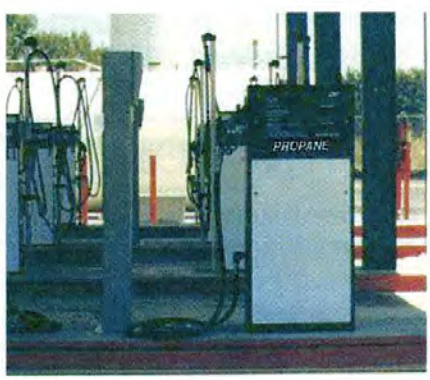
SMITH
PUMPS

"Success through Quality"

AL-36
(BOOKLET A)
(Rev. E)

HANDLING LIQUEFIED GASES EFFICIENTLY WITH POSITIVE DISPLACEMENT PUMPS



ISO 9000
AMERICAN INTERNATIONAL REGISTRARS CORPORATION

SMITH PRECISION PRODUCTS COMPANY
P.O. Box 276, Newbury Park, CA 91319 USA
1299 Lawrence Drive, Newbury Park, CA 91320 USA
Tel.: 805/498-6616 FAX: 805/499-2867
e-mail: SMPUMP1299@aol.com **web: www.smithpumps.com**

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1. THE IMPORTANCE OF PROPER PUMP DESIGN AND OPERATION

It should be noted that the concepts presented in this booklet, and other literature from Smith Precision, whether empirical, or theoretical, are strictly from the viewpoint of a pump manufacturer. Proper system design requires a site-specific engineering study, with due regard for all of the applicable local, State, and Federal codes and regulations, such as those promulgated by the NFPA, DOT, and ANSI.

SINCE liquefied gases are among the most difficult of all liquids to pump, the industry is indeed fortunate to have the cooperation of a number of competing pump manufacturers. Some manufacturers are specialists in the field, and are vitally interested in manufacturing pumps that meet the exacting requirements of liquefied gases under operating conditions. All would agree that the pump must be properly installed and properly operated, to obtain the best results for the user. In order to provide a pump that will do the transfer job safely and efficiently, the operator and manufacturer have found it desirable to cooperate in such matters as installation, operating procedures, and maintenance programs.

This booklet briefly describes the installation requirements, common to the usual makes and types of liquefied gas pumps, that handle low-pressure liquefied gases, such as LPG, CO_2, and NH_3. Techniques are suggested relating to operation and maintenance that will give added life to existing pumping systems, and that if followed, will improve the design of future pumping systems. Installation and maintenance manuals provided by the pump manufacturers relate in detail to their particular units. The pump user should *always* obtain such printed matter covering equipment that he is considering through the manufacturer's home office or sales representatives. Often such information, prepared at considerable expense, is available without charge, or at nominal cost.

In addition to pertinent safety regulations, and instruction manuals provided by the manufacturers, this booklet is intended to outline a generalized basis for proper pump installation and operation. Those who correctly run and service the pumping equipment, will definitely add a significant percentage of life to the transfer system. Many manufacturer's representatives often assist with training sessions, and safety certification programs are frequently made available through local authorities.

The Pump is the Heart of the System.

The pump is the heart of the liquefied gas transfer system. Both the pump manufacturer and the pump user are well aware that the pump is one of the most necessary pieces of mechanical equipment in the transfer process. Product cannot be handled if the pump is not working properly. The end user must not only insure that the right pump is chosen, but he must also install it properly, use it carefully, inspect, and repair it often enough to keep efficiency high. With careful attention, handling costs can be kept to a minimum. However, if the pump is installed improperly, or if the pump is abused, it will give very inefficient service, and greatly increase product handling costs.

Choosing the Best Pump for a Particular Operation

Many different sizes and use-specific models of pumps are available for handling liquefied gases, ranging from high to low capacity, and for applications from transfilling to recirculation. It is not economical to use a pump too large for actual needs, nor one too small for high flow when required. To select a pump which is right for the need, the manufacturer's recommendations must always be taken into consideration.

How to Select the Right Pump

In order to make a worthwhile recommendation, the manufacturers or their representatives, must always have complete information about application requirements, such as:

1. What liquids are to be pumped? If there is a mixture of liquefied gases, what is the percentage of each component? What contaminants are present in the product handled? What percentage of the pumped fluid are they?
2. Is this a recirculation system? Will the pump be "on" for more than 1-½ hours continuously? What is the maximum use interval?
3. Are tanks to be filled? If so, what sizes are filled? (Specify water volume capacities.) How many tanks of each size will be filled in a day?
4. What is the capacity of the tank(s) that the pump will draw from during this operation? What is the size of the liquid outlet in the pump

supply tank? Is this outlet in the bottom, end, side, or top, of the tank?

5. List the temperature range of the liquid(s).

6. Is the pump to be used in a mobile system, or is it to be mounted in a permanent location? What drive speed range is available? Will it be driven by air, hydraulic, electric motor, engine, or PTO? If driven by an electric motor, indicate phase and voltage of electricity available. If a motor already acquired is to be used, be sure to specify the label plate information, such as horsepower, speed, and frame number.

7. Is the pump to be installed in a new installation? (In this case, the pump manufacturer will send information on a proper piping system for the pump.)

8. Is the pump to be used to replace another in an existing installation? In this case, a rough sketch showing piping, valves, and fittings will be helpful. After reviewing this information, the manufacturer may be able to suggest a few minor changes that would improve pumping efficiency and service life. The sketch will be of greatest value if it shows the elevations relative to the pump, size and lengths of piping, along with the pipe size and types of all valves and other equipment in the lines.

9. What is the differential pressure required? Will a pressure equalizing line be used? If filling tanks, will a pressure equalizing line be used only when filling some tanks, or all tanks? Describe under what conditions it will, or will not, be used.

10. What is the flow rate desired? *Bear in mind that the pump output is limited by its piping system.* There is also a practical limit to filling speed for most tanks. The higher capacity pumps have the highest initial costs, and are more expensive to install, operate, and repair.

Initial Pump Cost Versus Long Run Economy

When several pump manufactures are asked for their recommendations and prices on a pumping unit to do a certain job, there will probably be a considerable variation in quoted initial costs. As is the case when buying most other kinds of equipment, lowest costs in general may mean lesser quality, and highest costs in general may mean higher quality. In many cases it is therefore not in the buyer's best interest to purchase on an initial cost basis alone. A pump may be intended for many years of service. In such cases, the long-term over-all cost is a more important factor. Higher priced pumps may have more application-specific options, last much longer between overhauls, pump with higher efficiency, and fill tanks faster. Such pumps are a better buy in the long run. Check with the manufacturer.

2. IMPORTANCE OF AUXILIARY TRANSFER SYSTEM EQUIPMENT

Proper choice of flow-limiting safety valves ("excess-flow check valves", or "internal valves"), strainers, and bypass valves, is important not only for safety reasons, but for reducing pump wear as well. The safety valve, or excess flow valve at the tank outlet should be of a size and type that is correct for the capacity of the pump. If a separate strainer is required, it should protect the pump without being a serious restriction to flow. The "primary", or "external" bypass valve, of course, is necessary to limit pressures to a safe maximum.

"Section 7." of this booklet discusses the importance of the proper location of the pump near the storage tank from which the liquefied gases will be supplied. The technical discussion in that section also describes piping installations that are properly sized so that liquid will flow by gravity to the pump in sufficient quantity to overcome adverse effects of flow resistance, vapor displacement, and heat gain, even during initial flow acceleration. Recommended sizes of pressure equalizing lines, are also considered briefly in "Section 7.".

Flow-Limiting Safety Valves

Flow-limiting safety valves, or excess flow valves, are often required to be installed in functional vapor or liquid ports, and especially in those that handle LPG liquid (see NFPA-58). These valves are required for safety, which does not necessarily correspond to their suitability to feed a line carrying liquefied gas to a transfer pump. *Suitability from a pumping standpoint depends upon the resistance to flow.* The lower the resistance to flow, the better for the pump. However, for safety reasons, great care must always be exercised in choosing the appropriate flow-limiting safety valve ("excess-flow check valve", or "internal valve"). Follow the valve manufacturer's warnings and recommendations. Comply with all applicable local, State, and Federal codes and regulations. See "Section 7." in this booklet.

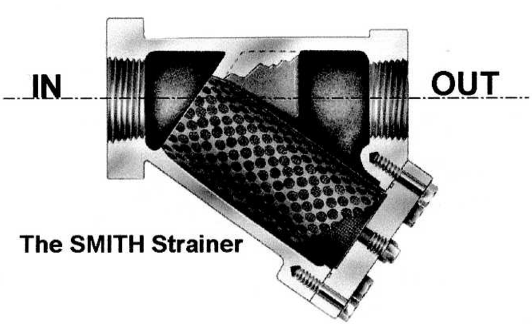
Strainers

In certain specialized services, strainers are either not required, or cannot be used due to excessive product contamination. However, in most cases their utilization is highly recommended. A strainer prevents solid matter such as weld-shot, rust, or tank scale, from entering the pump. If not incorporated into the supply tank's internal outlet valve assembly, an external strainer should always be installed in the inlet line between the supply tank, and the pump. Slightly corrosive impurities in the liquid handled may cause scaling, or rusting, in tanks that have been in service for some time. Of course, tanks that are taken out of service and have outlets open to atmosphere may accumulate considerable oxidation and/or moisture over a period of months. A few models of pumps have built-in strainers, but most do not. A separate external strainer is usually available from the pump distributor. To select a good strainer, consider the following points:

1. The strainer should be of the size and type that will not restrict the flow of liquid to the pump. Choose the next larger size than is used for piping if possible. Select one that has a large screen area. Screen areas differ between different makes in the same pipe size.

2. Choose a strainer that is easy to open for cleaning. A flanged opening to the screen is far easier to open than the plug type.

3. Be sure the screen is fine enough to trap small abrasive particles. A perforated screen with 1/16- in. or 1/32-in. holes is not very satisfactory. Select one made of wire cloth, with a particle entrapment capability of between .012 - .017 thousandths of an inch. Normally, this corresponds to the "40 x 40 Mesh" standard. Screens that are finer than 40-mesh protect pumps better, but may cause constant trouble by requiring frequent cleaning.



The SMITH Strainer

External strainers are inexpensive, and they last a long time (only the screen needs replacement). Good strainers are good insurance against pump damage. An external strainer should be installed where it can be worked on easily. Ease of maintenance is especially important in mobile installations, since an inconvenient location will probably result in infrequent cleaning of the screen. The screen should be inspected frequently to see that it is not broken, and that it fits the strainer body properly. Clean the screen as often as necessary, so it will not restrict the flow of liquid to the pump.

If the system has an external strainer, think of it first, at any time when pumping efficiency drops off suddenly. The screen may be completely blocked by accumulations of solid matter from an unusually dirty product load. If an internal valve is installed in the system, follow the proper safe disassembly procedure when it needs to be cleaned or replaced. Check with the equipment manufacturers, and the appropriate safety authorities in your area. Keep extra screens and/or parts on hand, as required.

Bypass Valve Selection

A bypass valve installed in the pump discharge line:

1. Protects the pump from working against excessive differential pressures, which might cause excessive wear.

2. Prevents electric motor overload (especially in bulk plant units).

3. Provides a safety feature to relieve pressure in the event the pump is operated against closed valves or a filled tank, through error (a safety code requirement.)

4. Bypasses part of the pump output when a high-capacity pump is used to fill small tanks that will not accept full output.

5. Helps to prevent excessive pumping system discharge pressure.

Many pumps available to the liquefied gas market have built-in bypass valves. Whether the pump has an internal valve or not, the transfer system requires an external bypass line. *Table 1* can be used as a guide in selecting the proper size external valve.

Several names for bypass valves are in common usage, including "safety valves", "relief valves", and "differential valves". All common bypass valves may be divided into two general types, "spring-actuated" and "diaphragm-actuated". Most external bypass valves are all of the spring-actuated type, as are the bypass valves that are built into pumps. Spring-actuated bypass valves are the least expensive, are easiest to install, and are satisfactory in every way except for the possibility of occasional chattering noise. The diaphragm-actuated valves are larger, more expensive, and require the installation of a tube or pipe connection to the tank vapor phase. Diaphragm valves seldom chatter.

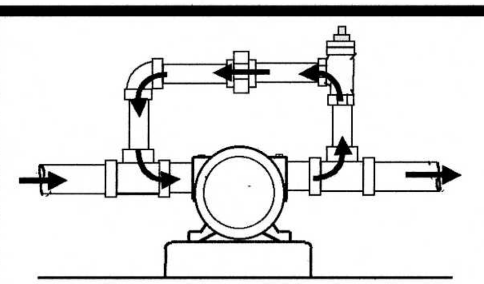


Fig. 1. The "Short Circuit" Bypass

***TABLE 1.* BYPASS VALVE SELECTION**

Capacity of Pump	Pipe Size of Bypass Valve
TO 10 GPM	1/2-in.
10 - 15 GPM	3/4-in.
15 - 35 GPM	1-in.
35 - 50 GPM	1 1/4-in.
50-100 GPM	1 1/2-in.
100-150 GPM	2-in.
150-250 GPM	2-1/2-in

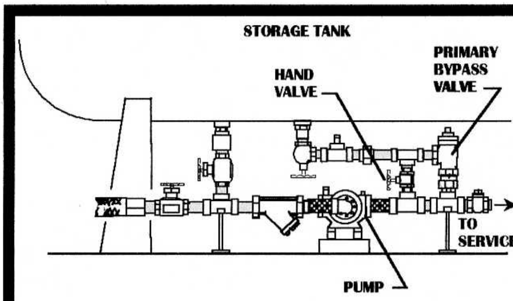


Fig. 2. Recommended Bypass Installation

SMITH BYPASS VALVES

Model	Size	Weight
WW-120	1/2-in.	9 lbs.
WW-340	3/4-in.	9 lbs.
WW-100	1-in.	12 lbs.
WW-114	1 1/4-in.	12 lbs.
WW-112	1 1/2-in.	12 lbs.
WW-200	2-in.	25½ lbs.
WW-212	2½-in.	25½ lbs.

Installation of Bypass Valves

External bypass valves can be piped into the pumping system in two ways. (*Figs. 1 and 2*). *Fig. 1* shows a "secondary" bypass valve set in a tee in the pump discharge line, with the bypass outlet piped to return to the pump inlet line. This arrangement is only satisfactory if there is a "primary" bypass valve set at a lower pressure which discharges back to the supply tank (see appropriate LPG safety regulations such as NFPA-58). Otherwise, the "short circuit" bypass will react the same way as an internal bypass valve. When activated, it causes immediate pump cavitation and vapor lock. The back-to-suction bypass can be said to be satisfactory in theory, but only if the pump is always stopped as soon as each transfer operation is completed. In all likelihood, such a system would cause many problems for the pump, and it is therefore only recommended as a "secondary" bypass system, to back-up the "primary" system in case it fails to function properly.

Primary bypass valves should be set to open at least 25 PSID less than the setting of the secondary (internal or external) bypass valve. This will insure that the back-to-pump valve will not open, during normal operation.

The fundamental reason for avoiding the "short circuit" bypass arrangement is that the recirculation of liquefied gas through a bypass valve would allow instantaneous excessive product vaporization within the pump, due to frictional heat accumulation. Even partial continuous recirculation for a period of one minute or less generally forms enough vapor to vapor-lock the pump. Resultant lack of liquid cooling effects usually causes fast pump wear, and excessive vapor causes difficulties in starting the liquid flow into the pump the next time it is used. When the bypass valve discharges to the storage tank, heated vapor is returned to the tank, where it can dissipate. The vapor is not recirculated, so it cannot build-up in volume, and can cause no trouble.

Bypass Valve Setting: The setting of a bypass valve is of the utmost importance. The maximum setting as per safety codes, or as stamped on the pump label plate, is not necessarily the proper setting for the system, or for the pump. The bypass valve setting must be properly matched to the system's capabilities, the pump use interval, and the appropriate pump drive speed. The recommended differential pressure must take all related functional installation aspects into consideration. These require a proper engineering study.

For example, the maximum allowed by Underwriters Laboratories, Inc. under Standard "UL-51" for LPG pumps, is 125 PSID. This recommendation is made on the basis of safety to prevent pressure overloading of the entire delivery system. By this safety criterion, a definite hazard results if the setting is higher. Unfortunately, an incentive exists to go to higher settings, because it is assumed that higher settings speed deliveries, especially when vapor return lines are not used. However, settings higher than 125 PSID are definitely not safe in the usual installation.

Unless all conditions are studied carefully from both functional as well as safety standpoints, and certified for higher pressures by the designated Authorities, bypass settings should be initially limited to 75 PSID, or less, for LPG bulk transfer and cylinder filling applications. Most common pumps not utilized in strictly intermittent service, especially when run continuously for more than 1-½ hours, must be run at less than their maximum design speeds, and should not be required to build maximum differential pressures. *There are some exceptions.* See other available literature, and contact the manufacturers for complete information.

In liquid Carbon Dioxide intermittent bulk transfer operations, we recommend a maximum bypass valve setting of 50 PSID. This recommendation not only relates to the highly polarized nature of the fluid in question, with its inherent lack of lubricity, but also to the maximum safe system discharge and storage pressures. Pumps utilized for CO_2 transfer under other conditions may require lower speeds, and lower differential pressure limitations. Contact the factory for additional information.

As far as the bulk transfer pumps are concerned, handling liquefied Anhydrous Ammonia at average ambient temperatures is very similar to LPG transfer. In these cases, the recommended bypass valve setting is 75 PSID. However, there are other common types of transfer, which require different limitations. These include continuous transfer, and accumulator vacating. Contact the factory for additional information.

Hand-Operated Bypass Valves: *Fig.* 2 shows a hand bypass valve piped around the standard spring-actuated external bypass valve. If the pump in a bulk transfer installation ever becomes vapor-locked, the hand bypass valve (which can be just an ordinary approved globe, angle, or ball valve, the same size as the bypass valve) may be opened, so that the vapor will be purged easily from the lines, as it flows back to the storage tank, at essentially "0" PSID.

Vapor can be formed by heat acting on the pump and pipe lines when it is not in use. This heat can come from a number of sources. With pumps mounted near the ground, the heat can come from sunlight; with pumps mounted on trucks, from the engine exhaust pipe, or from heated air blown past the engine. Pumps can pick up heat when mounted in heated, or partly heated structures, and also from other pipes carrying warm or hot fluids running too close to liquefied gas pipes. When vapor forms, it is important to get rid of it. An open valve in a pipeline running back to storage is the most direct, and safest route. Ordinarily, the hand bypass valve can be left open for less than a minute, and then closed, after which pumping will proceed normally. Improper insulation can cause excessive absorption of heat in a typical refrigerated CO_2 transfer system. In such cases, it may be necessary to cool the system down slowly by blowing-off product to atmosphere until ejected liquid is observed. Contact the safety authorities, and the factory for additional information on this and related subjects of concern.

3. LOW CAPACITY PUMPS

A "low capacity pump" is a unit called upon to deliver at a rate of 15 USGPM or less. Most of these pumps (such as the "E" and "D-Series") are utilized exclusively for *individually* filling small LPG cylinders or tanks, from 2 to 100 USG capacities. Other models are for continuous recirculation, or for vacating small tanks under specialized circumstances. *In typical individualized LPG and NH_3 cylinder filling, such small pumps can fill single cylinders without vapor connections just as fast as larger pumps, because cylinder valves will accept product only at these slow rates; with a large pump, the extra capacity will be wasted by running back to the storage tank through the bypass valve.* These small pumps are also used to fill up to 100 USG tanks on occasion, where fast filling is not important. Small pumps have many important advantages, including a lower first cost. The installation is less expensive because piping, valves, and fittings in smaller sizes can be used.

Specialized LPG carrousel cylinder filling systems are not covered in this discussion. Contact the factory for additional information as required.

With low capacity CO_2 pumps, tank filling is usually not accomplished without connecting a vapor return line. However, under unusual circumstances, cylinders are surge-filled in stages, between cycling periods of vapor pressure relief back to cold storage. Normally a specialized piston pump is recommended for these operations. In no case should a standard CO_2 pump ever build differential pressure exceeding 50 PSID. Contact the factory for additional details.

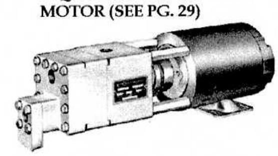
Sometimes bulk plants require high capacity pumps to unload tank cars with outlets which are not overly restricted by required safety valves ("ESV's"), and/or truck transports, and to load delivery trucks or tankers, in a short time. At such plants, if occasional filling of small tanks is also necessary, it is very wise to purchase a second small pump. A large pump can be worn out unnecessarily if used to do a low volume job. The repair cost of a large pump may cost as much as a separate small pump. With two pumps at a plant, one can serve as a working spare. The piping can be adapted so that when service is interrupted unexpectedly, the second pump can do both jobs during the emergency period.

Small pumps require smaller motors, which can be operated on ordinary Single Phase current. Less power is used, reducing expense of electricity. Upkeep costs are less because all parts are smaller and less expensive to replace, and in some designs, the working parts are of simpler construction. If small tanks are filled, one-at-a-time, it is a mistake to purchase a large pump. Of course, if there are many small tanks to fill, a larger pump can be provided with an appropriate manifold. Several tanks can then be filled at once, taking full advantage of the larger pump's increased capacity. Continuous duty under these circumstances requires special consideration, with different use limitations.

"SQ-SERIES" PUMPS WITH MOTOR (SEE PG. 29)

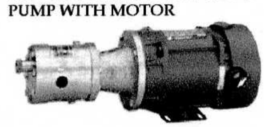
750 - 1800 RPM RANGE (CO_2, NH_3)

2 - 13 USGPM NOMINAL OUTPUT RANGE



GENERIC MODEL TYPE "MC-1" PUMP WITH MOTOR

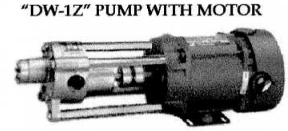
750 - 3600 RPM RANGE (LPG)
750 - 1800 RPM RANGE (CO_2, NH_3)
4 - 10 USGPM NOMINAL OUTPUT RANGE (LPG)
2 - 5 USGPM NOMINAL OUTPUT RANGE (CO_2, NH_3)



"DW-1Z" PUMP WITH MOTOR

1500 - 3600 RPM RANGE (LPG ONLY)

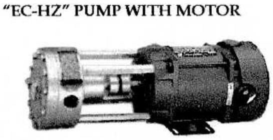
4 - 10 USGPM NOMINAL OUTPUT RANGE



"EC-HZ" PUMP WITH MOTOR

1500 - 3600 RPM RANGE (LPG ONLY)

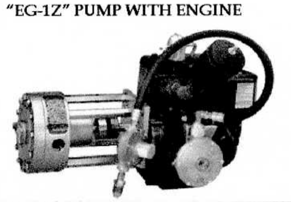
6 - 15 USGPM NOMINAL OUTPUT RANGE

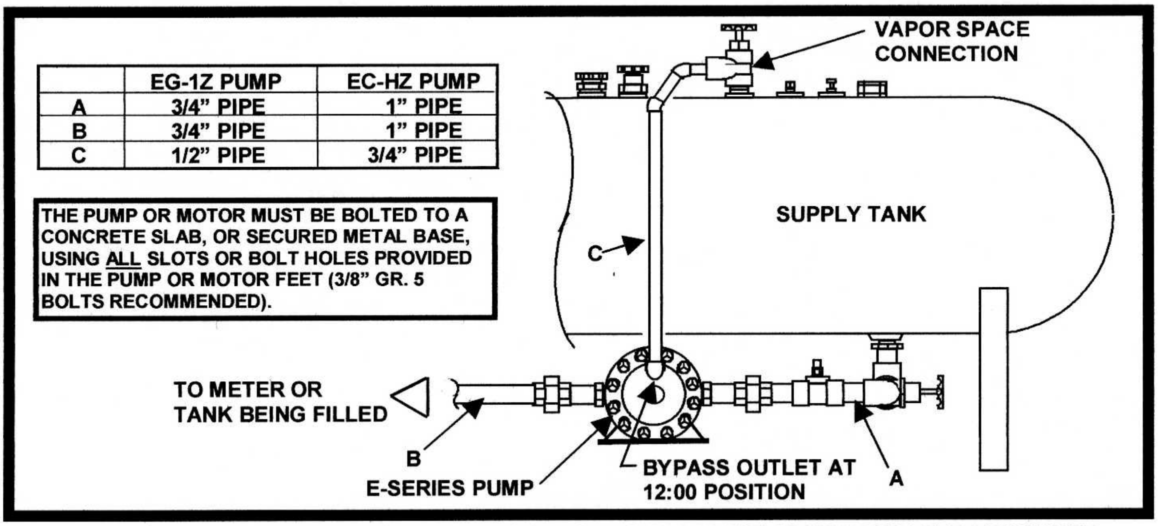


"EG-1Z" PUMP WITH ENGINE

1500 - 3600 RPM RANGE (LPG ONLY)

4 - 10 USGPM NOMINAL OUTPUT RANGE





	EG-1Z PUMP	EC-HZ PUMP
A	3/4" PIPE	1" PIPE
B	3/4" PIPE	1" PIPE
C	1/2" PIPE	3/4" PIPE

THE PUMP OR MOTOR MUST BE BOLTED TO A CONCRETE SLAB, OR SECURED METAL BASE, USING ALL SLOTS OR BOLT HOLES PROVIDED IN THE PUMP OR MOTOR FEET (3/8" GR. 5 BOLTS RECOMMENDED).

Fig. 3: GENERAL INSTALLATION OF E-SERIES LPG PUMP USING BUILT-IN BYPASS VALVE.

The installation of a small LPG pump can be made easily (*Fig. 3*). The small pump illustrated has a built-in strainer. If the pump requires a separate strainer, be sure that the strainer is properly placed between the storage tank and the pump inlet. A 1¼-in. excess flow valve is utilized in the bottom outlet of the tank, in *Fig. 3*, and the separate shut-off valve shown is an approved 1-in. globe, angle, or ball valve. An approved internal valve can also be utilized. For best results with both models mentioned above, item (A) is a 1-in. Sch. 80 heavy-duty steel pipe, with a ¼-in. hydrostatic relief valve installed in a tee. Item (B) is the outlet line, which can usually be the same size pipe as the pump outlet, or identically sized standard length hose, with the appropriate hose excess flow and end valves. No bypass valve is shown in *Fig. 3*, because the pump has a built-in bypass valve, which is arranged to discharge through an external line. Also, no pressure equalizing line is shown, since one is usually not necessary with small LPG and NH_3 pumps. A pressure equalizing line can be used if desired, as can an external bypass valve discharging to the supply tank (these would be required for small pumps in low-pressure liquid Carbon Dioxide service). Be sure to follow all safety regulations.

Common mistakes made in low capacity pump installations are:

(A) Having the supply line to the pump come from the side or top of the tank, instead of the bottom, is rarely satisfactory even with Propane. It is never a good idea, especially with Butane or Butane/Propane mixtures, as vapor lock problems result.

(B) Be sure to properly size the liquid meter in the discharge line, to measure delivery. The 1¼-in. size may be unsatisfactory. While some of these larger meters have been rated at flows as low as 5 USGPM, they may not be sufficiently accurate, at the lower flow rates attained with some small pumps, especially at higher differential pressures. It is best to size the smallest pumps for at least 7 to 10 USGPM delivery. If this is not possible the tanks should either be filled on a scale, or a smaller 1-in. meter should be used.

(C) Pumps that are unable to develop a good flow at 75 PSID have caused considerable trouble in the past. A 75 PSI differential pressure is required for filling nearly all kinds of small tanks with LPG and NH_3. Check the characteristics of units available to you. A pump may have a rated capacity of 10 to 15 USGPM against low differentials, but what is needed is a pump that will deliver at least against the 75 PSI minimum differential required for filling small tanks efficiently.

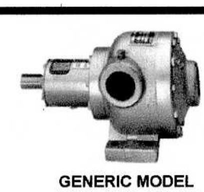
(D) *Be sure to check with the manufacturer before utilizing these pumps in services demanding more than intermittent run time.* Pumps that are utilized in non-intermittent duty should be run at less RPM and be required to build less PSID, than maximum. When pumps are capable of being constructed on an application-specific basis, do not utilize the "generic" models. Be sure to use the correct pump model as indicated by the manufacturer's construction designations for the job required. Contact the factory for more details on this and other related items of concern.

4. MEDIUM CAPACITY PUMPS

A "medium capacity pump" is a unit used when the required output is 20 to 50 USGPM of liquefied gas, during transfer operations. Such delivery rates can be attained when filling all sizes of tanks, except individually-filled cylinders. The medium sized pump can be used to do all kinds of work with reasonable efficiency. Pumps with a capacity of 35 to 50 USGPM are chosen in many cases, as these can be driven by 3 HP or 5 HP motors, with any type of electrical power available in the area. If electricity is not immediately available, *properly modified* gasoline, diesel, or LPG-powered internal combustion engines can be used. Medium sized pumps can unload transports at a rate of 2000 to 3000 USGPH. LPG pumps can fill motor vehicle fuel tanks having standard 1-¼ in. filler valves at 25 to 30 USGPM; and can fill cylinders having ¾ in. cylinder-type valves at 7 to 10 USGPM. Three to five cylinders can be manifolded for filling in the same time that it would otherwise take to fill one. With this type pump and a four-cylinder manifold, one man can be kept very busy filling 100-lb. cylinders and a good worker will average one filled every minute. These 35 - 50 USGPM pumps can also load delivery trucks and transports at rates of 2100 to 3000 USGPH. *Fig. 4 on the following page, illustrates what can be done with a medium-sized pump. The basic concepts shown on the following page are generally applicable for most transfer systems for light liquids, including liquefied gases.* Note how a typical transport tank is unloaded by connecting a hose (27) and opening a hand bypass valve (29). This method is the least complicated for piping a dual-purpose pump used for both loading and unloading. For filling motor vehicle fuel tanks with an LPG pump, a hose (16) is used, and liquid is measured with a 1-¼ in. meter, which performs satisfactorily with any medium sized pump filling tanks other than cylinders. The same hose can be used for filling delivery trucks. If it is not desired to meter the liquid into these trucks, a tee can be installed ahead of the meter between parts (10) and (37), and a second larger hose, of 1-½ in. or 2 in. size, connected there. Single small cylinders can also be filled through the meter with a hose (16), but usually the safer and more practical way is to provide a separate connection running to a convenient location where small cylinders can be filled by weight on a scale.

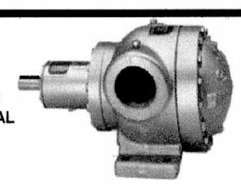
As the business grows, a pump of larger capacity, 100 USGPM or more for unloading transports faster, is advisable to reduce delays. Or, if product is delivered in RR tank cars, a compressor may be installed to realize a recovery of vapors that would otherwise be left in the car if a pump were used. In the warmer areas of the United States, when straight Propane is handled, considerable savings can be made with a compressor if the volume of fuel sold is relatively high. The medium sized pump can do the other work, and can serve as a substitute for the larger pump, if it is ever out of service due to an unexpected breakdown. Medium capacity pumps require 2 in. piping, valves, and fittings from the tank being unloaded to the pump inlet. *Medium capacity pumps do not necessarily have 2 in. inlets and outlets.* Discharge piping normally is sized to suit the tanks being filled and the filling speed desired. For example, to load delivery trucks without a meter, at the fastest possible speed, all pipe and valves in the discharge line should be 2 in.. For filling tanks through a liquid meter, it seems unnecessary to use pipe, valves, and fittings any larger than the pipe size of the meter, unless the distance to the meter is great. Lines running to a cylinder filling station for LPG or NH_3 can be sized according to the number of cylinders filled at a time. *In an average setup, a ½ in. line is large enough for filling one at a time; for two at a time, use ¾ in. line; for three to four, use 1 in. line; for five or six, use 1¼ in. line. (For 7 or 8, use 1-½ in line, and a "high-capacity pump". For 9 to 15, use a 2 in. line and a "high capacity" pump). When dealing with large tanks, a vapor-return connection is normally made, as for example, unloading tank cars not requiring highly restrictive safety valves ("ESV's"), transports, and tankers, or loading delivery trucks. With a medium capacity pump, this line should be at least ¾ in. size if short, or a 1 in. size if long. Growth and future expansion should be kept in mind when sizing lines. It is not much more expensive to install a 1-¼ in. vapor line than a ¾ in. or 1 in. line, and the large line will serve larger equipment, later.*

750 - 1800 RPM RANGE
15 – 35 USGPM NOMINAL
OUTPUT RANGE



GENERIC MODEL
TYPE "MC-1044H"

750 - 1800 RPM RANGE
21 – 50 USGPM NOMINAL
OUTPUT RANGE



GENERIC MODEL
TYPE "MC-2"

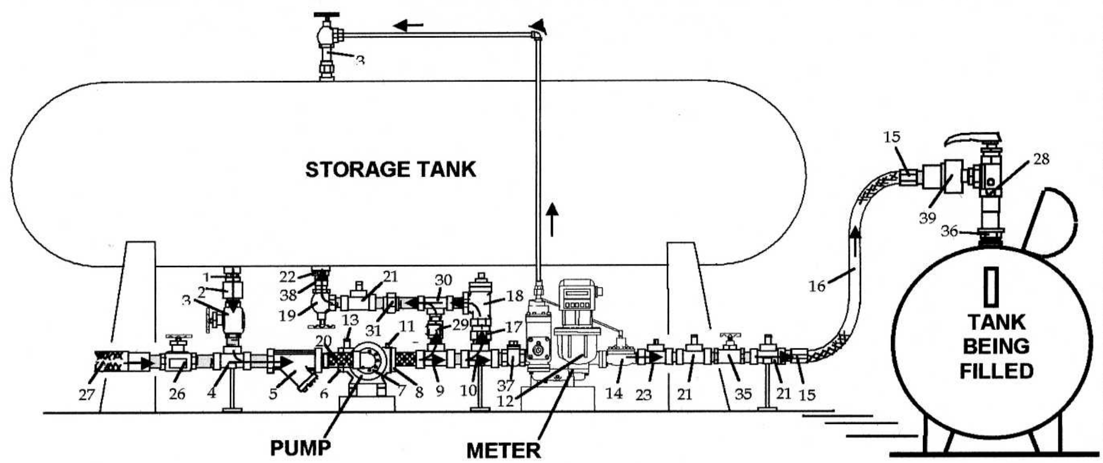
NOTE: The "Generic Model Type" shown in the installation drawing, below, of the "Traditional Basic LPG Pumping System", is "ATC-2R". To determine the actual model used for longest service life, and lowest noise levels in the above-depicted situation, see the tables for the correct drive speed ranges, and the proper construction designation codes, on pages 27 and 28. In reality, there are several use-specific models, based upon the basic model "ATC-2R". They are all exactly the same, or very similar, in outward appearance, but are assembled with different parts and/or distinct materials of construction. Typically, in cases such as this, the best model for long term semi-continuous service, would most likely be the use-specific SMITH model "ATC-2RH NSZ", run at a speed between 1100 - 1300 RPM. See the pictures, below. Note the similarities in external appearance of the two distinct models. If pumps are intended for other than intermittent duty, slower than maximum RPM and corresponding lower PSID are required, especially with CO_2. Contact the factory for additional information.

GENERIC MODEL TYPE "ATC-2R"

750 - 1800 RPM RANGE
21 - 50 USGPM NOMINAL OUTPUT RANGE

USE-SPECIFIC MODEL "ATC-2RH NSZ"

600 - 1500 RPM RANGE
20 - 50 USGPM NOMINAL OUTPUT RANGE



1 EXCESS-FLOW VALVE
2 COUPLING
3 SHUT-OFF VALVE
1,2,3,5 INTERNAL VALVE
4 TEE
5 STRAINER
6 BLIND FLANGE
7 INLET FLANGE
8 OUTLET FLANGE
9 TEE
10 TEE
11 1/4-IN. PLUG
12 METER
13 HYDROSTATIC RELIEF VALVE
14 BACK-PRESSURE VALVE
15 HOSE COUPLING
16 HOSE
17 UNION
18 BYPASS VALVE
19 SHUT-OFF VALVE
20 FLEXIBLE CONNECTOR
21 POSITION FOR HYDROSTATIC RELIEF VALVES
22 EXCESS-FLOW VALVE
22,19,38 INTERNAL VALVE
23 TEST PIPE PLUG
26 SHUT-OFF VALVE
27 HOSE
28 QUICK-ACTING HOSE END VALVE
29 SHUT-OFF VALVE
30 TEE
32 UNION
33 VAPOR RETURN LINE
35 SHUT-OFF VALVE
36 FILLER VALVE
37 CHECK VALVE
38 COUPLING
39 SWIVEL CONNECTOR

Fig. 4: TRADITIONAL BASIC LPG PUMPING SYSTEM

5. HIGH CAPACITY PUMPS

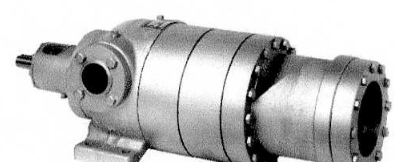
"High capacity pumps" include units capable of handling liquefied gases at flow rates in the range of 100 to 250 USGPM, or higher. These pumps are most usually located in refineries, production plants and storage depots, and are used for fast volume recirculating, loading and unloading operations.

Liquefied gases with higher pressures are easier to handle with large positive-displacement pumps than liquefied gases with lower pressures. The reason for this is that because of their high capacity, they are particularly sensitive to pump starvation caused by excessively restrictive, complicated, or lengthy supply lines between the tank liquid outlet and the pump inlet. When these lines are improperly designed the Static Head in the supply tanks may not be enough to bring sufficient gravity flow of liquid to the pump inlet, as required for best operation. Such installations overly restrict immediate liquid flow, or require the pump to develop suction on the inlet side. When a liquefied gas pump causes suction, vapor is formed. An excessive amount of vapor may accumulate or be formed by the pump, depending on how aggravated the conditions are in the pipeline. Such vapor passes through the pump and reduces the unit's ability to deliver liquid. In addition to capacity reduction, the vapor causes the pump to run partially dry; this dryness results in improper lubrication and cooling effects for the working parts (which are designed to be lubricated and cooled by liquid flow). As a result, most pumps "starved", or fed excessive vapor in this manner, have reduced capacity, are noisier, and wear faster.

For example, given two identical piping systems, one handling Propane and one handling Butane, both "starved" an equal amount through identical improper liquid piping, almost equal amounts of vapor, by weight, will be formed in the inlet lines. However, due to the higher pressure in Propane systems, the vapor bubbles take up a much smaller volume than they would in the Butane system, which is under far lower pressure. Therefore, at a temperature of 60°F., 1 lb. of Propane vapor takes up a volume of 1.01 $Ft.^3$, or about 7½ USG. However, a pound of Butane vapor at the same temperature has a volume of 3.40 $Ft.^3$, or over 25 USG. Obviously, the difficulties with pump starvation will be more than three times as evident in the Butane system.

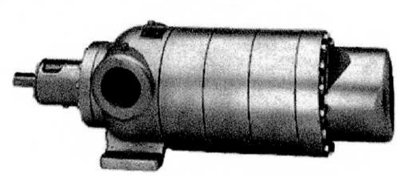
To solve this problem, inlet lines must be streamlined, short in length, and designed so that there will be a "Net Positive Suction Head Available (NPSHA)", for a gravity-flow of liquid to the pump inlet equal to its capacity, especially during initial flow acceleration. Pumps so installed do not develop suction, and are not "starved". The figures in the tables in Section 7 of this booklet indicate the design of proper inlet lines. Note that the pump may still cavitate if the inlet line is too long, in spite of a theoretically correct "NPSHA" value. Inlet line length is limited by (1) the natural vapor pressure of the product handled, (2) fluid density, (3) liquid quality, and (4) dynamic effects, involving vapor accumulation, heat transfer, and initial acceleration of the total liquid mass within the confines of the pump inlet line. The technical information provided in this reference is of a general theoretical nature; engineering texts and other authoritative references should also be consulted. There is no substitute for a careful engineering analysis of these factors. The proper design of a layout is extremely important. It would be very wise to have this accomplished by a professional engineer, experienced in both hydraulics and liquefied gas systems.

GENERIC MODEL TYPE "ATC- 4LF"



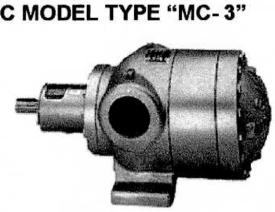
750 - 1800 RPM RANGE
63 - 150 USGPM NOMINAL OUTPUT RANGE

GENERIC MODEL TYPE "MC- 5"



750 - 1800 RPM RANGE
83 - 200 USGPM NOMINAL OUTPUT RANGE

GENERIC MODEL TYPE "MC- 3"



750 - 1800 RPM RANGE
42 - 100 USGPM NOMINAL OUTPUT RANGE

6. SLOW SPEED PUMPS (MOSTLY USED IN MOBILE APPLICATIONS)

INSTALLATION RECOMMENDATIONS

"Slow speed pumps" are designed specifically for PTO, gear reduction, and belt-drives. These units are often specifically fitted to be installed in *mobile* systems. Mobile systems present the most difficult problems of all liquefied gas pumping situations. Pumps used within these scenarios correspond to two design categories, "original" and "modern". Given the latest technological advancements in simplicity and safety, the difficulties associated with the "original" methods of delivering product to customer sites, have been substantially reduced. Many of the "original" style slow speed pumps are designed for use in mobile systems constructed very similar to stationary plants. These base-mounted pumps are frequently provided with multiple oversize porting. Some are reversible. A few of the observed problems and suggested ways to correct or alleviate the trouble in those "original" systems are included in the following:

1. Lack of space for piping can be a base-mounted PTO-driven pump problem. Not only is it always crowded under a truck or trailer, but the weight factor is important. Often more elbows are required to accommodate fittings to the space, and smaller sizes of valves and strainers are used, as compared to a bulk plant. *Correction: Pay particular attention to the design of the pumping system. Take time to consider various arrangements. Choose the simplest possible way.*

2. The tank that is mounted on a truck chassis cannot be located as high above the pump as a bulk plant tank. The truck tank must be as low on the chassis as possible, and the truck pump must be high enough for road clearance and for maintenance. Because of lack of Static Head to bring liquefied gas to the pump inlet, pump starvation problems are caused. *Correction: Use oversize valves and fittings as much as possible. Types of valves with low flow resistance can partially compensate for the low available Suction Head. Proper "Net Positive Suction Head Available (NPSHA)" must be maintained.*

3. Heated air from the truck engine and engine exhaust systems blows past the pump and piping, increasing the tendency to vapor lock. *Correction: Separate the exhaust pipes and muffler from the piping as much as possible. Insulate exhaust pipe and mufflers. Study air flow past the engine, and use baffles or deflector plates to divert warm air away from the pump and piping. If the pumping unit is mounted in a bucket box, be sure there is proper air circulation around the engine and away from the liquefied gas lines.*

4. If driven by an engine, the pump speed is not constant, as is the case with electric motor drives. Often, the engine condition, or the atmospheric conditions, have a noticeable effect on the pump drive speed. Some drivers may run the pump too fast, trying to speed deliveries. Over-speeding may result in considerable hardship on all the working parts of the pumping system, without increasing delivery much, if at all. *Correction: Install a tachometer on the engine. If a separate air-cooled engine is used, install a speed governor. Instruct the operators to maintain proper pump RPM.*

5. Preventive maintenance programs that would save considerable time and money are neglected for various reasons. Frequently, it is because of the location of items mounted under the truck or trailer, that makes such work difficult. *Correction: Simplified piping will make it easier to service the truck, properly. Then, provide proper tools. Have special wrenches made up if necessary to allow easy opening of strainers, bypass valves, and other critical components. Install safe, approved devices to facilitate work under the truck, or trailer, as necessary. Be sure the piping systems are designed specifically for disassembly, with as many flanges or unions as required to allow maintenance projects to be accomplished easily. Make use of flanged equipment, including the pumps, for ease of removal and reassembly to the system.*

6. While on the road, trucks and trailers are subject to vibration, turning, and fast stopping. Liquid in the tanks is in a constant state of turbulence while the truck is moving. Particles of foreign matter, rust, and scale in the tank will be mixed with the liquid and in some cases, particles will be ground smaller by this tumbling action.

"TC-1044HL" SERIES

450 - 900 RPM RANGE
30 - 60 USGPM NOMINAL OUTPUT RANGE

The foreign matter will not settle to the bottom of the tank and stay there, as happens in stationary tanks. Instead, the particles will be drawn into the pumping system. More trouble is always experienced in mobile systems with adverse effects caused by impurities, such as rapidly clogging strainers, and accelerated wear in system components. *Correction: Regular servicing of strainers can reduce the clogging. To make this job easier, improved piping layout and convenient location of the strainer is suggested. In extreme cases, dirt-trapping baffles can be designed into the tanks, and these can help greatly in keeping foreign matter out of the pumping system. Magnets can also be used.*

To repeat: Mobile pump service is difficult and should receive special attention. These pumps will generally wear faster and cause more trouble than bulk plant pumps, even though the design of the bulk plant pumps may be identical. The problems can be solved, but the design changes required to improve the service unfortunately result in higher costs for the finished truck or trailer. Therefore, the costs of a mobile delivery system should be studied carefully and desired features that will make it a fast pumping, trouble-free, and less expensive unit to operate in the long run, should be carefully weighed against initial cost.

Filling Consumer Tanks without Vapor Return Lines

Excluding CO_2 deliveries, most consumer bulk tanks (100 to 1000 USG capacity), especially in the LPG market, are filled directly through a meter on the delivery vehicle without the use of a vapor return line. Many years ago the average consumer tank had to be filled through the *liquid* phase. The resulting compression of vapor above the increasing liquid volume in the tank, would cause extremely high differential pressures up to four times greater than during the average liquefied gas delivery of today. The modern tanks are now filled through the vapor phase. The specialized filler valves cause liquid entering under pressure to purposely fan-out, taking full advantage of the "refrigerative effects" afforded by this action, as it sprays into the upper area of the tank being filled, lowering the back-pressure, by "vapor cooling".

Piping recommendations for Delivery Vehicles

These transfer systems, set-up for the "original" style of available pumps, have always presented the most difficult problems to resolve. The following Table 2 (below), is based on Fig. 4.(pg. 9). These situations are where the mobile piping on a bobtail, or trailer, is very similar to the stationary piping in a bulk plant.

TABLE 2. MINIMUM SIZE OF "ORIGINAL-STYLE" MOBILE SYSTEM PIPING COMPONENTS

Ref. No. (Fig. 4)	Name of Part	20 USGPM Size (In.)	30 USGPM Size (In.)	40 USGPM Size (In.)	60 USGPM Size (In.)	80 USGPM Size (In.)
1	Excess Flow Valve	2 x 1¼	2 x 1¼	3 x 2	3 x 2	3 x 2
2	Coupling	2	2	3	3	3
3	Shut-off Valve	2	2	2½	3	3
4	Tee	2 x 2 x 2	2 x 2 x 2	2½ x 2½ x 2½	3 x 3 x 3	3 x 3 x 3
5	Strainer	2	2	2½	3	3
6	Blind Flange					
7	Inlet Flange	2½	2½	2½	2½	2½
9,10	Tees	1¼ x 1¼ x 1	1¼ x 1¼ x 1¼	1½ x 1½ x 1¼	1½ x 1½ x 1½	2 x 2 x 1½
12	Meter	1¼	1¼	1½	1½	2
14	Back-pressure Valve	1	1¼	1½	1½	2
16	Delivery Hose**	¾	¾ or 1*	1 or 1¼*	1¼ or 1½*	1¼ or 1½*
17	Union	1	1¼	1¼	1½	1½
18	Bypass Valve	1	1¼	1¼	1½	1½
19	Shut-off Valve	1	1¼	1½	1½	2
20	Flex Connector	2	2	2½	3	3
21	Tee	1 x 1 x ¼	1¼ x 1¼ x ¼	1½ x 1½ x ¼	1½ x 1½ x ½	2 x 2 x ½
23	Tees	1 x 1 x ¼	1¼ x 1¼ x ¼	1½ x 1½ x ¼	1½ x 1½ x ¼	2 x 2 x ¼
26	Shut-off Valve	2	2	2	3	3
27	Loading Hose	2	2	2	2	2
28	Hose End Valve	¾	¾ or 1*	1 or 1¼*	1¼ or 1½*	1¼ or 1½*
29	Shut-off Valve	1	1¼	1¼	1½	1½
30	Tee	1 x 1 x 1	1¼ x 1¼ x 1¼	1½ x 1¼ x 1¼	1½ x 1½ x 1	2 x1½ x 1½
31	Union	1	1¼	1½	1½	2
35	Shut-off Valve	1	1¼	1½	1½	2
36	Filler Valve	1¼	1¼	1¼	1¼	1¼
37	Check Valve	2	2	2	2	2

* Use larger indicated size without pressure equalizing line.

** Standard system design criteria (which prolong pump life) were used to determine recommended sizes. They still apply to all outlet piping systems, both "original", and "modern". Use of smaller sizes, especially delivery hoses, can open internal pump bypass valves, cause excessive Differential Head pressures, extremes of internal wear, and bothersome functional noise.

There are many modifications, which can be made to the system shown on pg. 9, that illustrates theories and premises. No single piping diagram can possibly be used in all cases. Likewise, Table 2 may be used as a general guide for a liquefied gas transfer system to handle such products as CO_2, NH_3, or LPG ; but should be checked against actual conditions by an engineer experienced with these liquefied gas pumping systems.

Pump Drives in Mobile Systems

Nearly all types of mobile pump drives make use of the truck engine with a power take-off to drive the pump through a transmission device. Some utilize a separate air-cooled engine, or electric motor. The most common and least expensive pump drive arrangement for delivery vehicles utilizing the "original" style pumps, has been the power take-off connected to the pump with two universal joints, one mounted on the pump shaft and one mounted on the power take-off shaft, and a shaft with a slip joint connecting the two universal joints.

The pump and power take-off shafts should be parallel, although they need not be in line. However, the angle of the connecting shaft with the power take-off and pump shaft should not exceed 15 degrees. The slip joint (spline joint or sliding joint) must be used to allow for linear movement due to spring in the truck chassis, end play, and to allow for expansion and contraction due to temperature.

In the past, V-belt or chain drives were used between the PTO and pump, where the proper pump RPM was faster or slower than a reasonable PTO speed. Belt drives were preferred because if the transmission system jammed for some reason, the belts would slip before transmitting enough force to cause extensive breakage.

Another interesting power transmission method was the use of flexible shafting between the PTO and pump, where the universal joint drive was thought to be impractical because of a long distance to the pump, or the necessity of mounting the pump in a position where its shaft could not be parallel to the PTO shaft. The flexible shaft was satisfactory only when very carefully installed, in accordance with the recommendations of the flexible shaft manufacturer.

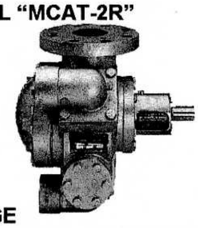
A third method of power transmission in the past was by means of hydraulics, where an oil pump was connected to the PTO, and a hydraulic motor was connected to the pump. The oil pump, reservoir, and hydraulic motor were interconnected with two pipe and hose lines, forming the "hydraulic circuit". These drives have been among the most expensive types, weighing more and occupying more space. However, under certain special circumstances, hydraulic drives are still required.

For example, a hydraulic drive is particularly desirable if the pump is mounted on a trailer, since the power connections between the trailer and tractor can be made with quick-coupled hydraulic hoses. A PTO drive to a pump on a trailer is difficult to work out in any other way. The added weight of the hydraulic drive system has become less of a problem with the use of modern "hydrostatic" drives. Of course, some applications have eliminated the pump altogether on the delivery trailers, and utilize ground pumps for unloading. Many trailer-mounted pumps have been supplied with their own independent power sources, including air motors, electric motors, and engines.

"Modern" Style Truck Pumps Mounted to Internal Valves

Those shown are specifically designed to bolt right on to the flanged outlet of a 3-in. multi-function internal valve, mounted directly to the main supply tank liquid outlet. These internal valves have a built-in strainer, a remotely-activated valving mechanism, and also have a liquid flow safety shut-off feature (which either prevents the main valve from opening until the

USE-SPECIFIC MODEL "MCAT-2R"



600 - 1200 RPM RANGE
36 - 72 USGPM NOMINAL OUTPUT RANGE

USE-SPECIFIC MODEL "MCAT-3L"

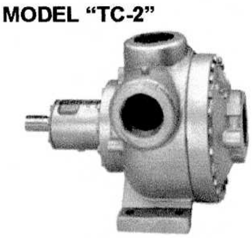
600 - 1200 RPM RANGE
72 - 114 USGPM NOMINAL OUTPUT RANGE

pump builds pressure, or behaves exactly in the same manner as an excess-flow check valve). This combination device has effectively eliminated the pump inlet line, which over the years has been the source of most trouble in mobile pumping systems. The pump, and internal valve assembly, are supported by the tank. The internal valve is usually activated from a remote location, either pneumatically, or manually. Internal valves have been proven over the years to be much better from a safety standpoint, than the original-style externalized valves and fittings, which were used for the same purposes. In addition, the internal valves that provide a flanged mounting for pumps, have comparatively much less resistance to flow, which is ideal for a mobile installation. However, just as any other mechanical safety devices, they must be periodically inspected and maintained. Obstructed flow through the valve due to debris intrusion, or any other reason, can cause excessive vaporization at the pump inlet, resulting in abnormal functioning and accelerated pump wear.

"Original" Style Base-Mounted Units

Base-mounted pumps are frequently used with internal valves in different configurations. Some mobile systems use internalized valves, but are still constructed in the "original" manner, similar to a stationary installation. Instead of sizing medium capacity pump inlet piping as would be done in a standard distribution plant, sizes used on typical delivery vehicles can be changed from 2-in. to 3-in.. Ball valves or gate valves could possibly be used instead of globe valves, to reduce some flow resistance; but a 3-in. internal valve can take the place of a length of pipe with fittings, an excess flow valve, a shut-off valve, and a strainer. Fabricators take advantage of the multi-functional internal valves with a built-in strainer element, to enhance the inherent safety characteristics, to simplify the external piping, and to greatly lessen the resistance to flow of liquid toward the pump inlet connection.

BASIC MODEL "TC-2"



250 - 500 RPM RANGE
25 - 50 USGPM NOMINAL OUTPUT RANGE

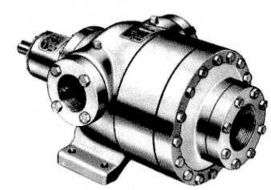
USE-SPECIFIC MODEL "TC-3F"

250 - 500 RPM RANGE
50 - 100 USGPM OUTPUT RANGE

USE-SPECIFIC MODEL "ATC-2R NSSA"

750 - 1800 RPM RANGE
21 - 50 USGPM NOMINAL OUTPUT RANGE

USE-SPECIFIC MODEL "ATC-3RH NS"



600 - 1500 RPM RANGE
33 - 100 USGPM NOMINAL OUTPUT RANGE

Outlet Lines in Mobile Systems

A great deal of effort has already been put into discussing the mobile pump inlet line situation. It is also important to consider at this point the outlet lines in mobile systems. General information of this kind can be found further on in this booklet, but it would still be a good idea to conduct a proper engineering study, and to consult with the other equipment manufacturers, prior to system construction

Pump *outlet* piping, as opposed to pump *inlet* piping, does not require as much attention with regard to its potential pressure drop characteristics. This is because the functionality and output capacity of the pump will not be seriously affected from the development of a *reasonable amount* of differential pressure. Therefore, within specified limitations, the outlet line can be smaller than the inlet line. The outlet line shown in *Fig. 4* begins with an approved, properly-sized, flexible connector (8) which helps to eliminate stress and vibration being transferred to the pump casing. The following item, the "primary" bypass valve (18), must be sized to handle the total pump output, and must always discharge back to the tank. (Review pgs. 3 - 5 in this booklet.) The "secondary" bypass valve, or the "internal" bypass valve, will discharge back to the pump inlet, but should never open during normal service. In many cases, the "primary" (external) bypass valve opens regularly, especially when the valve is closed at the end of the hose. This bypass valve is critical for maintaining acceptable pump service life. It must always alleviate excessive differential pressure, *before* the "secondary" valve opens. It is therefore a good idea to periodically check the "primary" bypass valve to prevent its malfunctioning or obstruction. If the "secondary" bypass valve opens, the pump immediately cavitates due to accumulating frictional heat, normally carried-off by the output flow. Cavitation should be avoided. It usually causes excessive functional noise, vibration, and accelerated internal wear.

The "primary" bypass valve should be set at least 25 PSID below the adjustment of the "secondary" bypass valve. The actual differential pressure setting will depend upon the flow resistance of the valve ("overpressure"), the use conditions, the natural vapor pressure of the liquefied gas handled, and the applicable safety regulations in the area. The bypass valve must be sized to maintain the desired differential pressure even when the *total* pump discharge flow passes through it. (see *Table 1*, on pg. 4). After the bypass valve, the next important component affecting liquid flow from a typical mobile system would be the meter, especially on an LPG delivery vehicle (item 12 in *Fig. 4*). Meters must always be utilized within the capacity ranges as recommended by the manufacturers. The vapor return line must be at least the same size as the outlet on the vapor eliminator to permit unrestricted flow back to the supply tank. Otherwise, vapor accumulations may interfere with the proper metering of liquid flow, and could be further aggravated when the liquid level is approaching the bottom of the tank.

The back-pressure valve (14) can be considered in the light of two important functions: (A) it maintains a pressure differential on the meter and the vapor eliminator, which pushes the vapor back into the tank; and (B) it serves as a safety shut-off point. If the hose were to fail when the pump is off, this valve should remain closed, thereby helping to prevent escape of handled product to atmosphere. With large meters, this externalized valve is similar to a diaphragm-actuated bypass valve, in that the upper side of its diaphragm must always be open to the supply tank vapor phase. The difference in pressure created by the pump, is transferred to the opposite side of the diaphragm. When it overcomes the internal spring tension, the valve opens. Care should be taken to periodically inspect this valve, and to replace the diaphragm as recommended by the manufacturer. This procedure eliminates a potential problem caused by utilizing the valve with a ruptured diaphragm. In that condition, the liquid flow through the valve could either be partially blocked, or totally restricted.

The Delivery Hose and Excessive Back-Pressure

When a proper engineering study is accomplished for the design of a mobile system, the effects of pressure drop through the delivery hose (16) must be given very careful consideration. More than any other component used on the discharge side of a liquefied gas pump, the hose can have a limiting effect on the delivery system output. The very worst problems of this kind occur in systems which utilize a comparatively long liquefied gas hose, mounted on a reel. In these cases, the length and diameter of the delivery hose are responsible for high back-pressure tending to limit the delivery rate, especially when the hose is less than a 1-in. nominal size. *In some cases this situation is aggravated by long lengths of piping between the delivery hose connection and the tank being filled.*

This adverse situation must be taken into consideration when sizing the pump, and determining the best way to design the delivery system. Excessive back-pressure is highly aggravated when the pump is very large in relation to a limited flow allowed through the hose. Therefore, if the external bypass valve is regularly opening during delivery, it is not necessarily set at the wrong differential pressure. In many such cases, the bypass valve opens because the pump is of excessive capacity for the way in which the mobile installation is constructed and utilized. A continual excessive recirculation back to the tank will raise the liquid temperature, cause aggravated turbulence, and may adversely affect the quality of fluid supplied to the pump, depending upon the size of the supply tank, its construction, and the amount of liquid returned through the bypass circuit. This would be especially true when handling liquefied gases with inherently low natural vapor pressures, at a time when the tank is less than half full. Even if the development of differential pressure is kept to within specified safety requirements, it may still be too high for the system to operate efficiently.

There are three ways that this excessive differential pressure (primarily caused by long, restrictive outlet lines) is alleviated in a mobile system:

1. Through the external bypass valve.
2. Through the pump's internal bypass valve.
3. Through pumping inefficiency ("slippage").

As previously mentioned, the common positive displacement rotary pumps of concern in this discussion will lose efficiency in proportion to the differential pressure. This means that even if the bypass valve does *not* open while the delivery is being made, higher differential pressure will *not* necessarily increase the delivery rate. Of course, if the bypass valve does open, that portion of the delivery is lost back to the supply tank. It is very important to properly match the delivery and receiving systems' transfer capabilities, to the pump capacity, drive speed, and differential pressure. This is the only way to insure optimum pump efficiency and durability, at the highest practical differential pressure, with the highest possible flow rate, under the prevalent delivery conditions.

Any differential pressure condition which results in more than a 50% reduction in pump output (as compared to the "nominal" output at the same speed), *should be avoided.* Standard low-pressure liquid Carbon Dioxide transfer is an exception to this rule, and the maximum differential pressure should be under 50 PSID even if the pump does not lose more than half its output to slippage factors. *The "primary" (external) bypass valve should not be opening excessively during every delivery.* Ideally, once the important installation functional factors are properly matched, while the consumer tank is being filled the differential pressure upon the pump approaches the bypass valve setting, but is not sufficient to cause the bypass valve to open. An oversized pump used in a mobile system should be slowed-down, to match the optimum system output. In this manner, the extra pumping capacity permits use of the unit at a slower speed which decreases internal wear factors, and helps to eliminate bothersome functional noise. As the unit wears, its drive speed can be increased as required, without going above the maximum design RPM.

Hose End Swivel Connectors.

Naturally, a long delivery hose which has been unrolled from the hose reel, and rolled up again many times, tends to twist or rotate in one direction or the other, as the pressure acts upon it during the filling operations. Sometimes, this makes it difficult for the operator to attach the end of the hose (16) to the filler valve (36). Once connected, any tension built up in the hose is transferred to the filler valve. It cannot be relieved without untwisting.

A properly applied swivel connector (39) mounted between the end of the delivery hose (16), and the quick acting hose end valve (28), allows the hose to completely untwist during delivery operations, effectively relieving built-up tension. In this manner, the hoses and the connections are not under stress during filling operations. Other types of receiving and loading procedures can benefit in much the same way through the use of other specialized swivel connectors. These devices contribute to safety during liquefied gas deliveries, by helping to prolong the life of the hoses, connections, and valves. They also allow the operator to do his job much easier.

Drive Speeds of Pumps in Mobile Systems

The speed of a pump installed in a mobile system is a major consideration in designing the appropriate drive. No compromise should be made that will force the liquefied gas pump to turn faster than the maximum speed recommended by the manufacturer. It is better to use a liquefied gas pump large enough so that the required delivery rate will be developed at less than maximum recommended speed. Slower speeds, *within the recommended RPM ranges,* cause most commonly-used pumps to last longer, and when a pump in such a system begins to lose efficiency, through wear, the driver can be allowed to speed it up to regain proper delivery rates. However, it is seldom desirable to postpone mobile pump repairs by racing pumps at speeds far in excess of their rated maximum. Such high speeds greatly accelerate the wear rate, wear the engine and transmission, and use more fuel.

The "slow speed pumps", commonly installed in mobile systems, are available with interior working parts designed for many different speed ranges. The most common speed ranges utilized, fall between 400 to 700 RPM. Some manufacturers have other models of pumps that can be run between 600 to 1200 RPM, and 750 to 1800 RPM. The latter, higher speed pumps, are particularly desirable for use with electric motors, engines, and hydraulic systems. It is important to note that many hydraulic motors are also designed for these higher speeds. High speed hydraulic motors are more efficient and are lighter in weight than low speed hydraulic motors.

7. TECHNICAL CONSIDERATIONS

Tables for Resistance to Flow Calculations

For the convenience of the reader who wishes to have a ready reference of technical data, useful for general design evaluation of piping systems, a number of tables are included in this section. *Table 3* allows computations to be made concerning resistance to flow of various sizes of pipe. The resistance to flow is proportional to the length of the pipe in the system; *Table 3* lists the resistance to flow for a 1-ft. length of pipe expressed in "Average Feet of Head". A 100 USGPM rate of Propane flow at 70° F., through a system rated at 30 Equivalent Ft. of 3-in. pipe, would normally cause an average resistance to flow of 30 x .025, equivalent to 0.75 Ft. of Head.

The blank spaces in Table 3 indicate that those pipe sizes are not usually recommended for the corresponding flow rates. The pipe sizes are either too large to be economical (upper right of the table), or are too small for proper pump performance (lower left of the table), except for special or unusual conditions. Also, these values are not exact. They do not apply in all cases, especially in "stand-by" services, or when the liquefied gases handled are contaminated with more highly viscous substances. They relate generally to what we understand average bulk transfer conditions to be with Propane. For figuring simple, approximate resistance to flow in pipes only when handling Butane, multiply the values in Table 3 by 1.15; for Anhydrous Ammonia, 1.21; and for CO_2, 1.98. <u>However, for figuring minimum tank liquid level required to maintain dynamic NPSHR at pump suction, by gravity alone, multiply the same values listed for Propane, by those in Table 4 (See Pg. 19)</u>. Be sure to consult standard engineering texts and other authoritative references for required additional information, regarding flow effects of product density.

Table 4 lists the resistance to flow of valves and fittings commonly used in the inlet lines of liquefied gas pumping systems. The resistance to flow in *Table 4* is expressed in projected "Equivalent Feet of Pipe". Used with *Table 3*, *Table 4* allows computations to be made that can be converted into "Projected Feet of Head". For example, a 3-in. inlet line that contained an average 3-in. excess flow valve, a globe valve, a 90-deg. elbow, a 3-in. strainer, and four 3-in. nipples six inches long, would be equivalent to 292 Ft. of 3-in pipe (*Table 5*). Using *Table 3*, at 100 USGPM, the minimum Propane liquid elevation above the pump should be 292 x 0.25, or 7.30 Ft.. This liquid level would remain the same for CO_2, NH_3, and Butane in an identical installation.

The figures given in *Table 4* represent average, theoretical resistance to flow values for several popular makes and styles of valves, strainers, and pipe fittings. The products of some manufacturers will have lower resistance to flow values, and those of others will have higher values. If the recommended values given are used, *only a conservative approximation of the resistance to flow in the piping will result.* It should be noted that design changes are likely to occur from time to time, and manufacturing variations also occur frequently. Greater accuracy is always required for properly designing a transfer system. Therefore, *the manufacturer of the valve, fitting, or strainer should always be consulted to provide the <u>exact current data</u> required for accomplishing the recommended engineering study, in the proper manner.*

In *Table 4* some of the items listed have relatively high equivalent pipe length values. This does not infer that an inlet line of such length would be capable of providing proper inlet flow to a liquefied gas pump. Inlet lines must be short, direct, and without intersecting "dead legs", to prevent unwanted vapor accumulations, and pump cavitational problems. Ideally, a typical pump inlet line should never have a horizontal run of more than just a few meters in length, especially when handling liquefied gases with inherently low vapor pressures. In those cases where this is not possible, proper "streamlining" and recommended operation procedures, *can probably minimize some excessive product vaporization potentials. However, if the pump cannot be mounted right under the tank, or close to it, there may very well be vapor locking or cavitational pump trouble from the effects of heat transfer, vapor accumulation, or "starvation", even when it appears that the appropriate "NPSH" criteria have been met.*

This would be especially true when handling liquefied gases with relatively low vapor pressures.

All components in use could not be covered in Table 4, which lists some popular examples. Table 4 is a representative cross-section of readily-available makes and types of valves and fittings. The omission of a particular size or type of valve or fitting is not intentional. Information on listed items in other sizes, or others not listed, is normally available from the manufacturers.

Possibly, different types of safety control valves may be substituted, or two or more valves in a smaller size may be manifolded where higher flow rates are desired. The manufacturers will provide updated resistance to flow data for their products if requested to do so.

Pump Resistance to Flow

Pumps also present a certain amount of resistance to flow to the passage of liquid within themselves. The most critical resistance to flow occurs from the point the liquid enters the pump inlet, to the point where the liquid is "caught" or "trapped" by the pump impeller(s). Opinions differ as to the necessity for pump manufacturers including a pump resistance to flow factor in calculations involving resistance to flow of pump inlet lines.

TABLE 3. AVERAGE RESISTANCE TO FLOW OF LIQUEFIED PROPANE, THROUGH CLEAN SCHEDULE 80 STEEL PIPE (AT 70° F.).

Resistance of 1 Ft. Lengths of Pipe
(Expressed in Feet of Head)

Flow Rate	Pipe Sizes						
U.S.G.P.M.	1	2	2½	3	4	5	6
10	.007						
20	.028	.008					
30	.060	.017	.007				
40		.031	.012				
50		.048	.020	.004			
60		.070	.028	.009			
70		.095	.038	.013			
80			.050	.017			
90			.063	.021			
100			.078	.025	.006	.002	.001
125				.036	.008	.003	.001
150				.051	.012	.004	.002
175				.068	.016	.005	.002
200				.088	.020	.007	.003
225					.025	.009	.003
250					.031	.010	.004
275					.037	.012	.005
300					.043	.014	.006
400					.065	.021	.009
450					.085	.027	.012

* The purpose of this table is to simply illustrate comparative pressure drop factors which are helpful in determining the Static Head requirement to maintain proper "Net Positive Suction Head Available (NPSHA)" at the pump suction connection in a typical, average bulk transfer application under average temperature conditions. Contact the factory if the installation in question is used for specialized services such as "alternate energy supply", "stand-by", "back-up", accumulator vacating, or recirculation.

Many centrifugal pump manufacturers are in uniform agreement that this factor is important, and expect to provide figures for their pumps. Regenerative turbine-type pumps, having somewhat similar designs and working principles, would be expected also to have a definite NPSHR factor. Some newer multi-staged side channel units have improved features, which help to cancel resistance to inlet flow factors.

TABLE 4: RECOMMENDED FLOW RESISTANCE FIGURES FOR GENERALLY EVALUATING LPG PUMP INLET LINES ** (HANDLING PROPANE AT 70° F.)

Type of Valves and Fittings	Projected Resistance in "Equivalent Feet of Pipe" for the Following Sizes:						
	1½"	2"	2½"	3"	4"	5"	6"
2-in. threaded internal valves	13	48	118				
2-in. excess flow check valves	30	103	275				
3-in. threaded internal valves	3	13	32	103	499		
3-in flanged internal valves	3	10	25	60	333		
3-in. excess flow check valves	5	25	50	160	250		
4-in. excess flow check valves	1	2	5	14	58		
Straight-through flow gate, ball, and plug valves, same nominal size as pipe	5	6	8	10	14	17	20
Globe valves, wide open, same nominal size as pipe	40	50	60	80	110	130	160
Angle valves, wide open, same nominal size as pipe	20	25	30	40	55	70	80
Swing check valves, same nominal size as pipe	10	13	16	19	25	31	38
90° elbow, same nominal size as pipe	4	5	6	8	11	13	16
45° elbow, same nominal size as pipe	2	2½	3	3½	5	6	7
Tee, flow through side outlet, same nominal size as pipe	8	10	13	16	21	27	33
Tee, flow straight through, same nominal size as pipe	2½	3	4	5	7	8½	11
Strainer, generic types, same nominal size as pipe	25	60	42	42	50	50	50
Strainer, generic types, next size larger than pipe	16	17	14	20	30	30	
Strainer, Smith W series, same nominal size as pipe	4	17	6	20			
Bushing or reducer, to one size larger or smaller	2	2½	3	4	5	6	7

** We cannot be responsible for the designs of the piping systems in which our pumps are used. Our figures are not intended to be specifically applicable in all cases, especially with internal valves and excess flow check valves.

Our figures only represent average, generally acceptable values: the *specific* resistance to flow for all components listed above is likely to vary from one manufacturer to another. We acknowledge the cooperation of the manufacturers who perform necessary tests on their products, so they can provide *specific* fitting, valve, and strainer pressure drop figures, which are absolutely required for proper piping design. Always consult directly with these manufacturers, or their designated representatives, for current component application information, design the pump lines accordingly, and *always follow their recommendations.*

This table views all components as functional items installed together in an average working system. Internal valves, excess flow check valves, and all other items have been objectively evaluated at relatively high flow rates, for the purpose of more realistically visualizing an LPG pump inlet line that substantially minimizes potential cavitation and/or vapor accumulations under average functional site conditions (see text, Technical Bulletin "AL-3", and Catalog "CP-3"). Therefore, based upon our experience, the above resistance figures will generally apply to a number of component styles, and will give the reader at least a basic impression of their resistance to flow in use, which can then be further refined before designing the system, by obtaining current manufacturers' data, and applying it as per their recommendations.

Our projected figures in pipe lengths allow for easy visualization of probable Head Loss. However, a pipe installed in a functioning system does not necessarily have the same dynamic flow characteristics as a listed component. Even though some of the items shown above have a resistance of hundreds of projected "Equivalent Feet of Pipe", this does not infer that an inlet line of equal length would allow sufficient liquid flow into the pump. Inlet lines must be short, to avoid excessive product vaporization due to heat gain and initial flow acceleration. Liquefied gases with comparatively low vapor pressures are more likely to cause cavitational problems in average installations.

TABLE 5. SAMPLE INLET LINE CALCULATION FOR 100 USGPM POSITIVE DISPLACEMENT PUMP.

Item	Inlet Line Component	Projected Resistance in "Equivalent Feet of 3-in. Pipe"
a	Avg. Excess Flow Valve 3" Size	160 Equivalent Feet (Table 4)
b	3-in. Globe Valve	80 Equivalent Feet (Table 4)
c	3-in. 90° Elbow	8 Equivalent Feet (Table 4)
d	3-in. Strainer	42 Equivalent Feet (Table 4)
e	(4) 3-in. Pipe Nipples, 6-in. length	2 Equivalent Feet
f	Total Resistence:	292 Equivalent Feet, a - e
g	At 100 USGPM, resistance to flow of 3-in. pipe is	0.025 of head per Ft. of pipe (Table 3)
h	Conversion of system equivalent pipe length into Ft. of head	7.30 Ft. of head (line "f" multiplied by line "g")
i	Pump resistance to flow for 100 USGPM (estimated)	1.00 Ft. of head (refer to text)
j	**Total resistance to flow of inlet line**	**8.30 Ft. of head (line "h" plus line "i")**

Common positive-displacement pumps with gears or vanes do not depend upon centrifugal force for their action. They require just a little head pressure to force liquid into their impellers. In these designs, the resistance to flow involves minor passageway friction within the pump, and is often negligible. Careful tests made over a period of years on typical positive-displacement pumps indicate that the pump resistance to flow factor may often be neglected for small and medium-sized units. However, for larger pumps handling LPG, CO_2, or NH_3, a nominal allowance should be made, such as: 100 USGPM unit, 1 Ft. of head; 150 USGPM unit, 1½ Ft.; 200 USGPM unit, 2 Ft..

Piston pumps, (as well as a few compatible diaphragm types), sometimes have complicated passageways. In addition, entering liquid must pass through a check valve within the pump. Transfer systems which require extremely high differential pressures with the standard liquefied gases of concern in this booklet, are often supplied with piston pumps that utilize a "booster pump" to insure adequate "Net Positive Suction Head Available (NPSHA)" at the inlet connection. It might therefore be inferred from these circumstances that resistance to inlet flow is a more important factor in piston pump design than in the aforementioned gear or vane pump design. However, it is not within the parameters of this discussion to prove or disprove this assumption.

As shown in *Table 5*, the 1 Ft. of Static Head estimated to cover the pump inlet resistance to flow is simply added to the calculated resistance to flow of the piping system. With Propane, the fittings and inlet piping have a resistance to flow of 7.30 Ft. of Static Head, to which is added the 1 Ft. of Static Head for the pump inlet, totaling 8.30 Ft. of head for the inlet system including the pump. If the same pump and installation were to handle liquid CO_2, NH_3 or Butane from an almost empty tank without "starvation", the bottom of the tank should also be about 8-1/3 Ft. above the pump inlet level . With low-pressure liquefied CO_2 the distance _cannot_ theoretically be reduced to about half that figure. Under average handling conditions, the viscosities of these liquids are nearly the same (about one-tenth that of water). Simple flow through short pipes does not cause notable frictional differences. *However, abrupt flow directional changes definitely have a notable effect on line resistance, and are proportional to the liquid density. As the weight per unit volume increases, the PSI gain per Ft. increases; but, what is gained in greater Static Head, is proportionately lost in increased inertial resistance to movement variations. Therefore, in as much as inlet line calculations are concerned, the same vertical distance, which has been figured to provide adequate NPSHR at the pump suction for Propane, does not change for an identical piping system and pump utilized in the same way for handling Butane, NH_3, or CO_2 under average conditions.* The minimum distance may be reduced by using valves and fittings with lower resistance to flow values. In some cases it may not be possible, or it may be too expensive, to design the pump inlet line so that the pump is not starved when the tank is almost empty. If it can be assumed that a supply tank will be at least one-third full of liquid most of the time, then the majority of the pumping will occur when the head is greater than the distance between the bottom of the tank and the level of the pump inlet.

Table 6 has been prepared, using LPG to illustrate the effect of pump starvation, if the supply tanks are not mounted high enough above the pump inlet. *Table 6* illustrates the effect of natural vapor pressures upon vaporization in the fluid supplied to the pump, and gives different results with Propane (a fluid with relatively high pressure), vs. Butane (a fluid with a relatively low pressure). As the ambient temperature-related natural vapor pressures change, it is easy to determine how a detrimental vaporization situation can be either improved, or aggravated. Other liquefied gases handled by SMITH pumps behave in much the same manner, with the exception of low-pressure liquid Carbon Dioxide, which has a relatively high vapor pressure, and is artificially held within a more constant temperature range. However, it must be noted that this liquid has no inherent lubricity, a factor which accentuates pump damage caused by lack of sufficient Net Positive Suction Head Available, at the pump suction connection. Any condition which causes excessive vaporization in the liquid supplied to the pump inlet, should be avoided, *especially* with CO_2.

To use *Table 6*, calculate how high the tank should be mounted. Determine the difference between the proper height and the actual height.

The table below serves to illustrate the point with Propane and Butane as examples. The percentage reductions in pump capacity listed in *Table 6* indicate the percentage of vapor formed by volume, for both Propane and Butane at selected temperatures. NH_3 and CO_2 are not illustrated. Assume the tank is mounted 3 Ft. lower than it should have been to provide the proper head. The percentage reduction in capacity is less than 10 per cent for Propane at high temperature, but at lower temperatures, the volume is more than 10 per cent. Butane at any temperature will form more than 10 per cent vapor by volume at any temperature. A volume of more than 10 per cent vapor in the handled fluid, can cause extra pump wear.

Caution: Any condition which will cause more than 10 per cent vapor volume in the inlet flow to an LPG or NH_3 liquefied gas pump, should be avoided. A more cautious approach is recommended for CO_2, especially in continuous duty, due to aggravated wear conditions from lack of lubricity. With liquefied gases, it is always best to design for extra "Net Positive Suction Head Available (NPSHA)" at the pump inlet connection.

TABLE 6. **PERCENTAGE OF CAPACITY REDUCTION IN LPG PUMPS WHEN THERE IS INSUFFICIENT STATIC HEAD PRESSURE**

Liquid and Temperature	The Difference Between "Required Elevation" and "Actual Elevation" In Equivalent Feet of Vertical Liquid Column											
	1	2	3	4	5	6	7	8	9	10	11	12
Propane 100° F.	0.7	1.4	2.0	2.7	3.3	4.0	4.6	5.2	5.8	6.5	7.1	7.6
Propane 70° F.	1.4	2.8	4.1	5.4	6.6	7.9	9.0	10.2	11.4	12.4	13.5	14.6
Propane 40° F.	3.0	5.9	8.9	11.1	13.6	15.8	18.0	20.1	22.0	23.9	25.7	27.3
Propane 10° F.	6.9	12.9	17.9	22.0	27.1	30.8	34.2	37.3	40.2	43.5	45.1	47.2
Propane -20° F.	16.3	28.0	36.8	43.7	49.3	53.9	57.6	60.8	63.7	66.1	68.1	70.0
Butane 100° F.	7.4	13.7	19.3	24.1	28.5	32.3	35.7	38.9	41.7	44.3	46.7	48.8
Butane 70° F.	15.3	26.5	35.1	41.8	47.3	51.9	55.8	59.0	61.8	64.2	66.3	68.3
Butane 40° F.	30.9	48.3	58.4	65.3	70.2	73.8	76.7	79.1	80.8	82.6	83.8	84.9

Note: The data in this table does not infer that lack of sufficient "Net Positive Suction Head Available (NPSHA)" at the pump inlet connection is proper or tolerable. In any case, "flooded suction" should be considered as an essential system design criterion. The less pressure the handled liquefied gas has, the more important "flooded suction" is.

Tables for Pump Discharge Line Calculations

The tables for inlet lines (Tables 3, 4, and 5) express the resistance to flow in terms of feet of head, or pipe. The tables for discharge lines (Tables 7, 8, 9, 10, and 11) use "pressure drop" or "back-pressure" in terms of pounds per square inch (PSI). The words "resistance to flow" and "pressure-drop" mean the same thing. A column of LP-Gas or liquid NH_3 4 Ft. high will exert about 1 PSI of pressure at the bottom of the column, or 1 Ft. of LP-Gas or NH_3 will equal about ¼ PSI pressure. Low-pressure liquefied Carbon Dioxide will raise the pressure by approximately double this figure. Due to the low viscosities of liquefied gases, standard pumps are sensitive to pressure restrictions in their discharge lines. The clearance between gears, vanes, or other moving parts, and the stationary parts, allows liquid to bypass back to the inlet side of the pump. This loss is sometimes called "slippage". Slippage varies with the make and type of pump, but in most cases under discussion here, liquefied gas pumps handling either Butane/Propane (LPG), NH_3, or CO_2 lose 3 to 10 per cent of their capacity for each 10 PSI differential pressure that they pump against. A worn pump will lose a greater percentage of its capacity for any given back-pressure.

In this manner, a standard 50 USGPM pump of the most efficient type, will have its capacity reduced to 35 USGPM when pumping against 100 PSID. A pump of the least efficient type could easily have its capacity reduced to zero under such conditions. In addition to causing the pump to lose capacity, a discharge line that is highly restrictive will cause faster pump wear, as some of the pump working parts will be carrying higher loads in proportion to the extra pressure developed. Pump discharge lines should therefore be designed to have as little pressure drop as possible. The most complicated discharge line is one involving a liquid meter, used on trucks for consumer "bulk" deliveries, or in stationary systems for filling fuel tanks on motor vehicles, single cylinders, and the like. *Fig. 4* illustrates such a system. Many other types of systems are much less complicated.

As an aid in the calculation of the total pressure drop in a discharge system, a series of tables are included listing the pressure drop (in PSI) for discharge system components. Table 7 lists data concerning resistance to flow for typical LP-gas meters. The resistance to flow through meters used with other liquids would be similar in nature. *For exact figures, please contact the meter manufacturers.* Table 8 lists comparative data for globe valves; Table 9 lists the comparative resistance to flow of 50-Ft. lengths of delivery hose of various diameters; and Table 10 lists comparative data for tank filler valves of different sizes. Table 11 comparatively tabulates tank back-pressure. Components such as various fittings that are not listed in the discharge system can be safely neglected in some cases, but not in others.

These tables are adequate for figuring general indications. Keep in mind that resistance to flow figures are determined separately by each supplier under tests specific to their particular product. Once all required components are assembled together in an inlet, or an outlet piping system, the flow dynamics can cause notable variations in pressure drop characteristics. *The true functional flow resistance may be different from that calculated by tabulating the given individual figures.*

TABLE 7. AVERAGE RESISTANCE TO FLOW IN METERS AVAILABLE FOR LP-GAS SERVICE (PRESSURE DROP IN PSI)

Delivery Rate USGPM	1¼" Size (5 to 30 USGPM)	1½" Size (12 to 60 USGPM)	2" Size (20 to 100 USGPM)
5	0.3	Not recommended	Not recommended
10	0.5	Not recommended	Not recommended
15	0.9	0.8	Not recommended
20	1.4	1.1	0.3
25	2.2	1.7	0.6
30	3.1	2.4	0.8
40	Not recommended	4.1	1.2
50	Not recommended	6.3	1.8
60	Not recommended	9.0	2.6
70	Not recommended	Not recommended	3.7
80	Not recommended	Not recommended	4.9
90	Not recommended	Not recommended	6.3
100	Not recommended	Not recommended	7.8

* This table is only for general comparative analysis of meters, and is based principally on meters often utilized in LPG services, which are the most common. For exact pressure drop figures as required, contact the meter manufacturers.

A sample calculation of the pressure loss in a typical liquefied gas discharge line is shown as *Table 12*. In the sample problem, a delivery rate of 40 USGPM is assumed through a relatively complicated system such as that shown in Fig. 4. In addition, the inlet line is assumed to have been designed properly, so that only the discharge line calculations are of significance. The problem is based upon straight Propane, under conditions that are as difficult as possible: summertime, temperature at 100° F., no pressure equalizing line, and with the customer's tanks having old style filler valves not equipped for vapor space filling.

Under the difficult LPG filling conditions imposed by the problem in Table 12, the tank back-pressure at 100° F. is far in excess of the pressure drop of the other components. The total pressure drop of 175 PSID in fact exceeds the maximum recommended bypass valve setting of 125 PSID. Unless one wishes to disregard safety regulations, it is very easy to see that with Propane on a hot Summer day, it is extremely difficult if not impossible to fill tanks having original-style filler valves, when a pressure equalizing line is not used. Where applicable, to convert listed Propane resistance to flow figures in these tables into average values for Butane, NH_3, or CO_2, multiply the Propane values by 1.15, 1.21, or 1.98 respectively.

TABLE 8. RESISTANCE TO FLOW OF AVERAGE GLOBE VALVES IN STANDARD PROPANE SERVICES* (PRESSURE DROP IN PSI)

Delivery Rate (USGPM)	Nominal Sizes ½"	¾"	1"	1¼"	1½"	2"
5	-0-	-0-	-0-	-0-	-0-	-0-
10	1.6	-0-	-0-	-0-	-0-	-0-
15	3.6	1.1	-0-	-0-	-0-	-0-
20	6.4	2.0	1.2	-0-	-0-	-0-
25	10.0	3.0	1.9	-0-	-0-	-0-
30	14.4	4.5	2.8	1.0	-0-	-0-
40	25.6	8.0	4.4	1.9	-0-	-0-
50	40.0	12.0	6.7	2.9	1.0	-0-
60	57.6	16.0	9.6	4.0	1.5	-0-
70	Too high	21.0	13.0	5.2	2.0	1.0
80	Too high	28.0	16.5	6.7	2.5	1.3
90	Too high	35.0	21.0	8.3	3.2	1.6
100	Too high	47.0	25.0	10.1	4.0	2.0

* This table is only for general comparative analysis of globe valves only. Other types of valves which have less resistance to flow may be substituted. This table does not apply to special services, or where the liquids handled are contaminated with highly viscous substances. Contact the manufacturers for exact resistance figures as required. Consult technical bulletins, engineering texts, and other pertinent authoritative references.

TABLE 9. RESISTANCE TO FLOW OF 50 FT. LENGTHS OF DELIVERY HOSE OF VARIOUS SIZES AND AT VARIOUS DELIVERY RATES*. (PRESSURE DROP IN PSI)

Delivery Rate (USGPM)	½"	¾"	1"	1¼"	1½"	2"
5	8.1	1.1	0.2	0.1	-0-	-0-
10	30.0	4.0	0.9	0.3	0.1	-0-
15	64.6	8.5	2.0	0.7	0.3	-0-
20	Too high	14.4	3.4	1.0	0.5	0.1
25	Too high	22.1	5.2	1.7	0.7	0.2
30	Too high	31.0	7.4	2.4	0.9	0.3
40	Too high	54.0	12.6	4.2	1.6	0.4
50	Too high	Too high	19.0	6.4	2.5	0.6
60	Too high	Too high	26.4	9.0	3.5	0.8
70	Too high	Too high	35.4	11.9	4.6	1.1
80	Too high	Too high	46.2	15.5	5.9	1.4
90	Too high	Too high	56.6	19.0	7.4	1.7
100	Too high	Too high	69.7	23.4	8.9	2.1

* This table is for comparative resistance to flow under average conditions for Propane. It does not apply to special services, or where the liquids handled are contaminated with highly viscous substances. Contact the manufacturers for exact resistance figures as required. Consult engineering texts, technical bulletins, and other authoritative references. For general indications with Butane, NH_3 or CO_2, multiply figures shown by 1.15, 1.21, or 1.98.

TABLE 10. RESISTANCE TO FLOW OF TANK FILLER VALVES OF VARIOUS SIZES AT DIFFERENT FLOW RATES* (PRESSURE DROP IN PSI)

Delivery Rate (USGPM)	Original Valves ¾"	1¼"	2"	Modern Valves ¾"	1¼"
5	2.9	0.4	0.1	11.0	0.1
10	9.2	2.0	0.3	14.0	0.3
15	20.0	2.8	0.6	17.0	0.6
20	35.0	4.5	0.9	20.0	1.1
25	54.7	6.8	1.5	22.5	1.7
30	Too high	10.0	2.2	24.0	2.5
40	Too high	17.8	3.9	27.0	4.4
50	Too high	27.8	6.1	50.0	6.9
60	Too high	32.4	8.8	Too high	10.0
70	Too high	44.1	12.0	Too high	13.6
80	Too high	57.6	15.6	Too high	17.8
90	Too high	Too high	19.8	Too high	22.2
100	Too high	Too high	24.5	Too high	27.8

*This table is only for comparative resistance to flow of Propane liquid under average conditions, passing through the types of filler valves utilized in the LPG industry for many years. It does not apply to other types of filler valves, special services, or where the liquids handled are contaminated by highly viscous substances. For Butane, NH_3, or CO_2, multiply by 1.15, 1.21, or 1.98 respectively.

TABLE 11. AMOUNT OF BACK-PRESSURE BUILT-UP IN TANKS FILLED WITHOUT THE USE OF VAPOR RETURN LINES (PRESSURE DROP IN PSI)*

Liquid	Temperature (F.)	With Modern-Style Vapor-Space Filling	With Original-Style Dip Tube Filler Valves
Propane	100°	31.1	124.4
Propane	70°	16.9	67.6
Propane	40°	8.9	35.5
Propane	10°	4.1	16.3
Propane	-20°	1.6	6.4
Butane	100°	3.8	15.1
Butane	70°	1.8	7.2
Butane	40°	0.8	3.1
NH_3	100°	8.8	35.3
NH_3	70°	4.4	17.6
NH_3	40°	0.9	3.4

* This table is only for consideration of comparative back-pressure in LPG and NH_3 tanks. Low-pressure liquid Carbon Dioxide tanks must always be filled utilizing vapor equalization lines, except for very unusual surge-filling circumstances not covered in this booklet. Liquefied Anhydrous Ammonia transfer, although similar in many ways to LPG transfer, may fall within a pressure category different than shown. Consult the tank manufacturers, engineering texts and other authoritative references for required additional information.

TABLE 12. SAMPLE CALCULATION OF PRESSURE LOSS IN AN LP-GAS PUMP DISCHARGE LINE

Assumptions: Delivery rate desired, 40 USGPM
Straight Propane
Summertime temperature of 100° F.
Original-style filler valves on customer tanks
No pressure equalizing line

Discharge Line Components	Reference Table	Differential Pressure at 40 USGPM (PSID)
Meter, 1¼-in. standard make with back-pressure valve (items 12 and 14, Fig. 4)	7	4.1
Valve, 1¼-in. (Item 35, Fig. 4)	8	0.0
Valve, 1-in. (Item 28, Fig. 4)	8	4.4
Hose, 1-in., 100 Ft. length (Item 16, Fig. 4)	9	25.2
Filler Valve, 1¼-in., in consumer tank (Item 36, Fig. 4)	10	17.8
Back-pressure built-up in tank being filled	11	+ 124.4

Total Pressure Drop = 175.9 PSID

If a pressure equalizing line can be used, the tank back-pressure item in *Table 12* can be omitted from the calculation. In such event, the vapor line could be designed to handle the return flow, and filling would be comparatively easy. Failing this, the recommended way to fill consumer tanks under the most difficult conditions, is to install modern-style filler valves using vapor-space filling on the consumer tanks.

Using Propane as an example, the basis of calculations using different temperatures and different types of filler valves, a series of recommendations can be made for the best over-all service with pumps used in different ways:

1. *Small pumps*: Design discharge lines so that the total pressure drop, including the tank back-pressure, is 75 PSID or less when filling single cylinders. Allow for the pressure drop of the cylinder valve in the figures.
2. *Medium capacity pumps used without meters*: for loading and unloading only, design for the least pressure drop conveniently and economically possible, not to exceed 40 PSID. In such calculations, if the pump is used to load delivery trucks, do not neglect to consider the pressure drop of the filler valve and other valves and fittings on the trucks. These items are often forgotten. Use a pressure equalizing line, especially with CO_2 transfer. *Be careful not to undersize the equalization line*. Make sure all lines between the two tanks (including the hoses) are the proper recommended sizes. (See appropriate service manuals).

TABLE 13. RECOMMENDED SIZE OF PRESSURE EQUALIZING LINE.

	Size of Pressure Equalizing Line	
Pump Size	If Short (in.)	If Long (in.)
10 USGPM	½	½
15 USGPM	½	½
20 USGPM	½	¾
35 USGPM	½	¾
50 USGPM	¾	1
100 USGPM	1	1¼
150 USGPM	1½	2
200 USGPM	2	2½

3. *Medium capacity pumps used with meters or for filling a number of LPG or NH_3 cylinders each day*: design for 75 PSID pressure drop, maximum.
4. Large pumps used on high-capacity delivery trucks: design for 125 PSID maximum pressure drop unless Summer temperatures in the area are unusually high. In such an event, reduce the back-pressure to a maximum of 100 PSID, with the exception of CO_2 deliveries *which must be kept to a maximum of 50 PSID.*
5. Large pumps used for high-volume loading and unloading: design for the least pressure drop conveniently and economically possible, not to exceed 40 PSID. *Use a pressure equalizing line, especially with CO_2 transfer. Be careful not to undersize the equalization line.* Make sure all lines between the delivery vehicle and the tank being filled (including the hoses, all valves, fittings, and pipes) are the proper recommended sizes.

Pressure Equalizing Lines (Vapor Return Lines)

Use a pressure equalizing line wherever possible. To do a good job, this line must not be too small, or it will not equalize pressures as it should. This is especially critical in low-pressure liquid Carbon Dioxide transfer operations. Refer to *Table 13* for the recommended sizes of pressure equalizing lines for LPG, NH_3, and CO_2.

Pressure Reduction in Tanks Being Unloaded Without Use of Pressure Equalizing Lines

The reader is referred to previous discussion on pressure increase in LPG tanks being loaded without use of pressure equalizing lines, including descriptive *Table 11*. This method of liquefied gas transfer results in extra pressure being required of the pump, as explained before, and is *not* recommended for liquid CO_2.

Table 14 shows the effect of eliminating pressure equalizing lines on tanks being unloaded. As liquid is drawn from the supply tank in such a system, the space formerly occupied by this liquid must be filled with vapor. Since the vapor cannot come from a pressure equalizing line, it must come from the liquid that remains in the supply tank. In this type of pumping system, the liquid in the tank being unloaded boils continuously while the pump is in operation. The necessary vapor can be created in no other way, and since boiling requires heat, and little heat is absorbed from the outside, most of the heat has to come from the liquid remaining in the supply tank. As heat is taken away from this liquid, the temperature of the liquid continually decreases. This lowering of temperature reduces the pressure in the tank being unloaded.

The situation would be more aggravated in a well-insulated, refrigerated tank, which would absorb even *less* heat from the external environment during such a situation. It should be mentioned here that in certain specialized consumer tank filling operations, even with low-pressure liquid CO_2, it has been observed that far-removed storage tanks must be filled through a relatively long restrictive liquid line, and sometimes without the advantage of a vapor return connection. In order to avoid building excessive differential pressure across the pump, the vapor phase of a CO_2 tank being filled in this manner may have to be vented slowly through a small valve, to relieve the back-pressure as it fills. This procedure cannot be safely accomplished with other more toxic or flammable liquefied gases, especially with LPG. However, when the liquid level drops in a tank, which is not connected to a pressure equalization line, its pressure decreases accordingly. This action causes the difference in pressures to rise between the supply tank, and the consumer tank. This increase in differential pressure results in the pump working much harder. In these cases, especially with *refrigerated* liquid transfer, it is very easy for the pump to develop differential pressures in excess of the recommended maximum, unless the external (or "primary") bypass valve is properly adjusted to eliminate such an occurrence. By allowing a continual bypassing of pumped fluid back to the tanker, while filling the removed consumer tank, the flow which has picked-up heat from the pump and is returning through the external bypass valve, replaces some of the heat which is lost due to the non-equalized growing vapor phase. Provided the tank is designed properly to accomplish recirculation heat gain within safe recommended guidelines, this action gradually builds-up pressure in the pump supply tank, and helps to relieve the potentially excessive differential pressure.

The amount of pressure reduction created in a pump supply vessel vacated without the use of a pressure equalizing line, depends upon two factors: (1) the temperature of the liquefied gas in the supply tank at the start; and (2) the percentage of total capacity of the supply tank that is unloaded at any one time. For example, in the case of LPG, a study of *Table 14* reveals that the higher the temperature of the liquid at the start, the greater the pressure reduction. Also note that the greater the percentage of product unloaded in any one operation, the greater the pressure reduction. Pressure reduction is almost negligible with straight Butane. Pressure reduction is also almost negligible with Propane at temperatures lower than 40° F.. *Table 14* shows figures only for LPG conditions where the pressure reduction is significant enough to be taken into consideration during the design of a pumping system. For greater in-depth information regarding LPG, and other liquefied gases under similar conditions, please refer to engineering texts and other authoritative references.

To illustrate the use of *Table 14* in a typical LPG transfer scenario, assume that the supply tank to be unloaded carries 2000 USG of straight Propane when filled to a safe level. In such a case, if the normal delivery from this tank is to be about 500 USG, 25 per cent of the liquid in this tank will be unloaded in each pumping operation. Reference to *Table 14* will show that if the starting temperature is 100° F., pressure reduction is 8.4 PSI; at 70° F., it would be 4.3 PSI; at 40° F., 2.1 PSI. On the other hand, if the average volume unloaded to one customer's tank is approximately 1000 USG, then the pressure reductions are more than double with each operation. If the tank should be completely unloaded of all its 2000 USG on occasion, the pressure reduction could be over 70 PSI if the starting temperature were 100° F.. Normally, each delivery should be considered as a separate case, since during the time the truck is on the road traveling to the next stop, enough heat may be transferred from the atmosphere to warm the remaining liquid again, and bring supply tank pressure back to normal. Under this reasoning, then, only the pressure reduction figure shown in *Table 14*, for the maximum temperature and the average percentage unloaded in a single delivery, need be considered. This pressure reduction figure should be added to the other figures in the sample calculation in *Table 12*, if one wishes to take this factor into account in the design of an LP-Gas pumping system not using a pressure equalizing line.

This factor was purposely left out of the sample calculation (*Table 12*) because *these figures are based upon mathematical theory and have not, as far as we know, been confirmed by a large number of actual tests.* Those tests which have been performed under actual delivery conditions with commercial mixtures over the years roughly confirm the data in Table 14, but only at some temperatures.

***TABLE 14.* PRESSURE REDUCTION IN TANKS BEING UNLOADED WITHOUT THE USE OF EQUALIZING CONNECTIONS, FOR STRAIGHT PROPANE ONLY**

Temperature of Propane in Tank at Start (Degrees F.)	Percentage of Volume of Tank Unloaded in One Operation 25%	50%	75%	100%
100	8.4 PSI	18.7 PSI	34.5 PSI	76.9 PSI
70	4.3 PSI	10.0 PSI	18.3 PSI	39.9 PSI
40	2.1 PSI	4.2 PSI	9.3 PSI	21.2 PSI

In cases where a large percentage of Propane is unloaded at one stop at high temperatures without the use of pressure equalization (short of continually recirculating a percentage of the pump output back to the truck tank), there have been two somewhat practical but more unusual means for overcoming excessive supply tank pressure reduction. One method is to paint the top of the supply tank a dull black, so that some extra heat will be absorbed into the system from the sun. The second method is to install a vaporizer bleeding a small percentage of product from the pump discharge line. The vaporizer would use heat from the truck engine, either from the engine cooling system or the engine exhaust system, or both, to vaporize the liquid bleed, and discharge it to the vapor space of the supply tank. Tests definitely indicate that such a vaporizer helps considerably by increasing supply tank pressure, lessening the need for differential pressure across the pump, speeding-up Propane delivery rates.

It should be understood that the aforementioned example, as well as all the others given in this booklet, are to be taken strictly within the context of safe, approved, methods for LPG transfer. Other liquefied gases such as Butane, and Anhydrous Ammonia, would behave in a fashion similar to Propane, but at lower pressures due to less vapor density, resulting in decreased tank filling back-pressure values. LPG and NH_3 pressures will vary greatly from one area to another, depending upon the ambient temperature and the quality of liquid handled. However, at the same site, with the same batch of product, *back-pressure is constant in consumer vessels being filled without vapor return lines, regardless of the size, from a 20-lb. cylinder on up, as long as they are fast-filled from almost empty to a safe level (except for very large tanks being filled).* This is because under these conditions, the energy required to "collapse" the vapor phase into liquid, as the liquid phase rises, remains practically at a constant level (see *Table 11*).

This "collapse" takes extra pressure to accomplish, as when vapor is compressed into liquid, it generates a considerable amount of heat. The amount of heat given off varies with the temperature of the liquid when the vapor collapses. During a typical fast filling operation, there is not enough time for much of this heat to be radiated away through the tank walls to the outside. Therefore, the temperature of the vapor space in the tank increases very rapidly, and this of course brings on an increase in pressure. This pressure increase, which we call "back-pressure"(or "differential pressure") slows deliveries.

Note that we have been discussing the temperature in the vapor space. The liquid in the tank stays cool, as liquids are practically incompressible, and there is not enough time for much of the heat in the vapor to be transmitted to it. The cool liquid does not mix with the hot vapor being compressed in the vapor space, and a high back-pressure is built-up.

8. ADDITIONAL ILLUSTRATIONS AND TABLES FOR SMITH PUMP APPLICATIONS

Most SMITH pumps are used for simple intermittent bulk-transfer operations. Recommended speed ranges, actual outputs, and corresponding model numbers with designation codes, are not necessarily the same as those shown in our sales literature, which reflects the vast majority of typical uses. For example, the basic model numbers, rated capacities, and rated drive speeds shown in catalogs "CP-1", "CP-3", and "CP-9", relate strictly to "standard" pumps. The factory will determine the correct "Model Type" and "Optional Features", in accordance with the actual use conditions. The "Designation Codes" in the following tables, are used by the factory to indicate the applicable "use-specific" construction configurations. These letters are stamped on the pumps immediately following their "basic model numbers". Standard installation, operation, and repair procedures refer to SMITH pumps by their "*generic model type*". For each generic model type, there can be many use-specific model numbers, each with distinct "designation codes". The more use-specific the pump becomes, the longer it can potentially last. Therefore, it is always in the user's best interest to fully consider all of the options before deciding on a specific model.

This section, "Section 8." contains additional information for most SMITH pump applications. Keep in mind that the following is based on *average* conditions. Required factory modifications may vary from those shown in some of the following tables, if the actual use situation is not exactly covered under the depicted categories, especially with LPG and NH_3.

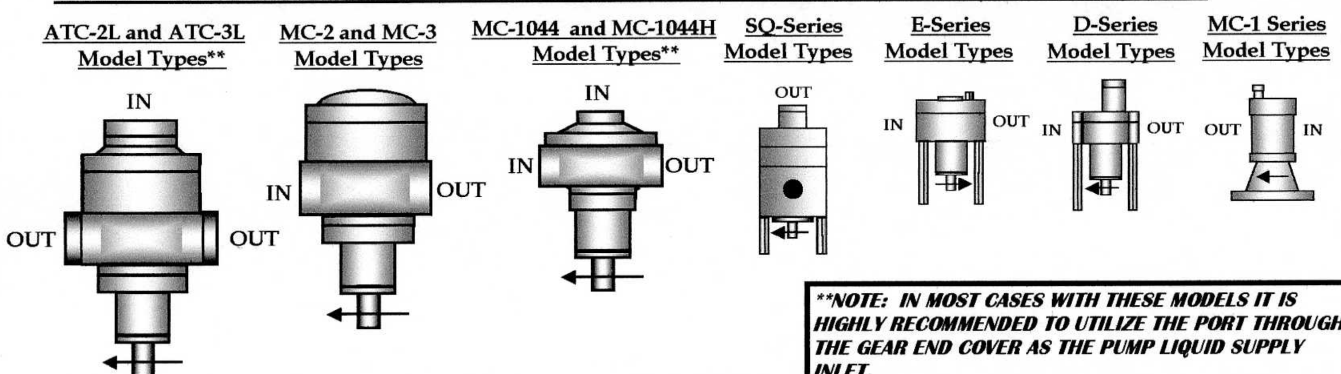
The table for liquid NH_3 transfer is self-explanatory. It does not apply to all cases, especially where the liquid temperature is less than 0° F., or the oil viscosity is greater than 110 Cks. (500 SSU). Contact the factory for additional information on pumping circumstances other than those shown; *additional pump modifications may be required.* The highlighted area refers to the general application limits acceptable for longest pump life with a standard unit, within the parameters of this discussion.

Low-pressure liquid Carbon Dioxide transfer covered by this discussion is more simply categorized, as shown in the corresponding table. Note the highlighted area, which indicates the general application limitations acceptable for the longest pump life with a standard unit, within the parameters of this discussion.

The LPG table refers to SMITH pumps handling mixtures consisting exclusively of Butane and Propane constituents with acceptable traces of other hydrocarbon fractions. The highlighted area indicates the general application limits acceptable for longest pump life, with a standard unit within the parameters of this discussion. Contact the factory if the liquids to be handled have high percentages of other liquefied petroleum gases (such as Butadiene, Butylene, Propylene, Pentane, etc.).

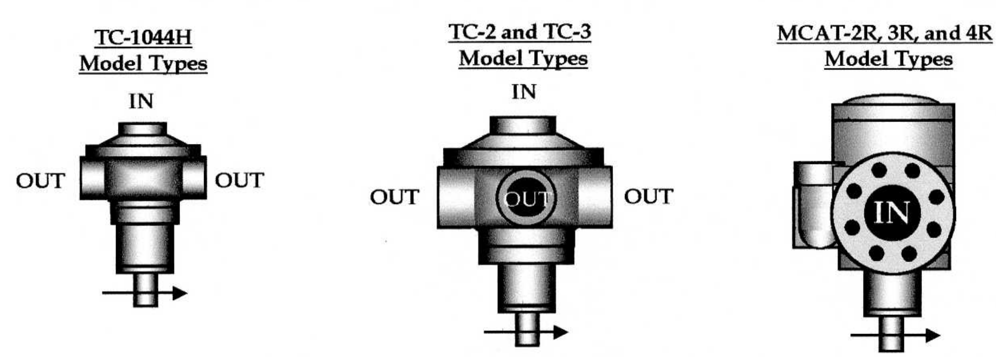
The pressure-temperature table is highlighted in areas of concern. Specific construction designations are required for SMITH pumps handling liquids at a vacuum, and also at temperatures approaching, or below, -40° F..

GENERIC SMITH MODEL TYPES MOST COMMONLY USED IN AVERAGE LIQUEFIED GAS APPLICATIONS



NOTE: IN MOST CASES WITH THESE MODELS IT IS HIGHLY RECOMMENDED TO UTILIZE THE PORT THROUGH THE GEAR END COVER AS THE PUMP LIQUID SUPPLY INLET.

GENERIC SMITH MODEL TYPES MOST COMMONLY USED IN SLOW-SPEED APPLICATIONS



EXPLANATION OF SMITH PUMP CONSTRUCTION CONFIGURATIONS USED IN DIFFERENT "MODEL TYPES" AND "OPTIONAL FEATURES".

Designation Code	Description
S	Extended temperature, pressure, and/or viscosity range
NS	High range gears: AIRCRAFT QUALITY STEEL
SA	Enhanced stress-resistant idler shafts: TUNGSTEN CARBIDE
H	Maximum flow gearing: for LOWER RPM APPLICATIONS
L	High-capacity standard configuration gearing: 25% INCREASE
F	Foot-bracket on small pumps for base mounting, or Flanged ports on "-2" medium capacity pumps on up: all provided with SMITH COMPANION FLANGES
Z	Heavy-Duty mechanical seals (LPG/CO_2): "SUPERSEAL"

"Optional Features", and "Model Types", are factory designations determined by pumping requirements. The basic model number stamped on the pump will be followed by any of the pertinent "Designation Codes" mentioned above. Together they make up the use-specific pump model number. The Designation Code "Z", a further refinement suitable for LPG and low-pressure liquefied Carbon Dioxide mechanical seal assemblies, is not compatible with liquefied Anhydrous Ammonia services.

MAXIMUM APPLICATION LIMITS FOR "ATC, MC, AND SQ-SERIES" SMITH PUMPS HANDLING LIQUEFIED ANHYDROUS AMMONIA W/ OIL OF LESS THAN 110 CKS VISCOSITY, *FROM 0° F. TO +100° F.*

Max. Use Interval	Recommended RPM	Max. PSID	Model Type	Optional Features
3 Min.	1400 -1800	250	SNSSA	L or H, F
7 Min.	1400 -1800	225	SNSSA	L or H, F
10 Min.	1400 -1800	200	SNSSA	L or H, F
13 Min.	1400 -1800	175	SNSSA	L or H, F
17 Min.	1400 -1800	150	SNSSA	L or H, F
20 Min.	1400 -1800	125	SNSSA	L or H, F
20 Min.	1100 -1300	80	HSNSSA	F
45 Min.	1400 -1800	100	SNSSA	L or H, F
2 Hrs.	1400-1800	40	Std.	NS,SA,H,L,S,F
2-1/2 Hrs.	1400 -1800	75	SNSSA	F
6 Hrs.	1300 -1800	60	HSNSSA	F
Over 6 Hrs.	750 -1000	40	HSNSSA	F

This table serves as a general basic application guide. See the Pressure-Temperature table on pg. 28. *Contact the factory for additional information regarding acceptable parameters for pumps used under different conditions.* These pumps can be reduction-run or direct-connected to electric motors. Before using pumps under these conditions, be sure to read and understand all available information in this bulletin, and others. Avoid hazardous use situations.

MAXIMUM APPLICATION LIMITS FOR SMITH "ATC, MC, AND SQ-SERIES" PUMPS HANDLING LOW-PRESSURE LIQUEFIED CARBON DIOXIDE, FROM -20° F. TO +15° F.

Max. Use Interval	Recommended RPM	Max. PSID	Model Type	Optional Features
1 Hr.	1400 - 1800	50	Std.	NS,SA,L,H,F,Z
2 Hrs.	1400 - 1800	50	Z	NS,SA,L,H,F
6 Hrs.	1100 - 1300	40	NSZ	SA,L,H,F
Over 6 Hrs.	750 - 1000	40	HNSSA Z	F

This table serves as a general basic application guide. See the Pressure-Temperature table on pg. 28. Contact the factory for additional information on use under different circumstances. These pumps can be reduction-run or direct-connected to electric motors. Before using the pumps under these conditions, be sure to read and understand all available information in this discussion, and others. Avoid hazardous use conditions.

MAXIMUM APPLICATION LIMITS FOR "MC AND ATC-SERIES" SMITH PUMPS HANDLING LPG (BUTANE, PROPANE, AND THEIR MIXTURES *AT POSITIVE PRESSURES*, FROM -40° F. TO +250° F.)

Max. Use Interval	Recommended RPM	Max. PSID	Model Type	Optional Features
1-1/2 Hrs.	1400 -1800	125	Std.	NS,SA,L,H,F
3 Hrs.	1400 -1800	125	NS	SA,L,H,F,Z
8 Hrs.	1100 -1300	80	NS Z	SA,L,H,F
12 Hrs.	1100 -1300	80	HNSZ	SA,L,F
Over 12 Hrs.	1100 -1300	60	HNSSAZ	F
Over 12 Hrs.	750 -1000	40	HNSSAZ	F

Note: "GC-1 Series" and "MC-1" Series SMITH pumps when utilized for small individual container-filling operations, may be run up to 3600 RPM

This table serves as a general basic application guide. See the Pressure-Temperature table, below. Contact the factory for additional information on pumps for these liquids at *negative* pressures, or under pumping circumstances other than shown. SMITH pumps can be reduction-run or direct-connected to electric motors. Before using the pumps under these conditions, be sure to read and understand all available information in this discussion, and others. Avoid hazardous use conditions. Follow all applicable safety regulations.

GENERAL PRESSURE-TEMPERATURE TABLE**

(APPROXIMATE PRESSURES GIVEN IN "PSIA")

TEMPERATURE	BUTANE	PROPANE	NH_3	CO_2
-50° F.	-	12.6	7.7	-
-40° F.	-	16.2	10.4	-
-30° F.	-	20.3	13.9	-
-20° F.	-	25.4	18.3	220.6
-10° F.	-	31.4	23.7	261.7
0° F.	7.3	38.2	30.4	308.6
+10° F.	9.2	46.0	38.5	361.8
+20° F.	11.6	55.5	48.2	422.0
+30° F.	14.4	66.3	59.7	-
+40° F.	17.1	78.0	73.3	-
+50° F.	21.6	91.8	89.2	-
+60° F.	26.3	107.1	107.6	-
+80° F.	37.6	142.8	153.0	-
+100° F.	52.2	187.0	211.9	-

** THE VALUES LISTED IN THIS TABLE ARE ONLY INTENDED TO SHOW APPROXIMATE COMPARATIVE TEMPERATURE-PRESSURE RANGES OF THE FOUR MOST COMMONLY-USED LIQUEFIED GASES MENTIONED IN THIS TEXT. SEE STANDARD ENGINEERING TEXTS FOR EXACT RATINGS ON THESE AND OTHER LIQUIDS. NOTE THAT AT COLDER AMBIENT TEMPERATURES, ALL BUT CARBON DIOXIDE LIQUID EXHIBIT NATURAL VAPOR PRESSURES LOWER THAN ATMOSPHERIC PRESSURE. GREAT CARE SHOULD BE EXERCISED IN DESIGNING TRANSFER SYSTEMS IN AREAS WHERE THESE TEMPERATURES ARE PREVALENT. SPECIAL PUMP MODIFICATIONS MAY BE REQUIRED, ESPECIALLY AT TEMPERATURES APPROACHING, OR BELOW -40° F..

Use of the Pump Performance Formulae

The performance formulae for SMITH Precision Pumps have a very real advantage over simple performance curves. Such curves apply to pumping capabilities of a *new* pump, in a perfect installation. The Smith formulae are conservative, and are applicable to a pump after considerable service, or in an installation that is somewhat less than perfect. When an installation is properly made, new SMITH pumps will actually perform *better* than indicated by the formulae. Pumps that are specified on the basis of the formulae and tables will have a long service life. The formulae are conservative and can be guaranteed for all SMITH pumps in proper installations that have been reviewed by our Engineering Department. Since the proper installation has a very important bearing on performance of a pump handling liquefied gases, our Engineering Department will gladly review a proposed piping layout without obligation. The customer is urged to furnish a complete drawing, or sketch showing relative elevations, sizes, makes, and types of all components in both inlet and discharge lines.

FORMULA 1: OUTPUT

$$Qd = Qr \times \left(\left(\frac{Nd}{Nr}\right) - (Fs \times Pd)\right)$$

FORMULA 2: HORSEPOWER

$$HP = \left(\left(\frac{8.5\ Nd \times Qr}{Nr}\right) \times 10^{-4}\right) \times (10 + Pd)$$

where Qd= actual pump delivery in U.S. gallons per minute

Qr = rated transfer capacity in USGPM (as given for pumps in table to the right)

Pd = differential pressure being pumped against, in pounds per square inch

HP= horsepower required to drive pump

Nd= actual speed of pump shaft, in revolutions per minute

Nr = rated speed of pump shaft (as given for each model pump in table to the right)

Fs = slippage factor (a variable depending on the viscosity of the fluid pumped, in accordance with table below)

RATED TRANSFER CAPACITIES FOR USE WITH FORMULAE 1 AND 2

Model Type	Rated Transfer Capacity USGPM	Rated Shaft Speed
EG-1Z, DW-1Z	10	3600
EC-HZ, DW-HZ	15	3600
MC-1 (LPG)	10	3600
GC-1 (LPG)	10	3600
GC-1 LZ (LPG)	13	3600
MC-1 (CO_2, NH_3)	5	1800
GC-1 (CO_2, NH_3)	5	1800
SQ-1	5	1800
SQ-H	7	1800
SQ-HH	13	1800
SQ-HH8	13	1200
MC-1044	20	1800
MC-1044H	35	1800
MC-2, MC-2Q, ATC-2L, ATC-2R	50	1800
MC-2H, ATC-2LH, ATC-2RH	50	1500
MC-3, ATC-3L, ATC-3R	100	1800
MC-3H, ATC-3LH, ATC-3RH	100	1500
MC-4, ATC-4RF, ATC-4LF	150	1800
MC-4H, ATC-4RHF, ATC-4LHF	150	1500
MC-5, ATC-5RF, ATC-5LF	200	1800
MC-5H, ATC-5RHF, ATC-5LHF	200	1500
MC-5L, ATC-5RF(L), ATC-5LF(L)	250	1800
MCAT-2R, MCAT-2L	42	700
MCAT-3R, MCAT-3L	85	700
TC-1044H	35	900
TC-1044HL	60	900
TC-2	50	500
TC-3	100	500

Note: Except for the "MCAT-Series", "Rated Shaft Speed" is maximum design speed and should never be exceeded. In many cases the recommended drive speed range will be below the "rated" shaft RPM.

SLIPPAGE FACTORS (Fs) TO BE USED WITH FORMULA 1

	+120° F.	+100° F.	+80° F.	+60° F.	+40° F.	+20° F.	0° F.	-20° F.	-40° F.	-60° F.
CARBON DIOXIDE						.0036	.0032	.0028	.0024	.0020
ANHYDROUS AMMONIA	.0053	.0049	.0045	.0042	.0038	.0033	.0030	.0026	.0023	.0020
BUTANE	.0034	.0033	.0032	.0031	.0028	.0026	.0023			
PROPANE	.0044	.0042	.0040	.0038	.0036	.0034	.0033	.0032	.0031	.0030

SMITH PUMPS

SMITH PRECISION PRODUCTS COMPANY
P.O. Box 276, Newbury Park, CA 91319 USA
1299 Lawrence Drive, Newbury Park, CA 91320 USA
Tel.: 805/498-6616 FAX: 805/499-2867
e-mail: SMPUMP1299@aol.com **web: www.smithpumps.com**