BOOKLET 'A'

Transferring LP-Gas With Liquid Pumps

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PUMP STARVATION
VAPOR LOCK
INLET AND DISCHARGE LINES
BYPASS VALVES
TROUBLE-SHOOTING CHART

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INTRODUCTION

THE PUMPING OF LIQUEfied petroleum gas with a liquid pump is a subject of great interest, since butane and propane are liquids being handled at their boiling points. As boiling liquids, they are quite different in their behavior from ordinary liquids such as water, oil, kerosene, gasoline, or diesel fuel, and must be handled with special consideration of these differences.

It is not difficult to create a good piping installation for working with these liquids when the special problems that exist are understood. While we would be the first to point out that the transfer of LP-Gas is something which no one yet understands perfectly, we have found much which is both helpful and essential to the successful handling of these liquids.

It is the purpose of this and the two succeeding articles to present the practical part of the theory behind LPG pumping to the general distributor or dealer, so that he may understand and apply this knowledge to his own plant.

THE PUMP INLET LINE

ON the average, 1 pound of butane or propane *liquid* will occupy 55 cubic inches of volume, about a quarter of a gallon. However, 1 pound of butane or propane *vapor* will occupy anywhere from 5 to 50 gallons of volume, depending upon the pressure in the system. Since the capacity of a pump is based upon its *volume* displacement, while its actual delivery is dependent upon the *weight* moved from one tank to another, it is important to keep volume-consuming vapor out of the inlet line, in order that liquid may be moved as fast and efficiently as possible.

Pumps are designed to move liquid, not vapor. They will not do a good job on gas. If very much vapor gets to the pump, it will cause the pump to become either *completely vapor locked,* and not move liquid at all, or *partially vapor locked,* and pump very slowly. This latter condition is called *pump starvation.* Very little liquid is moved, because most of the capacity of the pump is taken up by vapor instead of liquid. We must do everything we can to keep vapor out of the pump.

There are two ways vapor can get into the inlet line and into the pump. (1) Since LP-Gas boils or vaporizes even at very low temperatures when open to the air, it is kept in liquid form only by being stored in a closed tank under pressure. If anything happens to reduce this pressure suddenly, the liquid will boil in an attempt to bring the pressure back up to its original value. (2) Any heat which is added to the liquid after it leaves the storage tank may cause it to boil and form vapor.

(1) Vapor Formed in Inlet Line Due to Reduction of Pressure.

In order that we may understand the effect of pressure reduction in creating vapor in the pump inlet line, let us consider a common piping hook-up as shown in Figure I. Before the pump is started, we have a pressure in the tank that

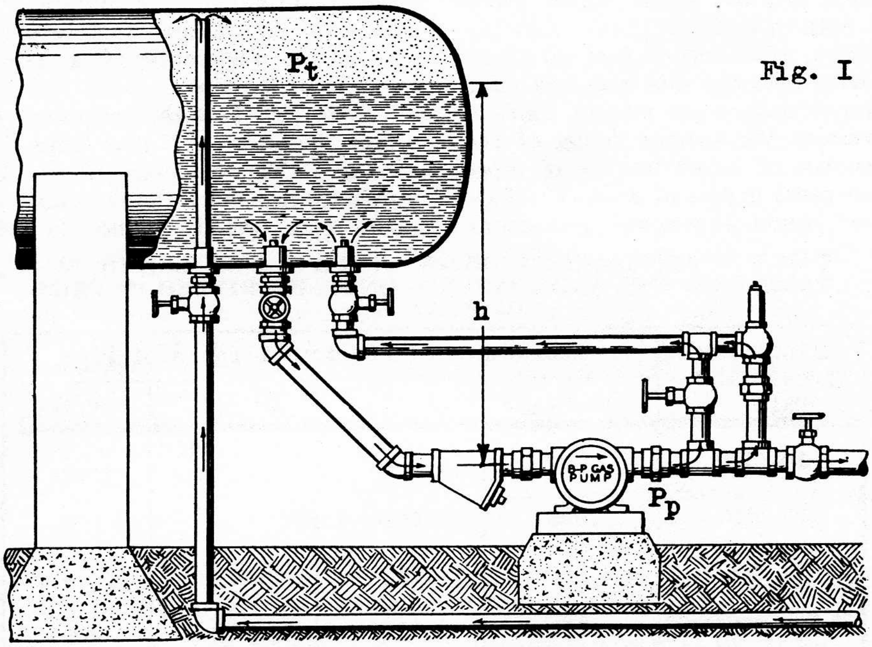


Fig. I

$P_p = P_t + h$

we will call P_t, and a pressure in the pump that we will call P_p. Now P_p is greater than P_t by the amount h, which is the height of the liquid level in the tank above the pump inlet. (Pressure h is the downward force caused by the weight of the liquid in the piping between the tank and the pump.) We can write the formula $P_p = P_t + h$. Now, when the pump is running, P_p must *stay* greater than, or at least equal to, P_t, or we will have that sudden reduction in pressure that will make the liquid boil and form vapor.

But some pressure must be used to bring the liquid from the tank to the pump inlet. So if P_t and P_p must be at least equal, we have only h left to do the moving job. Pumps should not have to suck LP-Gas to their inlets. If they try to do this, P_p gets to be a lower value than P_t, we have pressure reduction, and the liquid starts to boil. Therefore, h must be made great enough to overcome the "resistance-to-flow" of all the piping, valves, and fittings in the inlet line, and bring a flow of liquid equal to the pump's capacity to the pump. So here is the first rule:

h must be greater than or equal to the resistance-to-flow of all valves, pipes, and fittings in the LP-Gas pump inlet line.

In the **worst** possible case, where the storage tank is almost empty, h is the height of the bottom of the tank above the pump inlet. To know what the value of h should be, it is only necessary to add up the total resistance-to-flow of the piping, valves and fittings. Table I is the first of a series of three original tables which make it easy to do this.

The resistance-to-flow of pipe varies with the pipe size and fluid flow in gallons per minute. Table I presents the various values of resistance of 1-foot lengths of pipe, expressed in *feet* of head (h) of liquid butane or propane. For example, at 50 gallons per minute, you need an "h" of .048 feet to overcome the resistance of a 1-foot length of 2″ pipe.

Note how fast the resistance of pipe increases as flow rate increases. For example, if the 2″ pipe carries twice the flow rate, or 100 gpm, the resistance is .193 feet, more than four times the original figure of .048. A 3-inch pipe carrying 50 gpm has less than 20% of the resistance of the same pipe carrying 100 gpm.

TABLE 1. RESISTANCE-TO-FLOW OF PIPE (FOR LIQUID BUTANE, PROPANE, AND MIXTURES ONLY, EXPRESSED IN FEET OF HEAD, H).

Gallons per Minute Flow Rate	Resistance of One-Foot Lengths of Pipe			
	1½" Size	2" Size	2½" Size	3" Size
10 GPM	.007	-	-	-
20 GPM	.028	.008	-	-
30 GPM	.060	.017	.007	-
40 GPM	.111	.031	.012	.004
50 GPM	.174	.048	.020	.006
60 GPM	.250	.070	.028	.009
70 GPM	-	.095	.038	.013
80 GPM	-	.123	.050	.017
90 GPM	-	.156	.063	.021
100 GPM	-	.193	.078	.026

Table 2 presents data on the resistance-to-flow of the most commonly used valves and fittings. The values shown are listed in equivalent lengths of pipe. For example, we see from studying the table that the resistance of a 2″ angle valve is the same as the resistance of 25 1-foot lengths of 2″ pipe.

To obtain a value for the total resistance-to-flow in your inlet line, list all the fittings and valves and add up their equivalent lengths. Then add to this the actual length of pipe in the line. Multiply the total by the proper value taken from Table I.

As an example, let us take Figure II as a drawing of a standard

TABLE 2. RESISTANCE OF VALVES AND FITTINGS (EXPRESSED IN FEET OF PIPE)

Valves and Fittings	Size of Pipe Inlet Line			
	1½"	2"	2½"	3"
1¼" Weco Trol Valve	6	20	50	160
3" x 2" Rego #2139 Excess-Flow Valve	18	63	158	480
2½" x 1½" Rego #2138 Excess-Flow Valve	33	120	289	964
2" x 2" Rego #3192A Excess-Flow Valve	49	173	420	1450
2" x 2" Rego #3292 Excess-Flow Valve	49	173	420	1450
2" Shand & Jurs "Safetiflo"	45	163	390	1300
3" Kerotest #P99XO6 Excess-Flow Valve	3	11	26	90
2" Kerotest #P99XO7A Excess-Flow Valve	10	37	88	290
2" Kerotest #99XO7B Excess-Flow Valve	10	37	88	290
3" x 2" Bohnhardt Internal Valve, wide open	6	23	55	183
3" Rego #3500AR Excess-Flow Valve	3	11	26	90
3" Rego #3500AS Excess-Flow Valve	3	11	26	90
3" Rego #3500AT Excess-Flow Valve	3	11	26	90
2" Rego #3500AL1 Excess-Flow Valve	10	37	88	290
2" Rego #3500AM1 Excess-Flow Valve	10	37	88	290
2" Rego #3500AN1 Excess-Flow Valve	10	37	88	290
Okadee Valves, wide open, same size as pipe	3	4	3½	5
Globe Valves, wide open, same size as pipe	40	50	60	80
Angle Valves, wide open, same size as pipe	20	25	30	40
Plug Valves, wide open, same size as pipe	5	6	8	10
Gate Valves, wide open, same size as pipe	1	1	1½	1½
Swing Check Valve, same size as pipe	5	6	8	10
Elbow, 90°, same size as pipe	4	5	6	8
Elbow, 45°, same size as pipe	2	2½	3	3½
Tee, flow through side outlet, same size as pipe	8	10	13	16
Tee, flow straight through, same size as pipe	2½	3	4	5
Strainer(≁), same size as pipe	25	60	42	42
Strainer(≁), next larger size than pipe	16	17	14	20
Bushing, to one size larger or smaller	2	2½	3	4

≁ Sarco Strainer. Most other makes have more resistance.

pump inlet line. The drawing shows the parts in cross-section, and all parts are drawn to scale. There is one No. 2139 Rego excess-flow valve, one 3″ globe valve, one 3″ 90° elbow, one 3″ strainer, and about 1 foot of 3″ pipe as represented by the sum of the lengths of four 3″ x close nipples. Assuming that the pump is rated at 50 gallons per minute, the resistance-to-flow of the inlet line is calculated as follows:

	Equivalent Length
From table 2, the equivalent length of the No. 2139 excess-flow valve is	480 ft.
This value for 3″ globe valve	80 ft.
Value for 3″ elbow.........	8 ft.
Value for 3″ strainer......	42 ft.
Total	610 ft.
Add 1 foot length of pipe..	1 ft.
Total	611 ft.

Thus the total equivalent length of this system is 611 feet of 3″

pipe. From Table I, 1 foot of 3″ pipe carrying 50 gallons per minute of liquid has a resistance-to-flow of .006 feet. Therefore, the resistance of this inlet line in Figure II is 611 x .006 = 3.666 feet. In other words, when pumping 50 gallons per minute from one tank to another through 3″ piping, the bottom of the storage tank must be about 3 feet, 8 inches above the pump inlet if vapor formation in the inlet line is to be completely prevented.

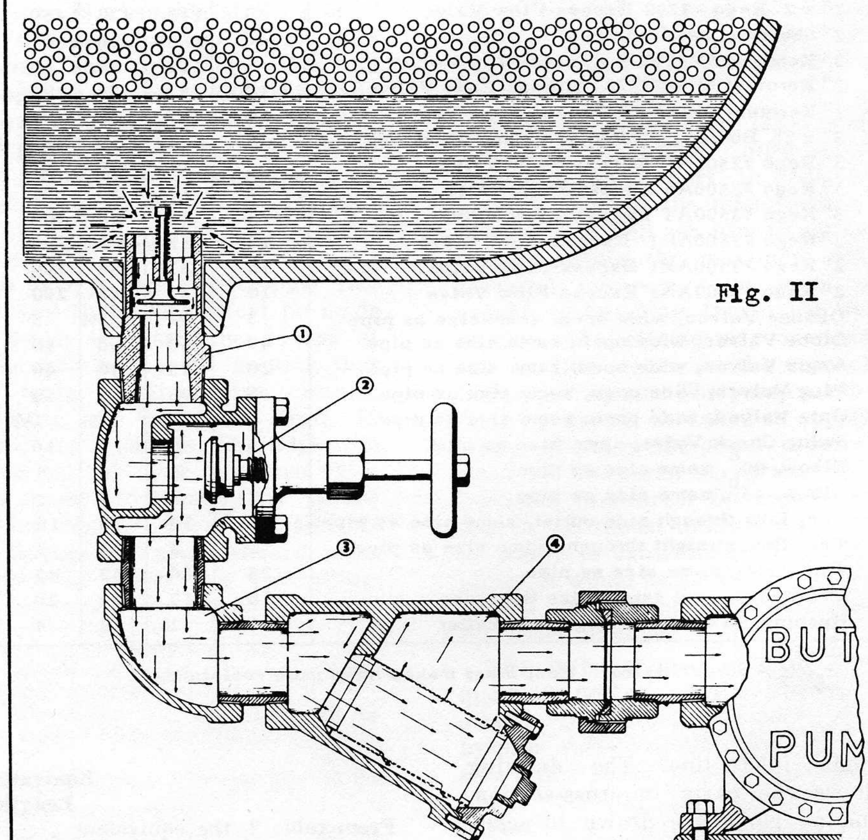


Fig. II

This drawing shows a pump intake assembly made up of (1) 3-in. excess flow valve: (2) 3-in. globe valve; (3) 3-in. elbow, and (4) 3-in. strainer, all of standard makes. It is worthy of note that the restricted flow area in the excess flow valve, just below the valve seat, is less than one-half the area of the 3-in. pipe, and that the excess flow valve as well as the globe valve become a serious flow impediment due to the numerous changes in fluid flow direction. The various units shown are drawn to scale.

Now let us see how high the tank should be mounted if we use 2″ pipe, valves, fittings, etc., instead of the 3″ size. In such a case, we have, from Table 2:

	Equivalent Length
Excess-flow valve	63 ft.
2″ Globe valve	50 ft.
2″ elbow	5 ft.
2″ strainer	60 ft.
Total	178 ft.
1 foot 2″ pipe	1 ft.
Total	179 ft.

Again, from Table I, 1 foot of 2″ pipe carrying 50 gallons per minute has a resistance-to-flow of .048 feet. The total resistance of a 2″ inlet line is therefore 179 x .048 = 8.59 feet.

We all know that a 2″ inlet line is in common use with 50 gpm pumps. We also know that bulk plant tanks are seldom mounted 8 or 9 feet off the ground. The conclusion is that in almost every LP-Gas pumping installation in use today, some vapor forms in the pump inlet line. In every case, the delivery of the pump is reduced below what it would be under ideal conditions.

Table 3 has been prepared to show the effect of the vapor formation in the inlet line upon pump capacity. It lists the percentage reduction in pump capacity when the storage tank is not mounted high enough.

We have seen an example of a case where for best pump efficiency, the tank *should* be mounted almost 9 feet above the pump inlet. Let us suppose it is actually mounted only 4 feet above the pump inlet. The difference between the 9 feet and the 4 feet is 5 feet. Entering Table 3 in the 5 ft. column, we see that if we are pumping *propane* at a temperature of 70° F, the pump capacity will be reduced only 6.6%. This means that about 46 gallons of liquid will still flow to the pump inlet every minute.

TABLE 3. PERCENTAGE REDUCTION IN LPG PUMP CAPACITY WHEN THE STORAGE TANK IS NOT MOUNTED HIGH ENOUGH.

Liquid and Temperature	Difference between the height the tank should be mounted, and the height it is mounted, in feet											
	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	5.6	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
Propene, 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

Now, in the winter months in the same system, with the temperature down to 10° F, pump capacity will be reduced 27.1%. Thus only 36 gallons will flow to the pump every minute. If we are handling *butane* at 70° F, with the same system, pump capacity will be reduced 47.3%, to 27 gallons per minute. And at lower temperatures, capacity in such a system is reduced to the point where pumping butane is impractical.

This explains why many pumping installations handle propane better than they handle butane. Additional study of Table 3 will emphasize the fact that pump capacity is reduced most at the coldest temperatures. Very careful attention must be given to using the larger sizes of valves and fittings in the inlet line, so the installation can be satisfactorily used in cold winter months, when, often, the load is greatest.

The three tables have been made up for use as guides only. The figures listed must not be considered to be 100% accurate in every case. They represent practical results of some actual tests, as well as theoretical calculations. Their use will give results that will be most helpful in checking any installation. Data presented apply equally well to all different makes of pumps, including gear, vane, regenerative-turbine, centrifugal, and piston types.

Summary

1. It is important to keep vapor out of the pump inlet line in order to move liquid at the highest efficiency.

2. One of the two principal causes of such vapor formation is a sudden reduction in pressure forced by pump suction.

3. This reduction in pressure can be prevented by mounting the tank at a height above the pump sufficient to provide enough inlet head to overcome the resistance-to-flow of the pipes, valves, and fittings in the inlet line. This makes it unnecessary for the pump to draw liquid to its inlet by suction. Use large-sized valves and fittings, having low resistance-to-flow values, in the inlet line whenever possible.

4. The resistance-to-flow of various sizes of valves and fittings are listed in Table 2. The values given can be added to obtain the total resistance of the inlet line. The required height of the storage tank can then be figured from the values given in Table I.

5. If your tank is not mounted high enough, the reduction in pump capacity resulting may be figured from Table 3.

6. This article applies to all makes and types of pumps. The figures may not all be 100% accurate, but they are close enough for practical use.

It has been established that the formation of vapor in the pump inlet line must be avoided. Vapor interferes with proper pumping, and results in reduced pump output. Not only must vapor be prevented from forming while the pump is running; it must also be kept from collecting in the pump and piping at times of the day and night when the pump is not being used.

There are two principal ways that vapor is developed. One is through pressure reduction, which has been discussed earlier. The second is through heat, which will be considered now.

(2) Vapor Formation Caused By Heat

Heat is a common source of trouble because the several ways that heat appears are not well understood by many engineers working in the LPG industry. Heat must always be considered carefully when designing a butane-propane pumping installation. It is important to do everything possible to eliminate all sources of heat around the pump and piping; and a way should be provided to get rid of vapor if it should be formed in the lines by the action of some heat source that cannot be removed completely.

A. Heat Caused by the Sun. This type of heat is perhaps the easiest to understand. We all know that many LPG pipe lines are exposed to the sunlight during the day because the lines are often placed aboveground. A certain amount of the sun's heat is absorbed by the liquid in the lines, and this will cause some of the liquid to boil and make vapor.

Vapor is not slow in forming as many people believe. With a bright sun on a clear day, a large volume of vapor can accumulate in a matter of a few minutes, when the pump is not running. It can be easily shown through a calculation with figures available in many engineering handbooks, that enough vapor can be formed in less than an hour to blow all of the liquid from the pump and inlet line back to the storage tank. If a means to remove this vapor is not provided, the sun's heat will create a large amount of vapor in the pump and piping in a short time.

Since sunlight is brightest in the summertime, more troubles from vapor formation are usually experienced in this season. However, vapor may be easily formed whenever the sun is out. The amount of vapor in the line depends as much upon the *brightness* of the sunlight as upon the *temperature* of the day. These troubles can occur as easily on a clear winter day with the temperature at 30°, as on a muggy, hazy summer day when the sun is mostly obscured, even though the temperature may be up to 80°.

The heat of the sun has a greater effect upon liquid butane than upon liquid propane. Because of the lower pressures in butane systems, vapor formed there takes up a greater volume than it would in a propane system. If the sun's heat takes 15 minutes to form a certain volume of butane vapor, an equal amount of heat will have to act continuously for 50 minutes to form the same volume of propane vapor.

We all know what happens if the inlet line gets full of vapor and the pump is started. The pump draws the vapor to itself, gets full of vapor, and is "vapor locked." Since pumps will not move vapor, and are efficient only when handling close to 100% liquid, the vapor-locked pump may grind away for a long time after it is started before it is able to push this vapor into the tank being filled. If we are trying to fill cylinders or other small tanks with this pump, the unit will have to build up a *pressure* on *gas* in order to purge itself of vapor.

During this period before the pump is purged, the pump is running bone dry. The heat generated by the pump itself is not carried away by liquid through-flow, and this heat instead builds up in the pump and aggravates the condition. The pump interior bearings and the pump packing may show damage or excessive wear due to the action of the heat generated in these parts while the pump is running dry. It is not unusual to note that pumps so abused have packing dried out or melted, and interior bronze bushings take on a "blue" or "blackened" appearance.

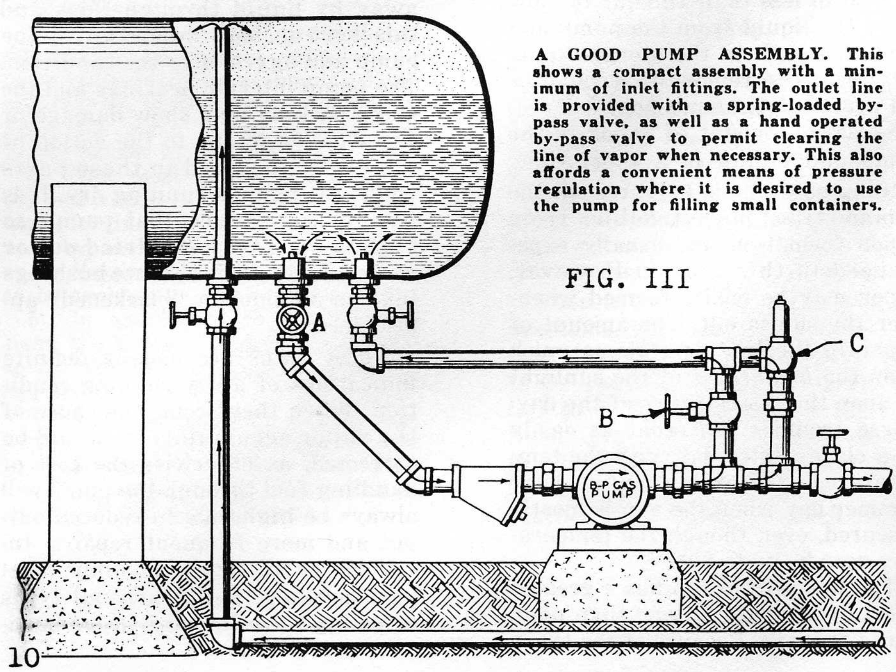
These signs are usually definite indications of a dry running condition. When they occur, the cause of the vapor accumulation should be corrected, as otherwise the cost of handling fuel through the pump will always be high, due to reduced output and more frequent repairs. Inasmuch as all types of pumps must have packing, and nearly all types of pumps have interior sleeve bushings to properly support the main shaft, these signs of dry running should be common to all makes of pumps used in LPG service.

B. Ground Heat. In parts of the country where severely cold winters are experienced, the pump may be mounted aboveground while the piping may be underground. The heat of the ground may cause vapor formation in the underground pipes in the same way that the sun's heat causes vapor formation in aboveground pipes.

C. Pumps Mounted in Partly-Heated Buildings. In areas where heavy snowfalls are common, it is customary to build a special shed or "pump house" to protect pumping equipment. This pump house should be open to the outside, so the pump will be at the same temperature as the storage tank and piping. If the pump house is heated, or partly heated, through being adjacent to another heated building, this heat will cause vapor to form in the pump housing. Generally speaking, it is satisfactory to have a portion of the pump discharge line in a heated building, provided that the pump is mounted lower than any heated part of this line. We have in mind in particular heated shelters built to house cylinder filling manifolds. The pump must be kept completely out of the heated area, however.

D. Exhaust Lines from Truck Engines. On trucks, in cases where it is necessary to run the truck engine exhaust close to any part of the pump piping, the piping or the exhaust line should be insulated. This will help prevent the transfer of heat and accompanying vapor formation in pump or piping.

E. Bypass Valve. The action of a pump bypass valve creates heat. In installations where the bypass valve is often in operation, the valve should be installed to discharge back to the storage tank, thus preventing the recirculation of heated LPG through the pump. This very impor-



A GOOD PUMP ASSEMBLY. This shows a compact assembly with a minimum of inlet fittings. The outlet line is provided with a spring-loaded bypass valve, as well as a hand operated by-pass valve to permit clearing the line of vapor when necessary. This also affords a convenient means of pressure regulation where it is desired to use the pump for filling small containers.

FIG. III

tant source of heat will be discussed in detail later.

F. Miscellaneous Heat Sources.

a. Steam or hot water pipes run too close to LPG pipes.

b. Warm fuel from refinery production lines run into storage tank through the same piping from which the loading pump makes withdrawal.

c. Truck pumps are exposed to heat reflected from the road when trucks are driven long distances in hot desert areas.

d. There are other less common heat sources that have not been mentioned. The above list should not be considered complete.

A satisfactory way to overcome difficulties with vapor formation in the pump and inlet piping is to make the inlet pipeline slope upwards to the tank, as in the installation pictured in Figure III. The slope need not be as great as shown. An inch or so per foot of length is enough so that any vapor bubbles formed can rise and travel back into the storage tank.

If there is some piping arrangement in the inlet line that will prevent this vapor from bubbling back to the tank, we call it a *vapor trap*. In a tank having a dip-tube liquid outlet, as shown in Figure IV, the dip-tube is such a trap. Vapor bubbles formed in the pump and adjacent piping will rise through the strainer and angle valve to the highest part of the pipeline, the point where the dip-tube runs through the tank wall. The bubbles will collect at this high point, because they will not run downhill through the dip-tube into the tank. For this reason, a storage tank with a liquid outlet in the bottom, as shown in Figure III, is much to be preferred. In this case, the vapor bubbles enter the tank and come to rest in the vapor space above the liquid, where they are completely dispersed.

(Text continued on Page 14)

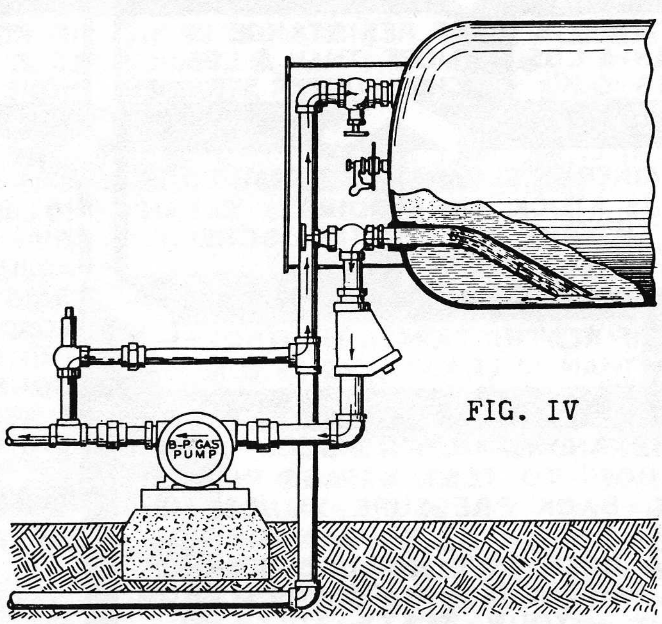
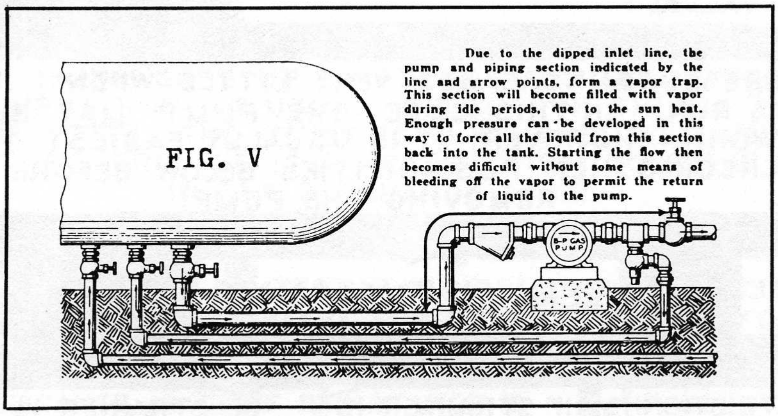


FIG. IV

Another common vapor trap is seen wherever inlet piping is run underground, as shown in Figure V. In the summertime, vapor forming in the pump and aboveground piping, due to the sun's heat, will tend to collect in the pump. In the winter, vapor formed in the underground piping, due to ground heat, will rise and collect in the pump.

If any part of the pump inlet piping is higher than another part between it and the storage tank, this high point cannot fail to be a vapor trap.

Sometimes vapor traps may be created by the way the installation is handled by the operator. Going back to Figure III, we again note a good pumping assembly that took special thought to design. The purpose of the sloping inlet line can be defeated if it is the practice of the operator to leave the tank valve A closed at all times when the pump is not running. This allows vapor forming in the pump and pipeline to collect behind the closed valve. In certain cases this vapor may lock the pump when it is started.



We have all seen piping systems where slight leaks are present. These leaks may occur in threaded pipe joints, through valve stems, through bad strainer gaskets, through pump packing, and numerous other parts. In such systems it is usual as a safety precaution to close all the valves at the storage tank when stopping work for the night.

When the pipelines are shut off, liquid leakage cannot be replaced from the storage tank. During the night, most of the liquid in the pipes may leak out, leaving a large proportion of vapor in the pipe lines. When the tank valves are opened in the morning, and the pump is started, it will have to purge itself of all of this vapor unless means for removing the vapor are provided. To minimize this trouble as much as possible, service the system to remove the leaks. Repack the valves, tighten leaky joints, and replace old gaskets. Obtain packing for the pump that will not leak. A little time spent in this type of service will pay dividends three ways:

1. Eliminate a fire hazard.

2. Eliminate a vapor lock condition that may wear the pump excessively.

3. Save as much as $5 a day in the value of fuel otherwise lost.

In some installations, vapor traps and vapor formation cannot be avoided. There may be other piping or obstructions in the area that have to be piped around, or an ideal system may be too costly to build. Relief from pump vapor lock may still be obtained if some means is provided to bleed off the vapor that collects in the pump and adjacent piping before the pump is started. Some operators have installed a 10% valve in the pump case, and before starting the pump, regularly open this valve until all the vapor is blown off into the air. While this practice does not necessarily break any safety rules, it is unquestionably hazardous. In addition, costly fuel is wasted, as well as the operator's time while he is waiting for the vapor to bleed off.

A simpler, faster, and completely safe way to purge the pump of vapor is to install a hand bypass valve, bypassing the spring-loaded bypass valve, as shown at B in Figure III. This valve can be an ordinary globe or angle valve of 1" size, or possibly 1¼" size for the largest pumps. The operator should be trained to open this valve every time before the pump is started, then start the pump and leave the valve open for a few seconds, depending on the length of the line and the volume of gas accumulation. The pump will be able to purge itself by pushing the vapor back to the storage tank against no back pressure, through the open valve. This is much easier on the pump than if it is forced to purge itself by forcing the vapor into small tanks or cylinders against a high back-pressure.

One of the most common sources of heat added to the pump inlet line is the built-in pump bypass valve, or the so-called "merry-go-round" bypass valve, where the discharge of the valve is returned to the pump inlet line. This type of bypass installation always causes trouble when the pump is pumping more LPG than can possibly be forced into the tank being filled. For example, take a 50 gallon-per-minute pump being used to fill a single 100-lb. cylinder. The flow rate into the cylinder is about 5 GPM, leaving 45 GPM to be bypassed.

In small-tank filling installations it is always good practice to pipe the bypass valve (C in Figure III) to discharge back to the storage tank. If this is not done, and the bypass valve is piped to discharge to the pump inlet line, the same liquid will run around and around in the pump and bypass piping, every time the bypass valve operates. Almost the full capacity of the pump, 45 GPM, will be recirculating through the bypass valve.

When liquid runs through a bypass valve, heat is generated by the friction in the valve. If a bypass valve is set to open at, say, 40 pounds differential pressure, and if 45 gallons per minute of liquid is running through the valve, 50 Btu of heat are generated every minute. Table 4 has been made up to show how much vapor this heat will form in 1 minute when handling LPG at various temperatures.

Table 4.

Temp. °F.	Butane	Propane
30°	3200 cu. in.	850 cu. in.
50°	2200 cu. in.	625 cu. in.
70°	1550 cu. in.	475 cu. in.
90°	1150 cu. in.	350 cu. in.

The volume of the circulating space inside a pump, bypass valve, and piping in a "merry-go-round" setup is seldom more than 200 or 300 cubic inches. The volume of the space inside a pump with a built-in bypass valve is even less. It is easy to see from a study of Table 4 that only a few seconds of running such a pump system generates enough heat to fill the pump full of vapor. Further recirculation will create enough vapor to blow all the liquid in the inlet line back to the storage tank. Now if the bypassed liquid is piped back to the storage tank, the heat returns *with the bypassed liquid.* The heat does not build up in the pump by recirculation. Such a bypass valve installation will not cause vapor lock trouble.

Note from Table 4 how greater volumes of vapor form at the colder temperatures, and how more vapor forms when butane is being handled than when propane is pumped. This is again due to the fact that any vapor formed takes up a greater volume at lower system pressures.

Because the vapor formation discussed in this article depends entirely upon heat, the precautions suggested apply to any system regardless of the make or type of pump used. While any pumping unit can be installed in almost any piping setup with somewhat satisfactory results, careful attention towards preventing vapor accumulations due to the action of heat will pay big dividends. In many cases pump delivery is speeded, and pump life is lengthened materially, when vapor is kept out of the pump. It is as important to study action of heat as the resistance-to-flow of the inlet pipeline.

Summary

1. The many sources of heat acting upon an LPG pump and its piping must be removed insofar as this is possible.
2. After this is done, means should be provided to prevent vaporlock in the pump caused by accumulated vapor formed in the pump and piping while the pump is not running, due to the action of the remaining heat.
3. The most practical means to prevent vapor lock are (1) the sloping inlet line, and (2) the hand-operated bypass valve.
4. Vapor traps in inlet piping are to be avoided wherever possible.
5. In small-tank filling installations, the bypass valve must be piped so its discharge returns to the storage tank.
6. These suggestions are as important as those pertaining to the resistance-to-flow of the inlet pipe line. They apply to the installation of all makes and types of pumps.

THE PUMP DISCHARGE LINE

UP to this point we have stressed only the importance of correct design of the pump inlet lines in obtaining the highest pump efficiency and the fastest delivery of fuel. Certain installations in common use also require careful consideration of the discharge line. These installations include delivery trucks and stationary pumping systems where the smaller tanks are filled. The discharge side of the piping in such systems contains more parts subject to wear and to deterioration in service than does the inlet line. The failure of any one of these many parts may cause a marked reduction in the speed of delivery.

An LP-Gas pump moves liquid by creating a differential pressure; that is, by forming a greater pressure on its discharge side than there is on its inlet side. This differential pressure is necessary in order to overcome the resistance-to-flow due to friction in the different parts of the discharge line, such as the following:

1. Discharge piping, valves, and fittings.
2. Meter and meter strainer.
3. Meter back-pressure valve.
4. Delivery hose (particularly if of small size, and very long).
5. Tank filler valve (particularly those on cylinders, which frequently have discharge holes as small as ¼ inch or even ⅛ inch in diameter).

Then after all this resistance is overcome, liquid finally reaches the tank being filled. Here, there has to be *enough differential pressure left* to collapse the gas in the cylinder into liquid, if a vapor return line is not used. We often find that by the time the liquid finally reaches the cylinder so much of the pressure has been absorbed by the resistance of the parts in the discharge line, that the actual delivery rate is tediously slow.

LP-Gas pumps usually have their capacities rated by the manufacturer as the gallons-per-minute they will deliver in transfer service, pumping against zero differential pressure. For example, a pump rated at 50 gallons per minute is supposed to deliver at this rate if perfectly installed, filling a large tank; and then only if a large vapor hose is connected to equalize tank pressures fully, and when there is no meter or other restriction in the discharge line.

Liquid butane and propane have very low viscosities. They are 10 times "thinner" than water. For this reason, pump capacities are greatly affected by increases in differential pressure. Capacities are reduced as pumps are called upon to deliver fuel against higher and higher pressures. For the units that our company manufactures, we often figure roughly that a pump loses about 5% of its rated capacity for every extra 10 pounds of differential pressure developed.

As an example, figure a 50-gallon-per-minute unit pumping against 40 pounds differential pressure. This pump has lost 4 x 5% = 20% of its rated capacity. Since 20% of 50 gpm is 10 gpm, the pump will deliver only 50 — 10 = 40 gpm when working against a differential of 40 pounds. In the same way, it can be shown that a 50 gpm rated unit will deliver only 25 gpm against a differential of 100 pounds.

In a poor installation, this loss would be in addition to that caused by vapor formation in the pump inlet line forced by pump suction. Many types of LPG pumps, particularly centrifugal and turbine types, are even more sensitive to increases in differential pressure.

We can see that it is important to keep the differential pressure down to a low figure, in order to increase the capacity of the pump and speed deliveries. An unregulated pump will develop any differential pressure necessary to overcome the resistance-to-flow of the various parts of the discharge line, up to the point where the pressure is so high that the pump capacity is reduced to zero. At the higher differentials, capacity and delivery are reduced; so the practical way to increase pump delivery is to cut down on the restrictions as much as possible.

Further on, methods of testing the restriction of the parts in the discharge line will be described, and we will tell how to remove the restrictions. Before we do that, however, it is necessary to understand the function and setting of the pump by-pass valve.

We all know that the pump is working harder when it moves liquid against higher differential pressures. There is a point at which it is impractical to build up higher pressures. In many types of service a differential pressure of 50 pounds is the practical limit. In other cases, differential pressures as high as 100 pounds may be required, and satisfactorily used. The by-pass valve is placed in the system so that the differential pressure will never exceed whatever value we have decided to use.

Say the by-pass valve is set to 50 pounds. As soon as the pressure in the discharge line exceeds the pressure in the inlet line by 50 pounds, the by-pass valve will open and allow enough liquid to run back to the storage tank to keep the differential pressure from ever going higher than 50 pounds. If the by-pass valve is set to 100 pounds, it will not open until the discharge pressure exceeds the inlet pressure by 100 pounds.

If the by-pass valve becomes worn out, or is set to open at too low a differential pressure, the pump may not be able to build up enough pressure to push liquid through the restrictions in the discharge line. The by-pass valve may allow most of the liquid pumped to go back to the storage tank. So it is important to know how to test a by-pass valve to see how much differential pressure is really being built up.

At this point, please refer to Figure VI, which is a diagrammatic drawing of a practical small-tank-filling installation, such as is often used for fueling motor vehicles. (Delivery truck piping is similar, having the same parts in the same order. The plan of this illustration is much easier to follow than a photograph or drawing of a truck layout where, because of lack of space, various parts are hidden behind the tank, frame, drive-shaft, etc.)

How to Test a By-Pass Valve

To test the by-pass valve, insert a pressure gage somewhere in the discharge line between the pump and meter strainer. A good place would be at point 20 in Figure VI. Read and record the pressure shown by the gage. Now start the pump, leaving the delivery hose valve closed, so that all the liquid moved by the pump is returned to the storage tank through the by-pass valve. Be sure to run the pump at its usual speed. While the pump is running, read and record the new pressure shown by the gage. The difference between the pressure reading taken while the pump was running and that taken before the pump was started, is the differential pressure developed to open the by-pass valve. This difference is the maximum differential pressure available to overcome the resistance-to-flow of the various units in the pump discharge line, and thus move liquid.

Let us say we have tested the by-pass valve on our propane truck in this way, and find that the pressure reading with the pump not running is 125 pounds. When the pump is running, the gage reading is 175 pounds. The difference between the two readings is 50 pounds, the maximum differential pressure that can actually be developed at this particular by-pass valve setting.

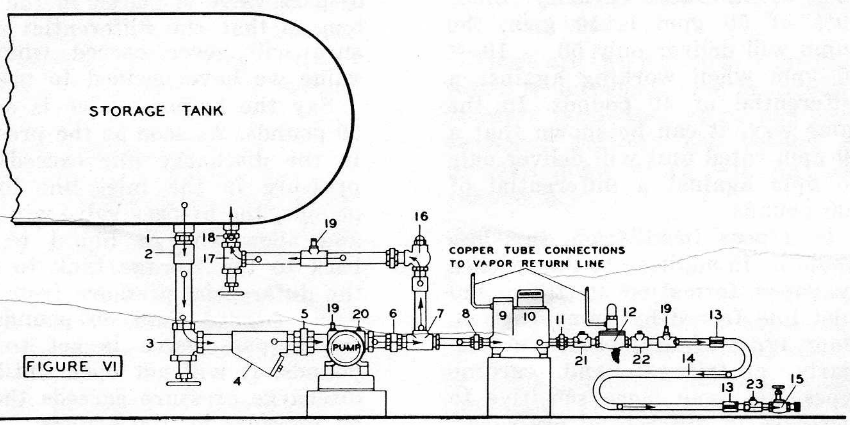


FIGURE VI

How to Test Resistance of Meter and Meter Strainer

To test the resistance-to-flow of the meter and meter strainer, we need two pressure gages. The one we used to check the by-pass valve is left in place, and a second gage is installed down the line from the meter, somewhere between the meter and the back-pressure valve, such as point 21 in Figure VI. This time, attach the delivery hose to a tank in the yard, open the hose valve, start the pump, and proceed to fill the tank in the usual manner. While this is being done, record the reading of each gage. The difference between the readings is the differential pressure necessary to move liquid through the meter strainer and meter. If this pressure difference is greater than about 5 to 10 pounds, it is usual to find that the meter strainer is clogged with dirt and causing too much restriction. However, if the strainer screen is removed and found to be clean, the meter itself may be worn, or its working parts may be stuck and require cleaning.

How to Test Back-Pressure Valve

To test the setting of the meter back-pressure valve spring, leave the gage installed between the meter and back-pressure valve, at point 21, and put the other gage in the line on the discharge side of the back-pressure valve, say at point 22. Again attach the delivery hose to a tank and proceed to fill the tank. The difference between the readings of the two gages is the back-pressure valve setting, or the resistance-to-flow of the back-pressure valve.

The diaphragm-type, back-pressure valve, which is one of the most widely used, will give practically no restriction when filling small tanks if the copper tube connection at the top of the diaphragm is run to a part of the pipe line carrying storage tank pressure. Even when the larger tanks are being filled, at no time should the pressure readings indicate a restriction of more than 10 pounds. If the difference in the two readings is more than this, the valve spring should be adjusted to the correct 10-pound reading.

Spring-loaded, back-pressure valves, without a diaphragm, ordinarily cause considerably more restriction. Correct adjustment will be the minimum spring setting found necessary to prevent meter "spinning" when the delivery hose is first connected and the tank valves opened. Readers desiring more information on back-pressure valves and their use to assure accurate metering of LPG, are referred to the article "Accurate Metering of Butane and Propane" by R. Stanley Smith, published in the September, 1947, issue of the BUTANE-PROPANE *News*. *

Some meters are provided with "built-in" back-pressure valves. In such cases valves are factory preset for average conditions, and the manufacturer should be consulted before adjustment is attempted.

How to Test Hose Line

To test the resistance-to-flow of the hose line, install a gage at each end of the hose, such as points 22 and 23, and fill a tank as before. The difference between the gage readings will be the resistance-to-flow of the hose. It is surprising how much restriction can develop in an old hose, particularly one of small size (½″ or ¾″), and unusually long (50 to 100 feet).

Suppose all of these tests are made. How shall the results be interpreted? In explanation, take the following example:

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* Reprints available upon request from the Smith Precision Products Company.

Resistance of meter and meter strainer	10 lbs.
Setting of back-pressure valve spring	20 lbs.
Resistance of long delivery hose	10 lbs.
Total resistance of discharge line	40 lbs.
By-pass valve setting	50 lbs.
Total resistance of discharge line	—40 lbs.
Differential pressure remaining	10 lbs.

Only 10 pounds of differential pressure is available at the end of the delivery hose to push liquid through the tank filler valve and collapse the vapor in the tank when filling. With such a small differential pressure available for the actual filling, delivery would be very slow, probably less than 5 gpm.

Reduce Resistance-to-Flow

In such a case we strongly recommend that every effort be made to reduce the resistance-to-flow at these points. Let us assume that the meter strainer was cleaned, lowering its resistance from 10 pounds to 5 pounds. The adjusting screw on the back pressure valve was unscrewed until the spring setting was 10 pounds instead of 20 pounds. A new delivery hose, having no measurable restriction, was installed. We now have

Resistance of meter and meter strainer	5 lbs.
Setting of back-pressure valve spring	10 lbs.
Resistance of delivery hose	0 lbs.
Total resistance of discharge line	15 lbs.
By-pass valve setting, unchanged at	50 lbs.
Total resistance of discharge line	—15 lbs.
Differential pressure remaining	35 lbs.

With more than three times as much differential pressure now available at the end of the hose to fill the tank, it could be expected that the delivery rate would be increased to at least 15 gpm.

After the restrictions in the discharge line are reduced as much as possible, delivery speed to very small tanks can be increased still further by tightening the adjusting screw on the by-pass valve to increase the spring setting to 75 pounds. In special cases, by-pass valves have been set to as high as 100 pounds. The resulting increase in the amount of differential pressure available to overcome the resistance-to-flow of the discharge line will automatically increase the amount available at the end of the hose to fill the tank.

Some LPG pumps are capable of operation at higher differential pressures than others. In order to be sure, consult the manufacturer of your unit and ask him to advise you regarding the maximum differential pressure your pump is capable of handling. Increasing the by-pass valve setting may overload the electric motor, in the case of bulk plant pumps. The pump manufacturer should be asked to supply figures showing the power requirement of the pump at various differential pressures. On trucks, of course, an almost unlimited supply of power is available to drive the pump. It would be an unusual pump indeed that would overload a 100 hp. truck engine.

The author has been asked this question perhaps more than any other: "Doesn't an increase in the by-pass valve setting cause excessive pump wear, necessitating frequent replacement of working parts?" My answer is that, of course, the pump is working harder if it is pumping to higher differentials. However, the pump will be able to fill the tank faster, and will not run for as long a period of time per gallon delivered. It is a fact that many dealers are now finding that in certain cases the labor savings resulting from speeding delivery far outweigh the increased operating costs due to more-frequent pump repairs. In particular, a fairly high by-pass valve setting is economical on delivery trucks where stops are not far apart, delivery is mostly to small tanks and cylinders, and the delivery hose is necessarily of long length.

SUMMARY

1. The maximum differential pressure built up by a pump is determined by the setting of the by-pass valve. Differential pressure is the difference between the pressure in the pump discharge line and the pressure in the pump inlet line.

2. When pump delivery is slow, tests should be made to determine if the meter, meter strainer, back-pressure valve, or delivery hose have developed a high resistance-to-flow.

3. Resistance-to-flow of the various parts in the discharge line must be reduced as much as possible, in order to speed delivery.

4. Increasing the by-pass valve setting to 75 pounds, and in some cases to as high as 100 pounds, will help speed delivery to small tanks and cylinders, but will cause faster pump wear. This higher setting is sometimes economical for delivery trucks.

INDEX

TROUBLE-SHOOTING CHART

FOR DELIVERY TRUCKS AND SMALL-TANK-FILLING BULK-PLANT INSTALLATIONS

THIS CHART IS BASED ON THE ASSUMPTION THAT THE PUMP MOVED FUEL AT A SATISFACTORY RATE WHEN FIRST INSTALLED, AND THAT THIS DELIVERY RATE HAS NOW SLOWED TO A VERY LOW FIGURE. IT IS ALSO ASSUMED THAT NO TROUBLE IS BEING EXPERIENCED WITH VAPOR FORMATION IN THE PUMP INLET LINE.

FIRST INSTALL A PRESSURE GAGE IN THE PUMP DISCHARGE LINE SOMEWHERE BETWEEN THE PUMP AND THE METER. RUN PUMP AGAINST CLOSED VALVE IN DISCHARGE LINE, SO ALL LIQUID PUMPED MUST RETURN TO STORAGE TANK THROUGH BYPASS VALVE.

PRESSURE GOES UP 50 POUNDS OR MORE WHEN PUMP IS RUN AT USUAL SPEED IF THIS IS THE CASE, THE PUMP IS O.K., AND THE CAUSE OF THE TROUBLE IS A RESTRICTION SOMEWHERE IN THE DISCHARGE LINE.

PRESSURE INCREASES VERY LITTLE WHEN PUMP IS RUN. IN THIS CASE THE PUMP <u>MAY</u> BE WORN. HOWEVER, IT IS USUALLY EASIEST TO CHECK OTHER POSSIBILITIES BELOW BEFORE REMOVING THE PUMP.

TEST METER FOR RESTRICTION

IF RESISTANCE IS LESS THAN 5 LBS, METER IS O.K.

IF RESISTANCE IS MORE THAN 5 LBS, CHECK METER STRAINER

IF STRAINER IS CLEAN, METER IS STUCK. REPLACE METER, OR CLEAN IT OUT.

IF STRAINER IS DIRTY, CLEAN THE SCREEN.

TEST BACK-PRESSURE VALVE FOR RESTRICTION

IF RESTRICTION IS NO MORE THAN 10 LBS., VALVE IS O.K.

IF RESTRICTION IS GREATER THAN 10 LBS., AND VALVE IS DIAPHRAGM TYPE, ADJUST VALVE TO 5-10 LBS. IF SPRING-LOADED VALVE, NOTHING MUCH CAN BE DONE. REPLACE WITH A NEW VALVE OF DIAPHRAGM TYPE IF POSSIBLE.

TEST DELIVERY HOSE FOR RESTRICTION

IF RESTRICTION IS LESS THAN 5 LBS, HOSE IS O.K.

IF RESTRICTION IS MORE THAN 5 LBS, REPLACE HOSE.

<u>OPEN</u> PUMP STRAINER

IF STRAINER IS DIRTY, CLEAN THE SCREEN. THIS WOULD HAVE BEEN THE <u>CAUSE OF TROUBLE</u>.

IF STRAINER IS CLEAN, TRY ADJUSTING THE BYPASS VALVE.

IF BYPASS VALVE CAN BE ADJUSTED, SET IT TO SOME PRESSURE BETWEEN 50 AND 75 LBS. THIS WOULD HAVE BEEN CAUSE OF TROUBLE.

IF BYPASS VALVE WILL NOT ADJUST, REMOVE IT FROM LINES AND TAKE IT APART TO CHECK WORKING PARTS FOR WEAR.

IF BYPASS VALVE IS WORN, REPLACE THE WORN PARTS OR INSTALL A NEW VALVE. THIS WOULD HAVE BEEN CAUSE OF TROUBLE.

IF BYPASS VALVE WORKING PARTS APPEAR TO BE O.K., THE PUMP IS PROVEN TO BE WORN UNLESS THERE IS SOME VERY UNUSUAL TYPE OF TROUBLE ELSEWHERE IN THE SYSTEM. CHECK WITH THE PUMP MANUFACTURER FOR REPLACEMENT PROCEDURE.

PAGES 18 AND 19 IN THIS BOOK DESCRIBE HOW TO TEST BYPASS VALVES, METERS, BACK PRESSURE VALVES, AND DELIVERY HOSES. IF YOUR PUMPING SYSTEM DOES NOT INCLUDE SOME OF THESE PARTS, ELIMINATE THEM FROM YOUR TESTS.

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