tail trucks left operators with a number of undesirable choices. One method was to empty the tank with the truck pump's auxiliary inlet. This results in running the pump dry with considerable resultant wear. Another choice was simply to vent the tank to a flare. This resulted in the waste of valuable propane. The only really good solution was too expensive to be practical - mounting a compressor on the truck to create a differential pressure between the tanks.

The Coro-Jet Ejector offers an economical solution to the problem. The Coro-Jet works in conjunction with the truck pump to create a low pressure suitable for emptying a tank. The truck's pump continues to operate in a "wet" state throughout the entire evacuation cycle.

Ejector pumps use a venturi to convert some of the fluid's potential energy (energy from the fluid's pressure) to kinetic energy (energy from velocity) by accelerating the fluid. This energy conversion results in the pressure of the fluid being reduced. The reduced pressure can then be used to create a pressure difference between two points to induce a flow. The flow rate created by the Coro-Jet is usually between 5 to 10 GPM depending on the piping and flow rate of the pump.

The construction of the Coro-Jet is extremely simple and highly reliable. Propane is pumped into Port A and forced through the nozzle. The nozzle accelerates the liquid and causes a reduced pressure in the manifold which causes liquid from the tank being evacuated to be drawn in through Port B (See Figure 4.1B). Port C discharges back into the tank. The pump simply circulates the propane through the ejector system and never runs dry.

*Patent Pending



MODEL	NOZZLE DIA.	APPROXIMATE PUMP FLOW RATES
CJ125A	3/8"	35 TO 60 GPM
CJ125B	7/16"	55 TO 100 GPM

Figure 4.1A Coro-Jet Assembly*

On new trucks, CORKEN recommends the installation shown in Figure 4.1B. In this design, the Coro-Jet is placed ahead of the meter and reel so the pump can provide maximum pressure to the Coro-Jet. On existing trucks which lack a special tank opening for the jet, the design in Figure 4.1C may be utilized. This design utilizes the standard tank openings on a bob-tail truck.

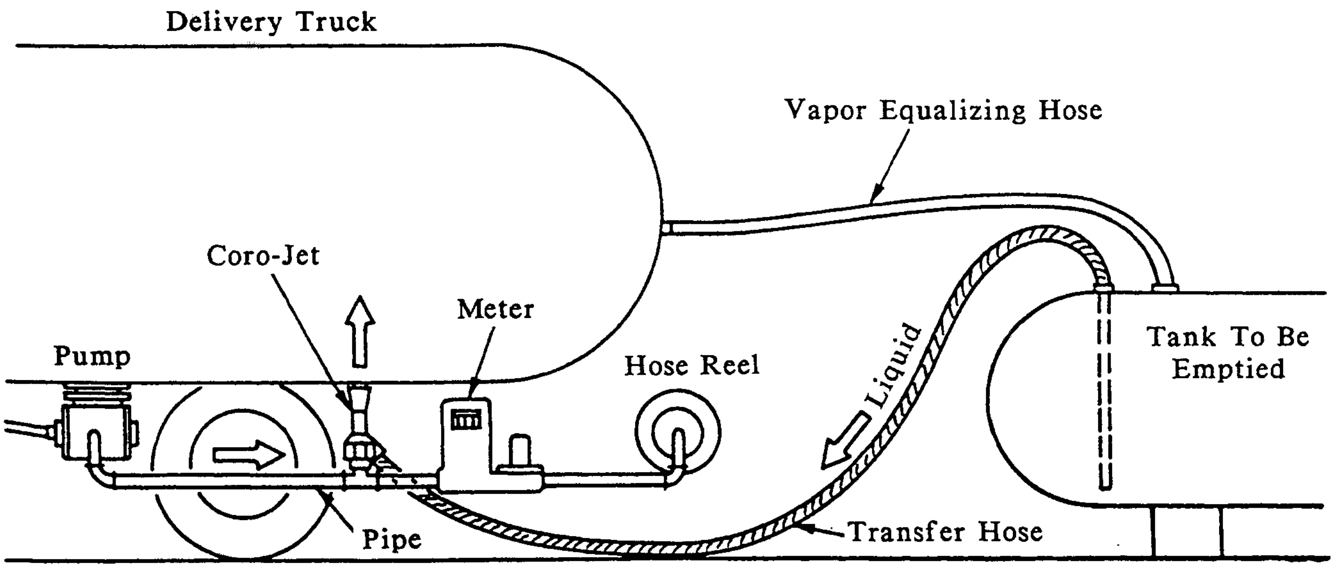


Figure 4.1B Suggested Coro-Jet Installation (For New Trucks)

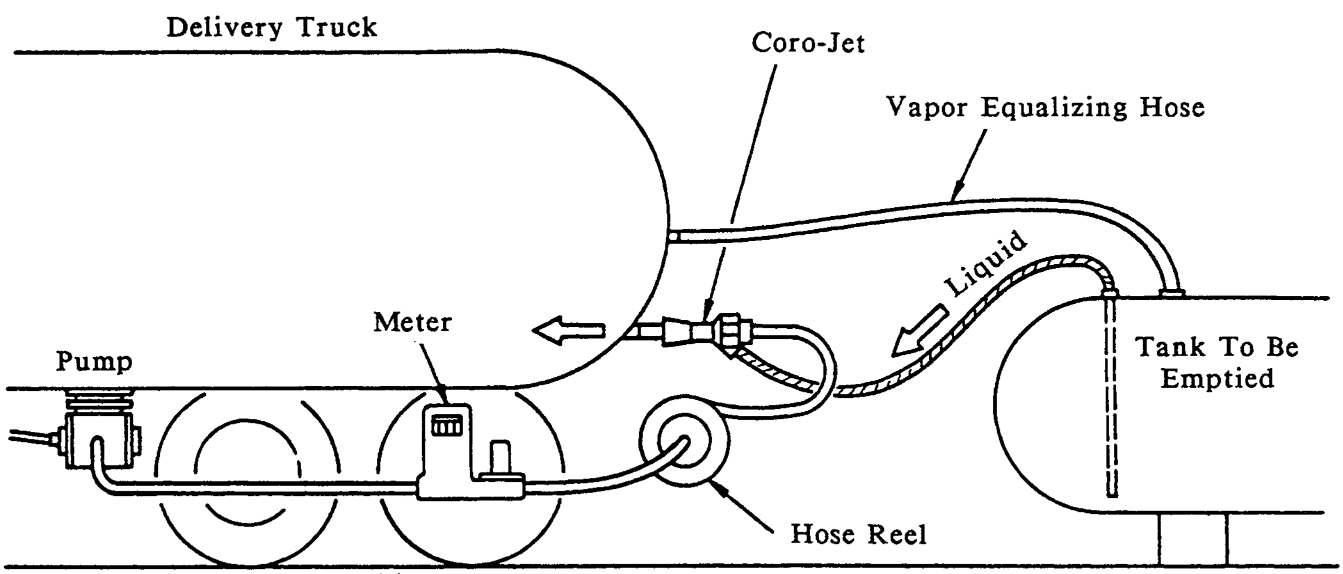


Figure 4.1C Alternate Coro-Jet Installation (For Existing Trucks)

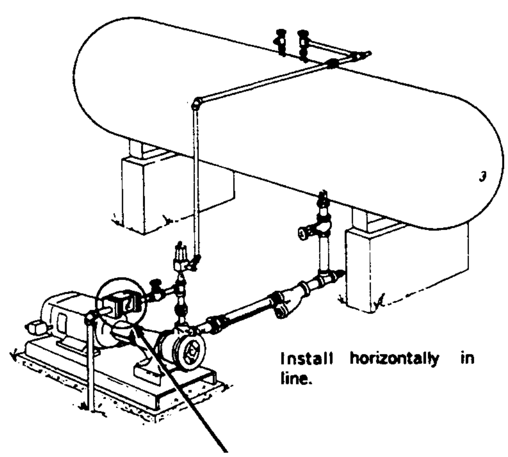
4.2 The Flo-Chek Valve

Check valves are an indispensable part of many LP gas pump systems. A check valve is a simple device that allows liquid to flow in only one direction. The majority of these valves are used in two types of applications on LP gas pumping systems.

1)On pumps with long discharge lines, a check valve should be installed as shown in Figure 4.2A. This prevents vapor formed in the discharge line from displacing liquid in the pump. The pump primes more quickly when it is filled with liquid than when it is filled with vapor.

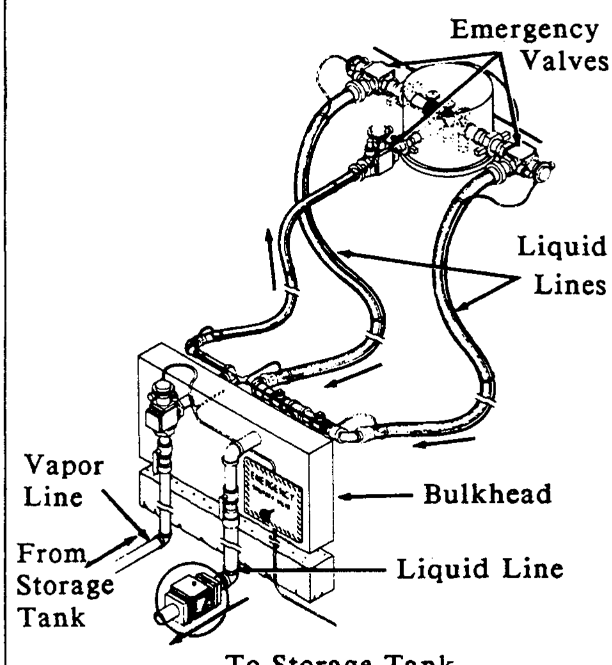
2)On tank car unloading systems, a check valve may be used on the incoming liquid line to the bulkhead (See Figure 4.3B). If the hose to the incoming liquid line ruptures, the direction of flow is reversed. Reversing the direction of flow causes the check valve to close off and stop flow of the storage tank to the atmosphere.*

*For more information on emergency valves See Chapter 9 of LP-Gas Transfer Systems and Equipment by the National LP Gas Association, 1301 West 22nd St., Oakbrook, Ill. 60521.



Flo-Chek Valve On
Pump Discharge

Figure 4.2A



Flo-Chek Valve Used
On A Tank Unloading System

Figure 4.2B

The check valve manufactured by CORKEN, the Flo-Chek, also contains a flow indication device. The valve construction is shown in Figure 4.2C. An external pointer is connected to the valve flapper through a seal assembly. The operator may determine the flow conditions by observing the position of the pointer. If the pointer is pointed straight down, the valve is closed and there is no flow. If the pointer flutters, the valve is partially open and flow is erratic. If the pointer is 45 to the right and not fluttering, the valve is full open.

The Flo-Chek valve has two important advantages over regular check valves:

1)The operator may determine when a transfer operation is complete by watching the pointer.

2)The flow conditions indicated by the pointer can be very helpful to troubleshooting problems with the transfer system.

CORKEN manufactures the Flo-Chek valve in sizes 1-1/4" through 4". These sizes correspond to the complete range of CORKEN pumps.

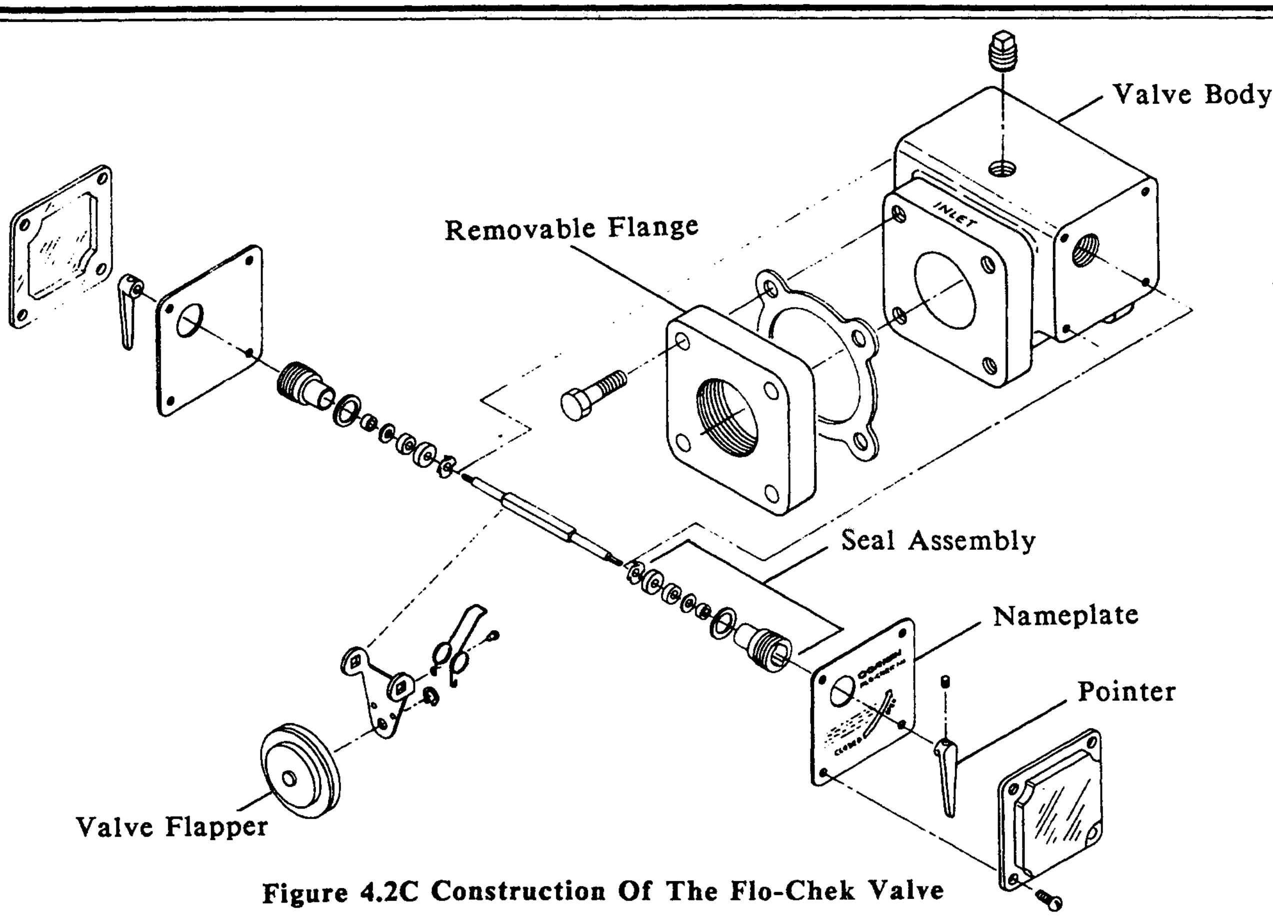
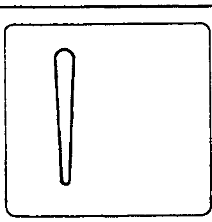
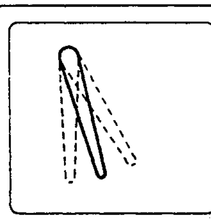


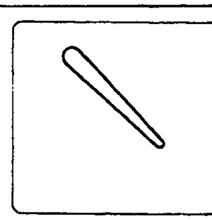
Figure 4.2C Construction Of The Flo-Chek Valve



No Flow
When pointer is down, there is no flow in system. Valve is closed.



Erratic Flow
Unstable position indicates vapor or cavitation. Valve is partially open.



Full Flow
When pointer is in position shown, there is flow in the system. Valve is completely open.

Figure 4.2D

APPENDIX A
Liquified Gas Data

GAS	'N'	MW	SPECIFIC GRAVITY LIQUID WATER=1	LIQUID VISC. CP @ F	MATERIAL TO USE ICA BNVT
Anhydrous Ammonia NH_3	1.31	17.0	0.62	.2 @86	AXA AAXA
Butadiene C_4H_6	1.12	54.1	0.63	.15@60	AAA ABAA
1-Butene C_4H_8	1.10	56.1	0.60		
N-Butane C_4H_{10}	1.09	58.1	0.58	.2 @60	AAA ABAA
Carbon Dioxide CO_2	1.28	44.0	0.82	.13@0	AAA ABXA
Chlorine Cl_2 *	1.36	70.8	1.40	.4 @32	AXX XXXA
Dimethylamine DMA	1.15	45.1	0.65	.19@77	AXX XBBA
Dimethylether DME	1.11	46.1	0.63	.3@100	AAA XXAA
Ethane C_2H_6	1.19	30.1	0.37		AAA AAAA
Ethyl Chloride C_2H_5Cl *	1.19	64.5	0.92	.8 @60	AAA AAXA
Ethylene/Ethene C_2H_4	1.22	28.1	0.57		AXX XXXA
Ethylene Oxide C_2H_4O	1.20	44.1	0.87	.3 @32	BXX XXXA
Hydrogen Chloride HCl *	1.40	36.5	1.05		AXX XXXA
Hydrogen Sulfide H_2S	1.32	34.1	0.99		AXB XXXA
Isobutane	1.09	58.1	0.56	.2 @60	AAA ABXA
Isobutylene	1.10	56.1	0.60		AXX XXAA
Isopentane	1.07	72.2	0.72	.2 @68	AXX AXXA
Methyl Acetylene Propodiene MAPP			0.56	.1 @77	AXA XBAA
Methyl Chloride CH_3Cl *	1.28	50.5	0.94	.2 @86	AAX XXAA
Monoethylamine		45.1	0.68		AXX XXXA
Monomethylamine MMA	1.20	31.1	0.66		AXX XXXA
N-Pentane C_5H_{12}	1.07	75.2	0.63	.2 @68	AXX AXAA
Propane C_3H_8	1.13	44.1	0.51	.1 @68	AAA AAAA
Propylene/Propene C_3H_6	1.15	42.1	0.52		AXX XXAA
Refrigeration Gases:					
R11 (MF)	1.11	137.4	1.50	.4 @86	AAA AXAA
R12	1.14	120.9	1.35	.2 @86	AAA AAXA
R13	1.17	104.5	0.94	.4 @95	AAA AAAA
R21	1.18	102.9	1.42	.4 @77	
R22	1.18	86.5	1.23	.2 @86	AAA XAXA
R112 (BF)		204.0	1.59	1.2@77	AAA A AA
R113 (TF)	1.09	187.4	1.59	.6 @86	AAA AXAA
R114	1.08	107.9	1.49	.4 @86	AAA AAAA
R115	1.08	154.5	1.25	.3 @77	AAA BAAA
R1301/R13B1 Halon	1.18	149.0	1.42	.2 @77	AAA AAXA
R502	1.13	111.6	1.24	.2 @80	AAA AAXA
Sulfur Dioxide SO_2 **	1.29	64.1	1.39	.3 @86	ABB BBBA
Sulfur Hexaflouride SF_6	1.07	146.1	1.37	.35@70	AAA AAXA
Trimethylamine TMA	1.18	59.1	0.62	.2 @77	
Vinyl Chloride VCM CH_2:CHCl	1.18	62.5	0.91	.2	AXX XBAA

* Chrome Oxide Piston Rods should be considered.
** Ethylene Propylene O-Rings should be used.

I - Iron
C - Copper
A - Alum

B - Buna N
N - Neoprene
V - Viton
T - Teflon

A - Good
B - OK
X - Do Not use.

APPENDIX B
Approximate Vapor Pressure (PSIA)

TEMPERATURE	°C →	-29	-23	-18	-12	-7	-1	4	10	16	21	27	32	30	43
	°F →	-20	-10	0	10	20	30	40	50	60	70	80	90	100	110
Anhydrous Ammonia	NH_3	18	24	30	39	48	60	73	89	108	129	153	181	212	247
Butadiene	C_4H_6	5	7	9	11	13	17	20	25	30	36	43	51	59	69
1-Butene	C_4H_8					15	18	22	27	32	38	45	53	62	72
N-Butane	C_4H_{10}						15	17	21	26	31	37	44	52	61
Carbon Dioxide	CO_2	215	257	306	360	422	491								
Chlorine	Cl_2	18	23	29	35	43	51	61	73	85	100	117	135	157	178
Dimethylamine	DMA						10	13	17	21	26	31	38	45	52
Dimethylether	DME	12	16	20	25	30	37	46	55	65	77	90	105	121	140
Ethane	C_2H_6	160	188	220	255	294	337	385	438	494					
Ethyl Chloride	C_2H_5Cl						8	11	13	17	21	25	30	36	42
Ethylene/Ethene	C_2H_4	290	335	385	445	510									
Ethylene Oxide	C_2H_4O								15	18	22	27	32	39	46
Hydrogen Chloride	HCl	155	186	221	260	304	358	407	475						
Hydrogen Sulfide	H_2S	54	66	80	96	116	138	162	172	223	258	278	340	385	438
Isobutane				12	15	18	22	27	32	38	45	53	62	73	84
Isobutylene				9	12	15	18	22	27	33	39	46	54	64	74
Isopentane												15		20	
Methyl Acetylene Propodiene	MAPP										109				
Methyl Chloride	CH_3Cl	12	15	19	24	29	36	43	52	62	73	86	100	117	135
Monoethylamine								9	11	14	17	21	26	33	39
Monomethylamine	MMA	5	6	9	11	15	19	24	29	36	44	53	64	76	90
N-Pentane	C_5H_{12}														
Propane	C_3H_8	25	31	38	46	55	66	78	92	107	124	144	165	189	215
Propylene/Propene	C_3H_6	32	39	48	58	73	82	97	113	131	152	175	200	228	258
Refrigeration Gases:															
R11	(MF)							7	9	11	13	16	20	24	28
R12		15	19	24	29	36	43	52	61	72	85	99	114	132	151
R13		126	149	177	205	240	278	320	366	417	473				
R21						8	10	12	15	19	23	28	34	40	47
R22		25	31	39	48	58	70	84	99	117	137	160	185	213	243
R112	(BF)	Boils at 199 F (93 C)													
R113	(TF)											7	9	11	13
R114					8	10	12	15	19	23	28	33	39	46	54
R115		22	28	34	42	51	61	73	86	101	118	137	155	181	210
R1301/R13B1	HALON	49	59	71	84	100	117	137	160	185	211	242	275	312	355
R502		30	36	46	56	67	80	95	112	130	152	175	200	230	260
Sulfur Dioxide	SO_2	6	8	10	13	17	21	27	33	40	49	59	71	84	99
Sulfur Hexaflouride	SF_6	79	97	110	130	150	180	208	245	288	325	370	410	465	505
Trimethylamine	TMA						12	16	19	23	28	33	39	46	54
Vinyl Chloride CH_2:CHCl	VCM				16	19	23	28	34	40	48	56	65	76	88

PRACTICAL TIPS FOR MAXIMIZING PERFORMANCE OF CORO-FLO PUMPS INSTALLED OVER UNDERGROUND TANKS OR ON TANKS WITH LOW FOUNDATIONS

The Corken Coro-Flo Regenerative Turbine Pump has an unrivaled reputation among bottle filling pumps. However, in some underground pumping applications it has received an undeserved reputation for vapor locking in systems where vane pumps don't vapor lock.

The Coro-Flo Regenerative Turbine Pump offers several advantages over vane pumps on underground piping applications. The LP gas liquid pumped from an underground tank is actually boiling as it enters the pump. In effect, the pump must handle a liquid/vapor mixture even after the pump is primed. Vapor is a poorer coolant and lubricant than liquid so more vapor means more wear will occur at rubbing surfaces in the pump. The Coro-Flo Pump reduces these rubbing surfaces to a single mechanical seal, a decisive advantage over vane pumps. The Coro-Flo Pump is also much quieter than vane pumps in most audible frequencies.

The primary advantage of a vane pump over a regenerative turbine is its ability to evacuate vapor from the suction piping against a relative high discharge pressure - in effect, vane pumps can be used as compressors. Regenerative turbine pumps can only move vapor against relatively small differential pressures.

Fortunately, there is absolutely no reason why an LP gas pump over an underground tank should be required to double as a gas compressor. Indeed, any application that forces a pump to act as a compressor will result in unnecessary damage to the pump.

Each time an underground pumping system starts up, the piping between the pump and liquid level in the tank must be evacuated of vapor to prime the pump. A well designed system will only require the pump to slightly pressurize the vapor to push it back into the vapor space of the underground tank. In well designed systems, the Coro-Flo Pump will give superior performance. The practical tips for maximizing performance of underground pumping systems can be split in two groups:

1) Tips to minimize the volume of vapor to be evacuated in order to achieve rapid priming.

2) Tips to minimize the amount of differential pressure required to push the vapor pulled from the suction piping back to the vapor space of the feed tank.

Tips for minimizing the amount of vapor that must be evacuated are:

A) Keep the length of suction line as short as possible (about 5 ft. for 1000 gallon tanks and 10 ft. for 6000 gallon tanks). For 1000 gallon tanks, use models 9, 10, 12, or 15. For 6000 gallon tanks use models 13 or 14.* Not only does this reduce the vapor volume to be evacuated, it holds the amount of vapor the pump must handle after priming to a reasonable level. While vane pumps do tend to generate larger suction lifts than turbine pumps, they spend more and more time as gas compressors and less and less as liquid pumps at the deeper depths. Operating any LP gas liquid pump as a vapor compressor will result in lower capacity, accelerated wear and poor service life. On applications where a vapor return line can be used, LP gas compressors can be used instead of pumps to allow liquid transfer from deeper depths.

B) Don't bury the tank over 1 foot deep.

C) Locate the pump directly over the tank as close to the ground as possible. For best results, rotate the pump head 90^{o} so no bends are required in the suction pipe.

(See Figure A).

---

* This data is based on actual field tests in customer installations.

D) Use 3/4" suction pipe for models 9,10 & 15, 1" for model 12 and 1 1/4" for models 13 & 14.

E) Eliminate the suction strainer (you can rely on gravity to do this job). The strainer creates a pressure drop which causes the vapor to expand before reaching the pump. It also causes more vapor formation to occur in the liquid after the pump is primed.

Tips for minimizing the differential pressure required to evacuate the suction piping:

F) Install a backcheck valve in the discharge line as shown in Fig. A. This is especially important on discharge lines over 20 ft. The backcheck valve isolates the pump from the discharge pressure during priming. On hot days, pressures in the above ground, uninsulated pipe can greatly exceed pressure in the below ground dip pipe. By isolating the higher pressure during priming, the pump can avoid doing double duty as a gas compressor. Make sure to use a soft seat check valve that forms a tight seal when closed (such as the Corken Flo-Chek Valve).

G) Install an excess flow valve as shown in Fig. A (Rego 901H5 or equivalent). This gives the vapor an "easy" low-pressure drop route back to the feed tank during priming. The valve will close as soon as liquid flow exceeds 3 GPM.

H) Use a B166 continuous by-pass valve. This valve routes most of the vapor present at the pump discharge after priming back to the feed tank. This minimizes the possibility of any vapor present at the pump discharge from creating an unstable flow.

I) Vent the vapor eliminator on the liquid meter back to the tank, not to the bypass line. During bypass, pressure will be present in the bypass line. Under this condition, no differential pressure exists to allow vapor to flow out of the vapor eliminator back to the tank.

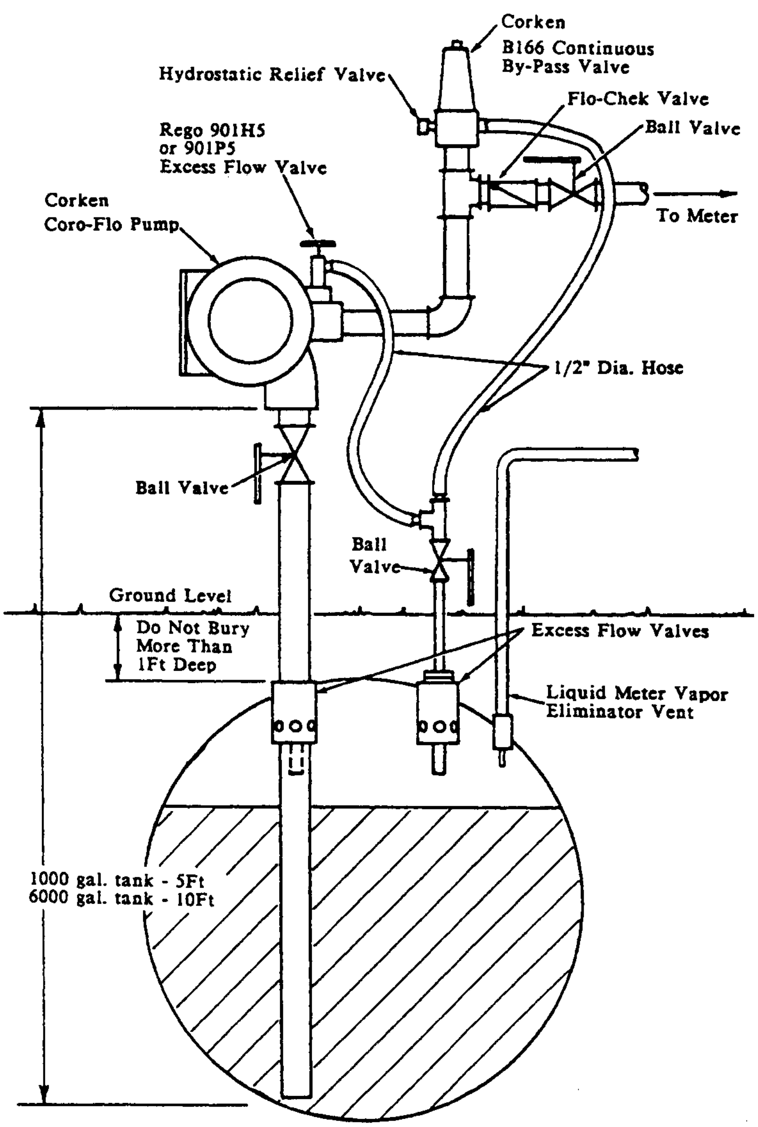
J) Minimize the number of fittings and elbows and only use full flow ball valves in the suction and by-pass piping.

K) Use an excess flow valve instead of a back check valve at the entry of the bypass line into the vapor space of the feed tank. (This is good practice on any system, it is of particular importance on underground systems).

Tips F thru K can also be applied to above ground tank systems with low, little, or no suction head in order to prevent vapor locking Also, some systems have an automatic shutoff valve between the pump and the feed tank. These pumps should be controlled so the shutoff valves open about 15 seconds before the pump starts up.

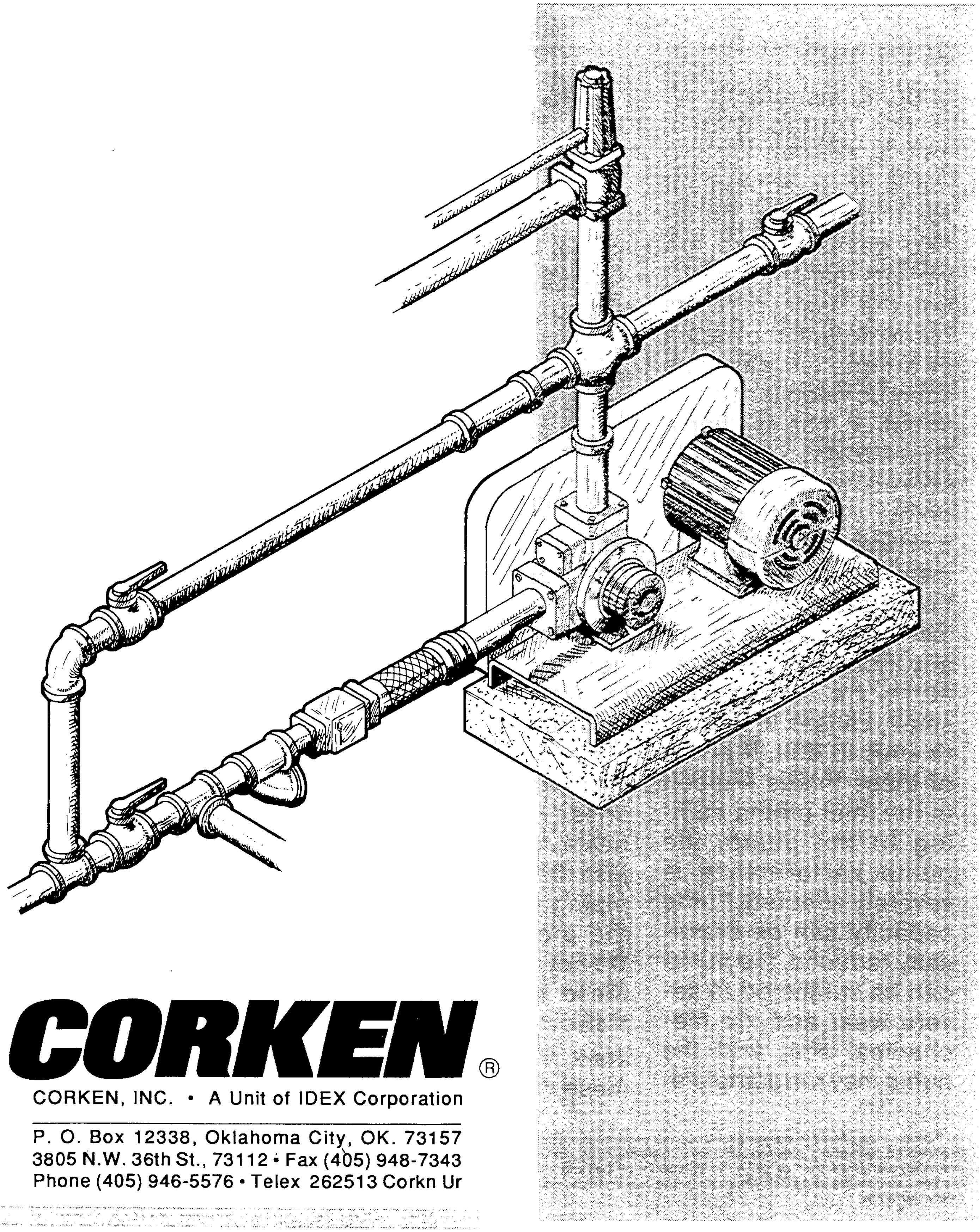
Finally, for best results, installations in 50 Hz countries should V-belt drive the pump so it can be operated at 3600 RPM.

If you are considering an underground installation, we suggest you follow these tips carefully for the best performance. If you have further question on proper installation of Corken pumps over underground tanks, contact Corken. Our customer engineering staff will be glad to help you "do it right the first time".



DESIGN HANDBOOK
LIQUEFIED GAS PUMP INSTALLATION

SUPERCEDES Z400



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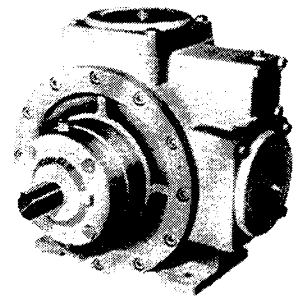
Phone (405) 946-5576 • Telex 262513 Corkn Ur

THE APPLICATION OF PUMPS TO LP-GAS TRANSFER



Of the many hundreds of pump manufacturers in the United States, only a handful recommend their equipment for transferring liquefied gases. There are various reasons for this, but the basic problem has to do with the nature of a liquefied gas. The specific peculiarity of a liquefied gas is that a liquefied gas is normally stored at its boiling point . . . exactly at its boiling point! This means that any reduction in pressure, regardless of how slight, or any increase in temperature, no matter how small, causes the liquid to start to boil. If either of these things happen in the inlet piping coming to the pump, the pump performance is severely affected. Pump capacity can be drastically reduced, the pump can be subjected to severe wear and the mechanical seal and the pump may run completely dry causing dangerous wear and leakage.

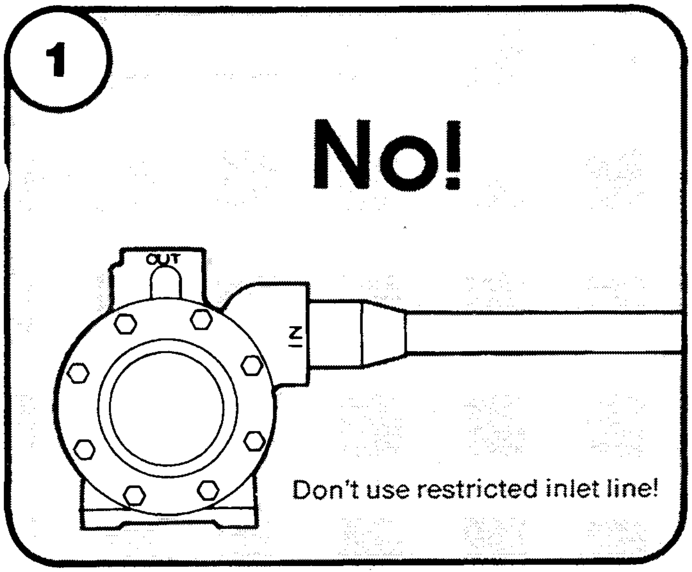
Although we cannot change the nature of the liquefied gas, there are many things we can and must do, to design an acceptable liquefied gas pumping system.

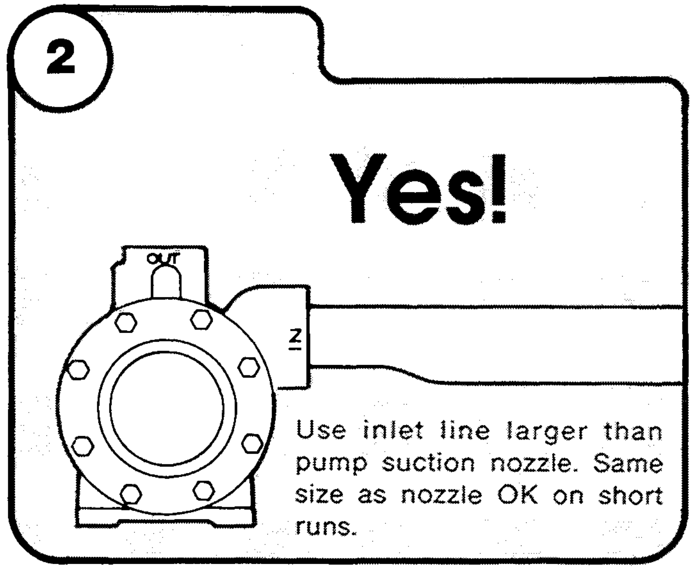
Many of these design hints are incorporated in the accompanying illustrations. You will note that each drawing is over-simplified and illustrates just one principle. Normal fittings, strainers, unions, flex lines, valves, etc. have been ignored so that just that portion of the piping which applies to the problem is shown. **Do not pipe a plant from these incomplete illustrations!** You should also note that all of these rules can be violated to a degree and still have a workable pumping system. You may see several places where your plant is at variance from some of these. However, you should be aware that every violation is reducing your pumping efficiency and increasing your pump maintenance cost. The principles apply to all makes and styles of liquefied gas pumps . . . rotary positive displacement, regenerative turbine or even centrifugal types.

This booklet is used in Corken Training Schools. Corken cooperates with gas marketers, trade associations and other groups to conduct complete training schools for persons involved in the transfer of liquefied gases. These presentations include product information, safety, plant design and equipment service/maintenance. Training slides and cassettes are also available from Corken. Other information is available in various sections of your Corken Catalog.

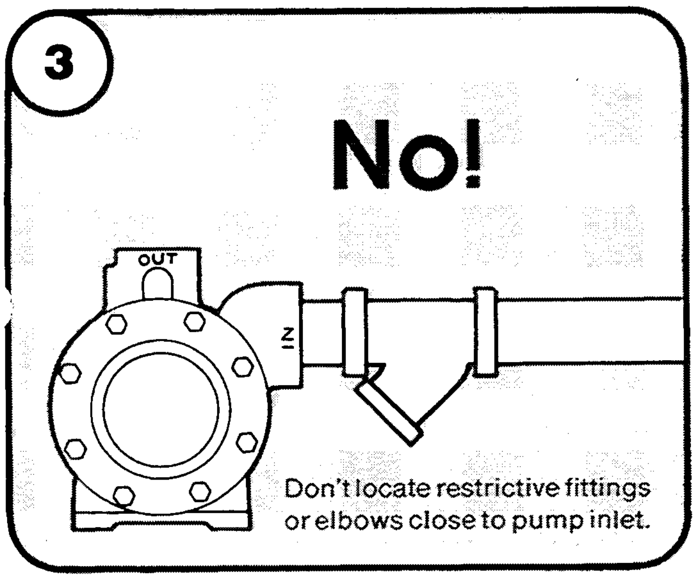
WARNING

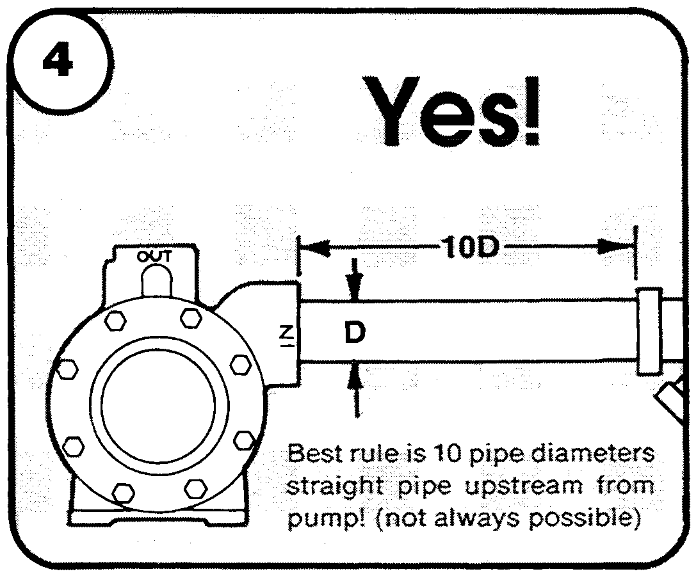
(1) Periodic inspection and maintenance of Corken products is essential (2) Inspection, maintenance and installation of Corken products must be made only by experienced, trained and qualified personnel. (3) Maintenance, use and installation of Corken products must comply with Corken instructions, applicable laws and safety standards (such as NFPA Pamphlet58 for LP-Gas and ANSI K61.1-1972 for Anhydrous Ammonia). (4) Transfer of toxic, dangerous, flammable or explosive substances using Corken products is at user's risk and equipment should be operated only by qualified personnel according to applicable laws and safety standards.



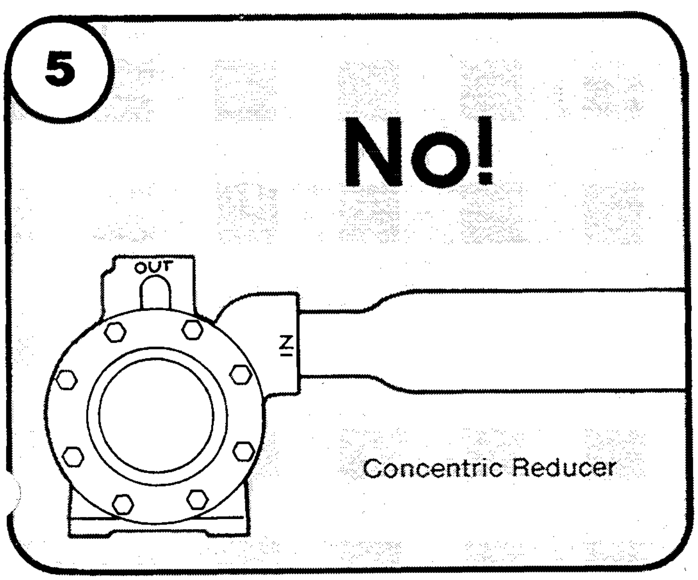


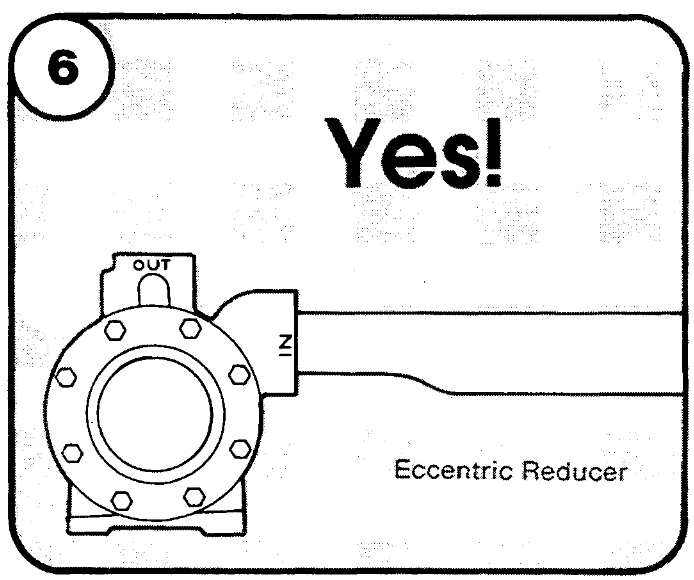
Pressure drop caused by restriction in suction line will cause vaporization and cavitation.



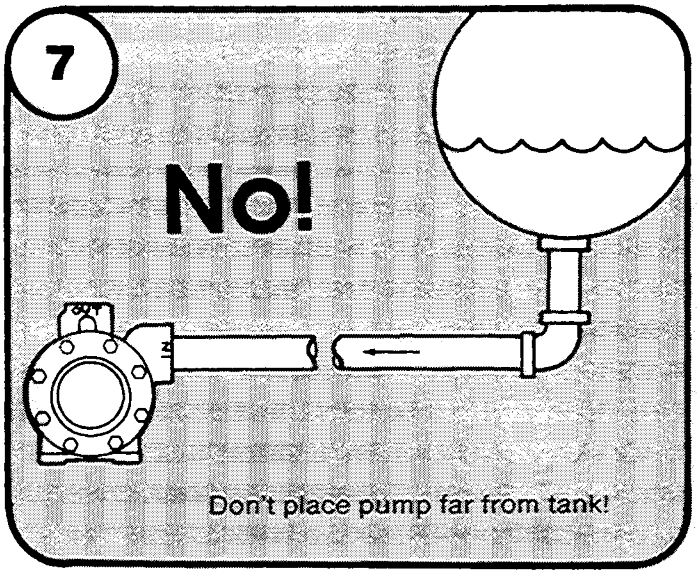


Turbulence caused by flow interference close to the pump accentuates incipiant cavitation.

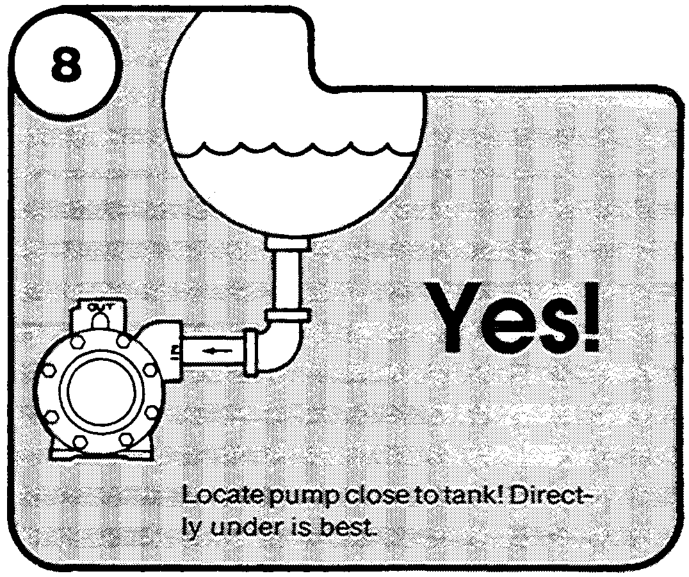




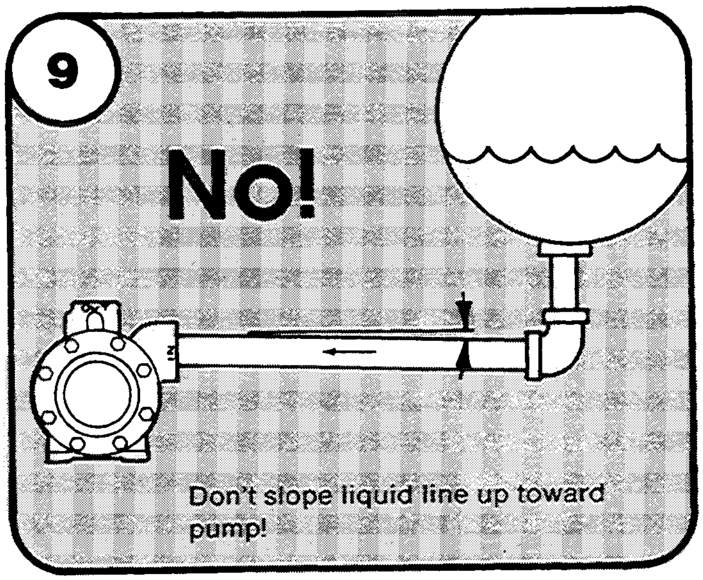
An eccentric reducer should always be used when reducing into any pump inlet where vapor might be encountered in the pumpage. The flat upper portion of the reducer prevents an accumulation of vapor that could interfere with pumping action.



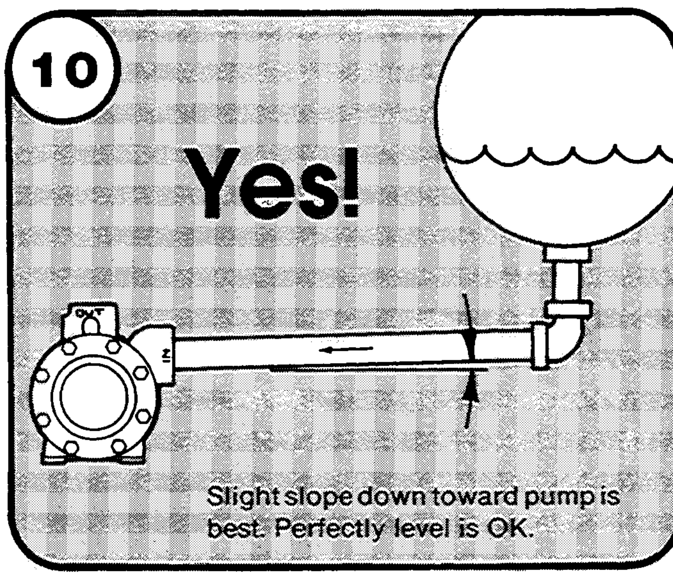
Don't place pump far from tank!



Locate pump close to tank! Directly under is best.

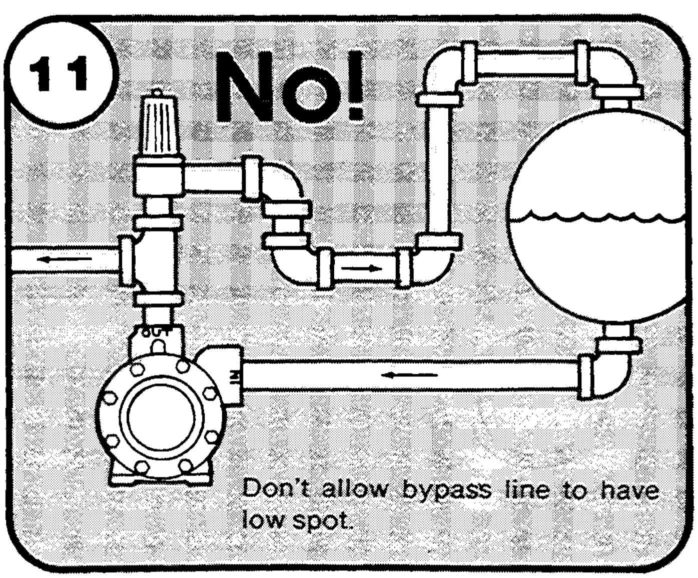


Don't slope liquid line up toward pump!

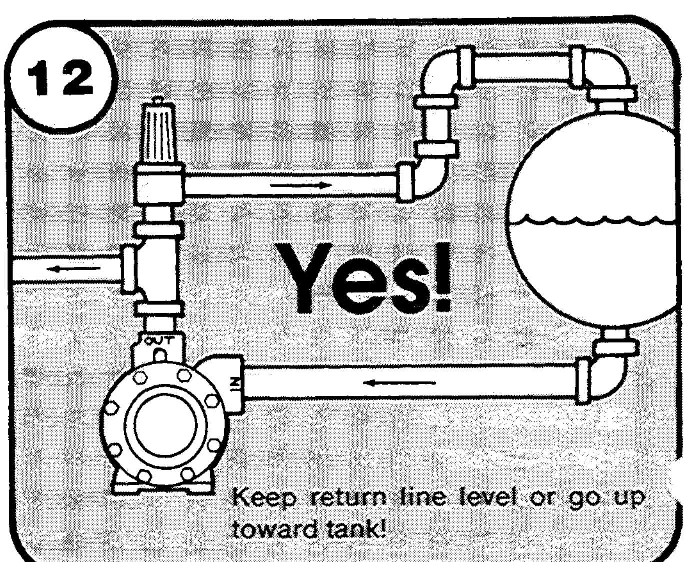


Slight slope down toward pump is best. Perfectly level is OK.

Vaporization in the pump inlet line can displace liquid in the pump so that pump may start up in a dry condition. A slope back toward the tank of only an inch or two in a 10 foot run will allow vapor to gravitate back into the tank and be replaced with liquid.

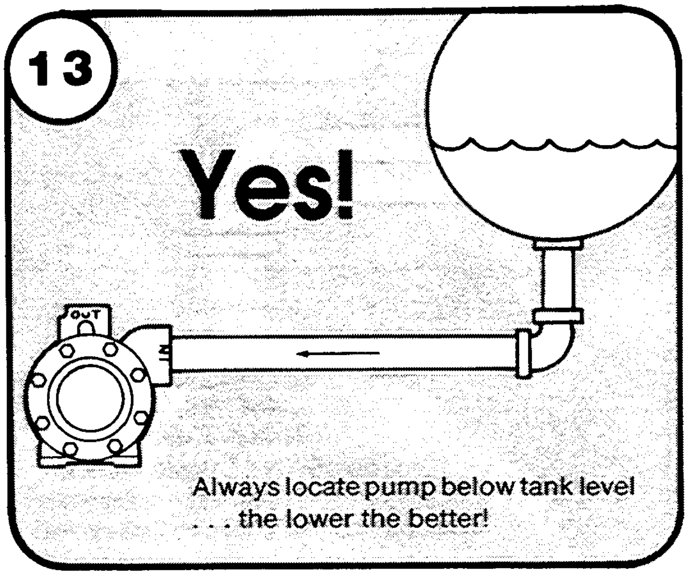


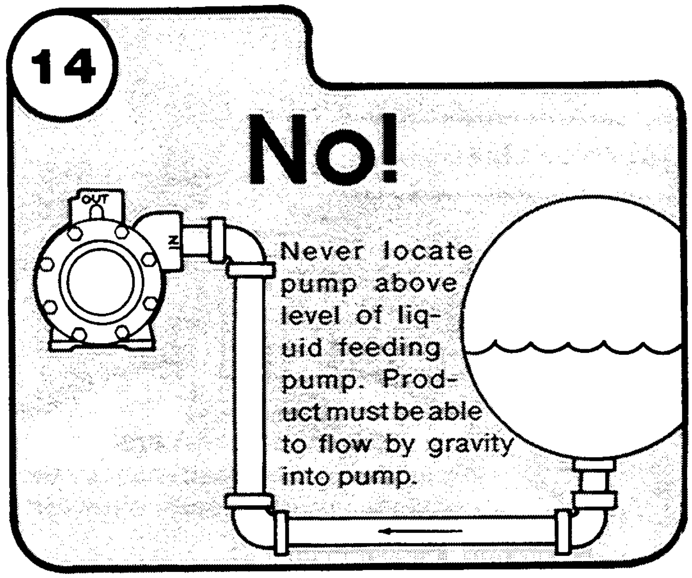
Don't allow bypass line to have low spot.



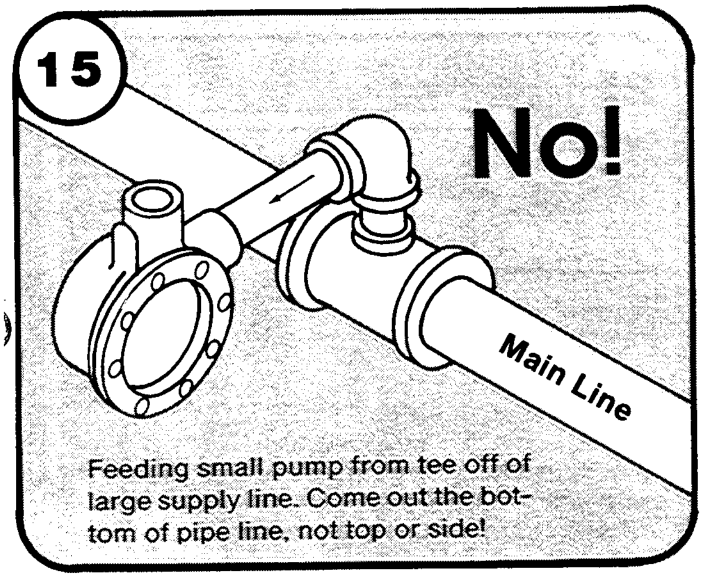
Keep return line level or go up toward tank!

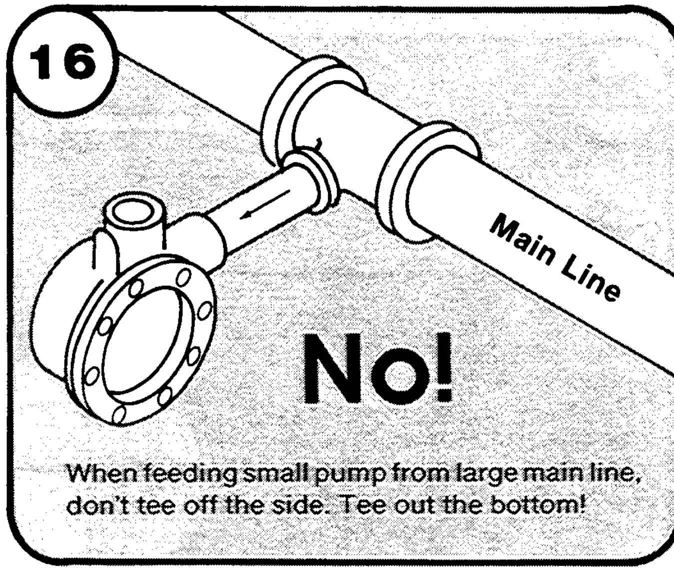
Low spots in bypass line can collect liquid which prevents normal vapor passage for priming purposes just like the P trap in the drain of a kitchen sink. This is not a problem for bypass lines where vapor elimination is not required.



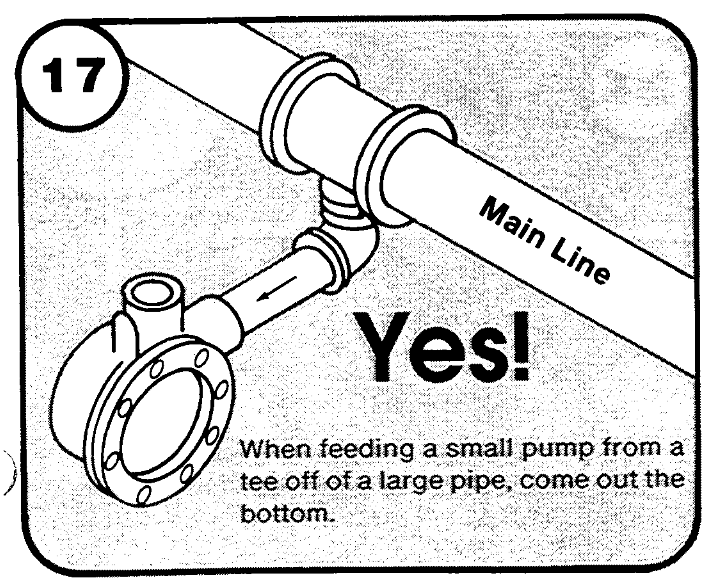


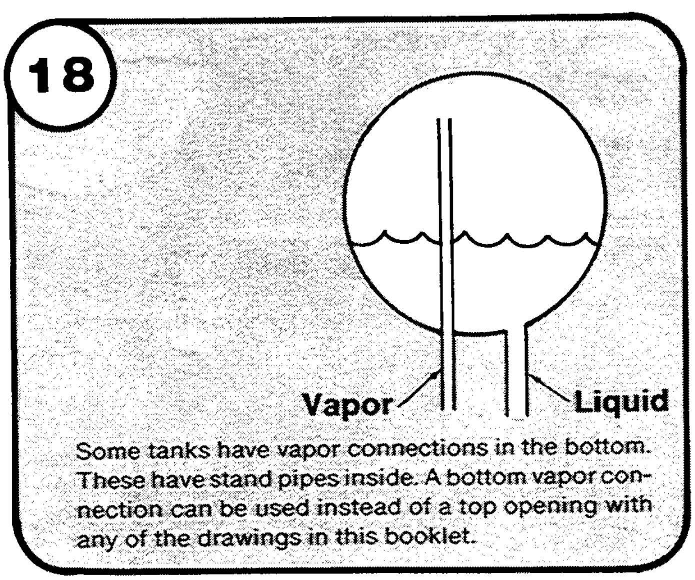
Since liquefied gases boil when drawn into a pump by its own suction, the pump must be fed by gravity flow to give stable, trouble-free operation.

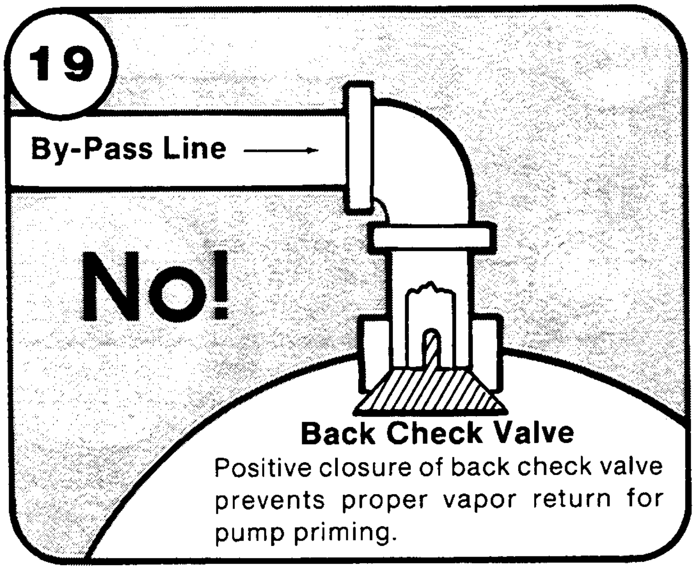


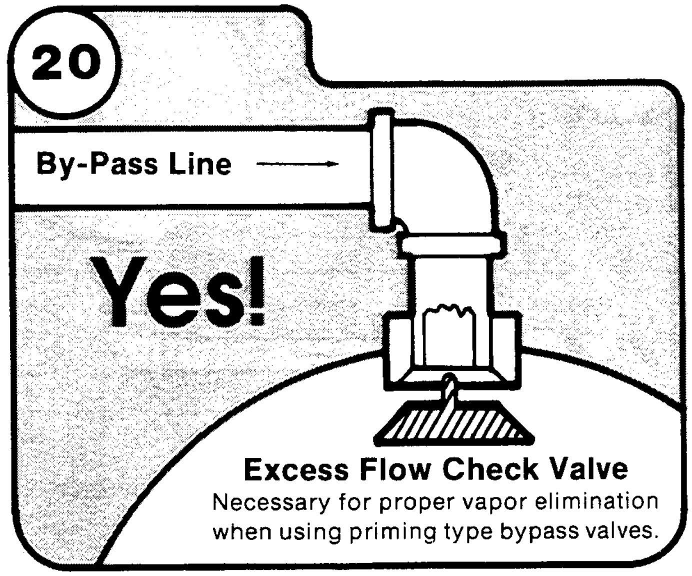


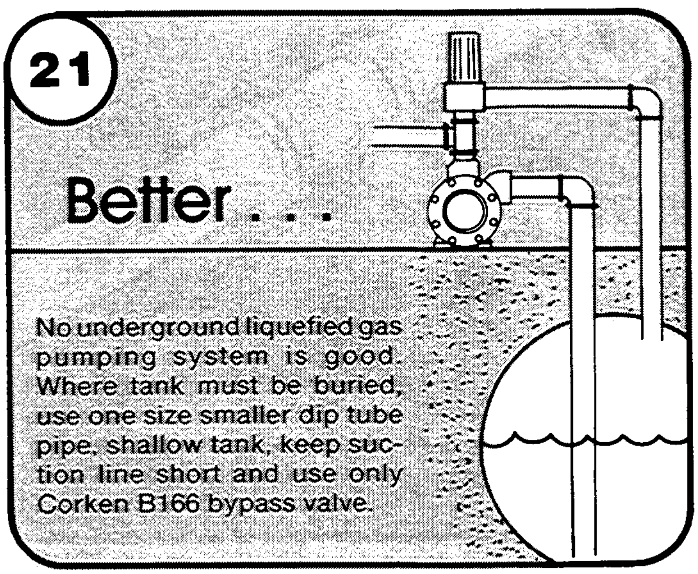
Low capacity flow through large lines often does not sweep out vapor. Flow occurs like liquid in a flume. Drawings 15 and 16 would allow vapor slugs to be drawn into the small pump causing erratic performance. Drawing 17 shows the best chance for stable feed into a small pump from a large line.

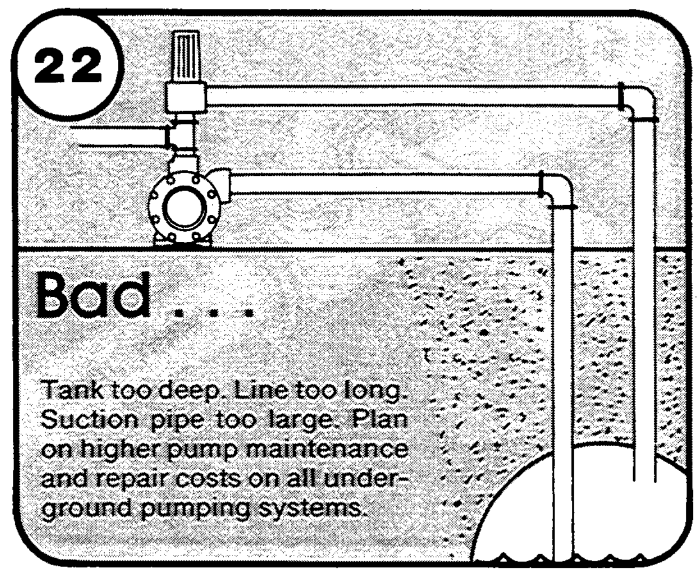




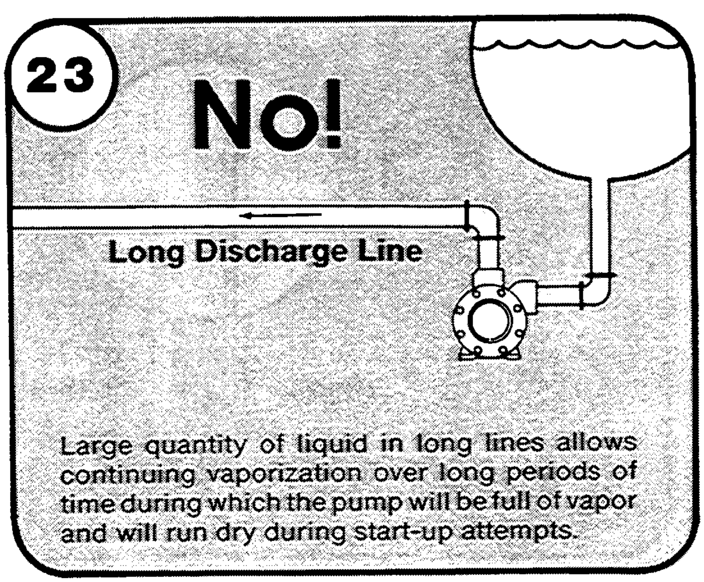


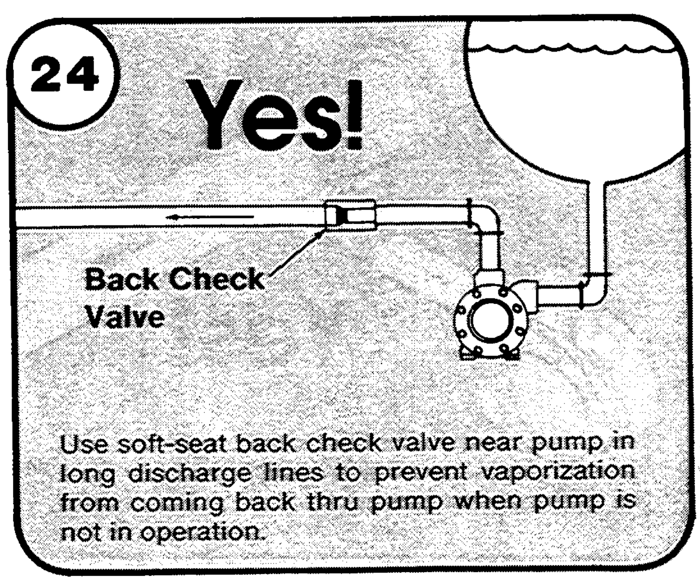






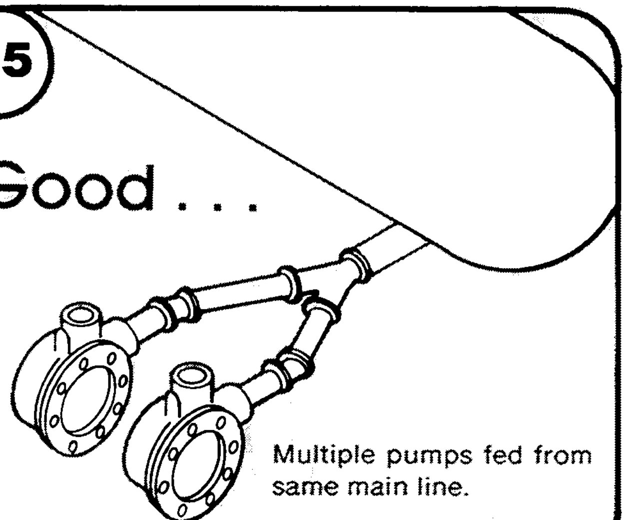
Where pumping from underground storage must be done, consult Engineer Data Page Z402.





25

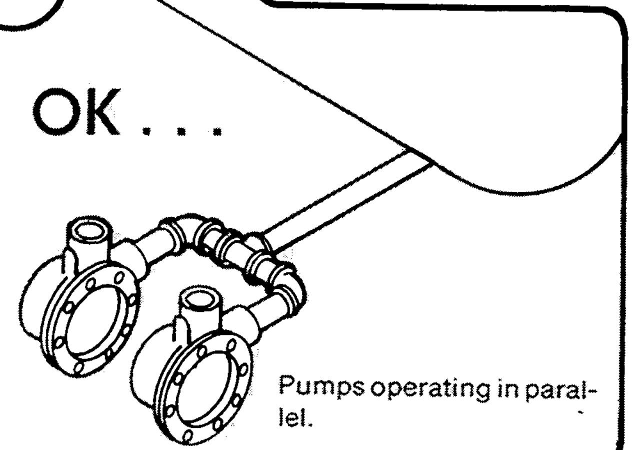
Good . . .



Multiple pumps fed from same main line.

26

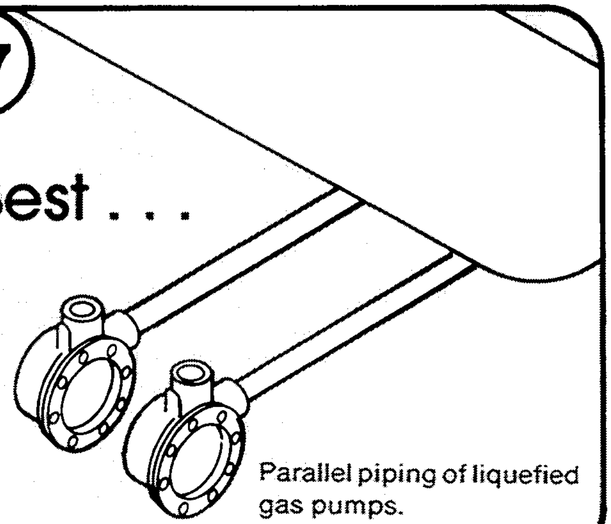
OK . . .



Pumps operating in parallel.

27

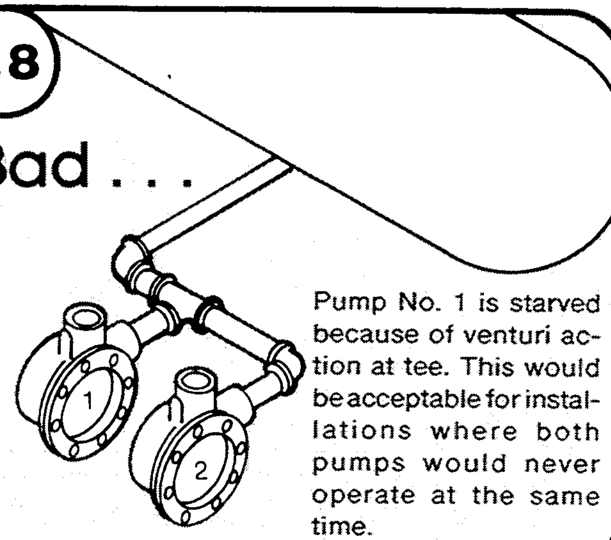
Best . . .



Parallel piping of liquefied gas pumps.

28

Bad . . .

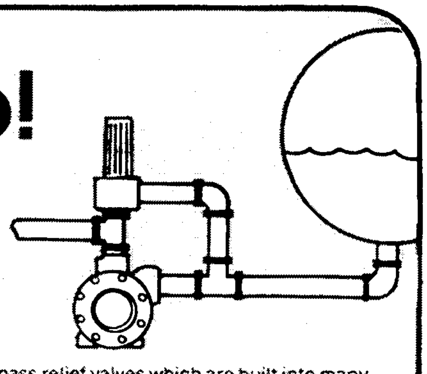


Pump No. 1 is starved because of venturi action at tee. This would be acceptable for installations where both pumps would never operate at the same time.

Inquire about Corken's Duplex-Series Pump Set.

29

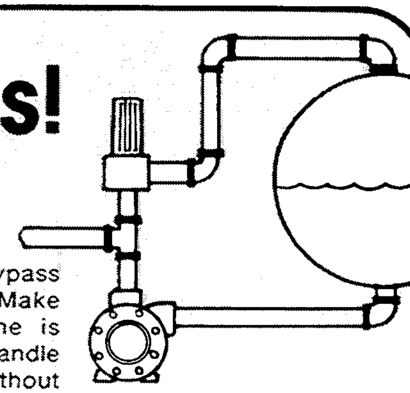
No!



Don't pipe bypass line back into suction piping! Heat Buildup in recirculated products causes flashing of liquid to vapor with immediate cavitation and ultimate dry-running. This is why the bypass relief valves which are built into many positive displacement pumps should not be used for normal bypass action when handling liquefied gases. The internal valve should be considered to be a back-up safety relief in addition to a back-up safety relief in addition to a back-to-tank bypass valve and should be set to relieve at a pressure 10 to 20 psi higher than the working bypass. Some built-in bypass valves have the capability of being piped back-to-tank so check with the pump manufacturer.

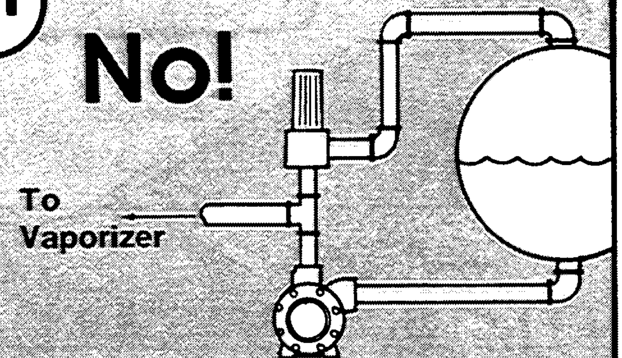
30

Yes!



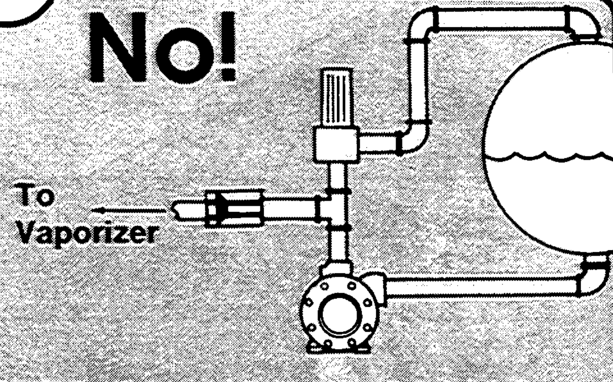
Always pipe bypass back to tank! Make sure bypass line is large enough to handle full pump flow without excessive pressure build-up. Note that bypass line must be capable of bypassing full pump capacity without excessive pressure build-up. High pressure rise can cause bypass valve to chatter and vibrate.

31 No!



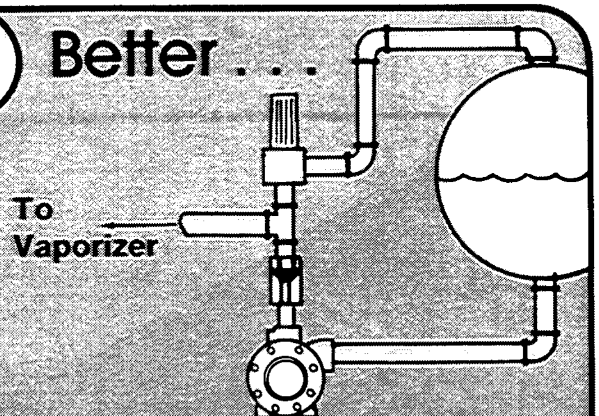
On vaporizer feed pumps, a back check valve should be installed between pump and vaporizer to prevent back-flow of vapor from entering pump.

32 No!



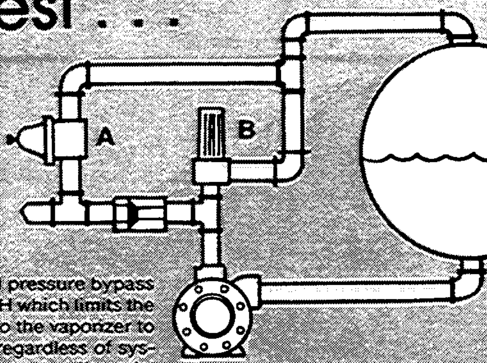
Back check must be located to allow back-flow into tank from vaporizer.

33 Better . . .



Back check valve protects pump but allows back flow thru bypass valve into storage tank. **Use back check without spring loaded valve to allow normal vapor elimination.**

34 Best . . .



Where A is a constant pressure bypass control valve and B is Corken B166 bypass and vapor elimination valve.

Valve A is a fixed pressure bypass like the Fisher 98H which limits the feed pressure into the vaporizer to a specific value regardless of system vapor pressure. A differential bypass valve like the Corken B166, T166 or B177 controls a fixed difference in pressure between the pump discharge and the tank. Differential valve B must be set to the maximum acceptable differential of the pump while fixed pressure valve A is set for the vaporizer pressure requirement.

35 CORKEN B166 BY-PASS VALVE FUNCTIONS

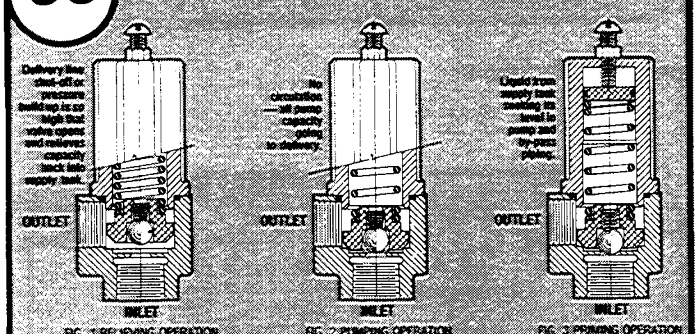


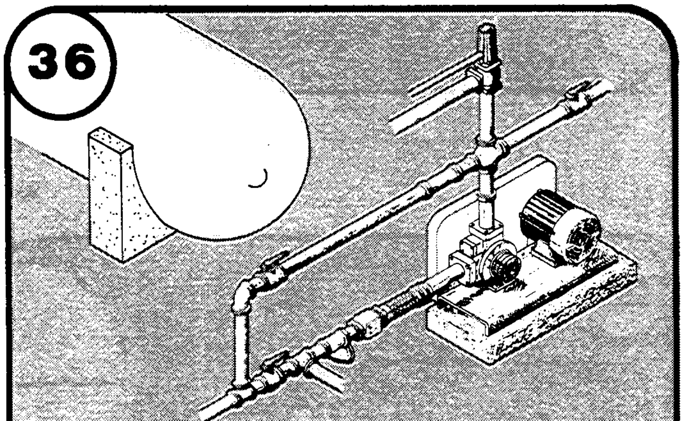
FIG. 1 RELIEVING OPERATION OPEN

FIG. 2 PUMPING OPERATION CLOSED

FIG. 3 PRIMING OPERATION OPEN

For pump capacities under 100 GPM, use a bypass valve with built-in vapor elimination where possible. Like Corken's B166 or T166 Valves.

36



Some bypass valves, like the Corken B177, require tank pressure sensing lines. Check instructions for your valve.

SUMMARY

1. MINIMIZE PRESSURE LOSSES IN PUMP SUCTION LINE. PRESSURE DROP CAUSES INCREASED VAPORIZATION WHICH, IN TURN, CAUSES DECREASED PUMP PERFORMANCE AND INCREASED PUMP MAINTENANCE.
2. AVOID VAPOR TRAPS IN PUMP SUCTION LINE AND LIQUID TRAPS IN PUMP BYPASS LINES. VAPOR POCKETS IN THE PUMP INLET CAUSE ERRATIC PUMP PERFORMANCE AN LIQUID POCKETS IN BYPASS LINES INTERFERE WITH VAPOR ELIMINATION FROM THE SYSTEM.
3. CONTROL VAPOR FROM BACKING UP INTO PUMP FROM THE DISCHARGE LINE.
4. MINIMIZE HEAT BUILDUP IN THE PUMPING SYSTEM BY PIPING BYPASS LIQUID BACK TO THE TANK RATHER THAN DIRECTLY TO THE PUMP INLET.
5. MAXIMIZE THE ELEVATION DIFFERENCE BETWEEN THE TANK AND THE PUMP.
6. ALWAYS USE EQUIPMENT APPROVED FOR USE WITH LP-GAS AND CAREFULLY FOLLOW THE REQUIREMENTS OF NFPA
7. DO NOT PIPE A PLANT FROM THE DRAWINGS SHOWN HERE. THEY ARE SCEMATIC ONLY AND INTENDED TO ILLUSTRATE SPECIFIC PIPING PRINCIPLES.

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