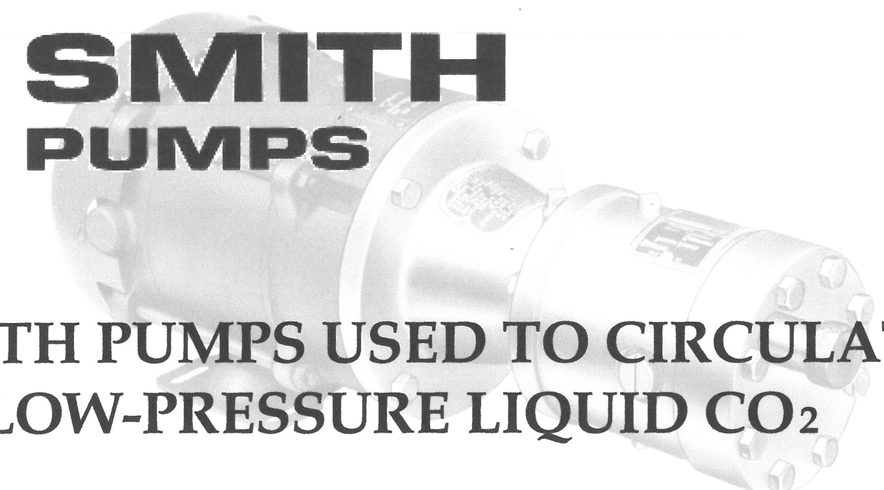
SMITH
PUMPS



SMITH PUMPS USED TO CIRCULATE LOW-PRESSURE LIQUID CO_2

It is important to note that CO_2 transfer represents a unique type of pump application, which only relates in a general sense to other common liquefied gas pump transfer situations. The extraordinary nature of this particular liquid, the way it is stored, and the way it is handled, require that special precautions and considerations be given to the system design, and to the handling equipment, above and beyond what would normally be thought of as "conservative", in most other services. These are of particular concern when the operation is classified as "continuous", as opposed to the vast majority of uses, which are either "intermediate", or "intermittent".

There are several important, and special, factors involved with the application of Smith pumps for low-pressure liquid Carbon Dioxide continual transfer. Within these categories, exist two types of systems involved with recirculation: one requires that continually or eventually, a certain amount of the product will be vented to atmosphere; the other does not require atmospheric discharge and the total flow returns to the supply tank.

This discussion will generally touch upon the following unique aspects of this service, which can greatly affect the functioning of the pump in either type of installation: (1) the insulation; (2) small capacity pump theory; (3) bypass line with a check valve; (4) the return leg; (5) recommended Smith model types; (6) strainers; (7) gear backlash measurements; (8) debris; (9) carbonic acid; (10) filters; (11) static head upon the pump; (12) size and shape of the supply tank; (13) placement of the pump; (14) lift in the outlet line; (15) horsepower of the motor; (16) flexible drive couplings; (17) differential pressure bypass system; and (18) conclusion, with a reminder about the Smith pump "Exchange Plan".

(1) INSULATION.

Many kinds of circulation line insulation techniques exist, for both double and single conduits. Some are better than others in a certain instance. All require adequate study to determine the most practical application, given the use conditions at hand.

However, one key factor in the success, or failure, of such a system is the condition and quality if the insulation, or any other condition which affects the total amount of "heat gain" during the operation. The liquid handled, in this case, is a liquefied gas, and once it passes through the pump, it has an "artificial head pressure" upon it; but, at the same time it has picked-up heat from the pump, and is absorbing heat from its surroundings. The lower the velocity is within the transfer system, the more heat will be picked-up on its way to, and back from, the use point(s). In order to insure that the liquid, as delivered to the area to be cooled, can be utilized to its fullest extent, everything possible should be done to minimize the amount of vapor accumulations within the loop.

(2) SMALL CAPACITY PUMPS.

Regardless of the diameter and length of the lines, the purpose of the pump in an average circulating system is to simply maintain a small, nominal flow of liquid to compensate for minor heat gain, vapor accumulations, and to insure that "solid liquid" is supplied on demand. Due to the realities present in these situations, very often compromises must be reached. Most of the systems do require that the pump be in continuous operation for more than six hours in a typical 24 hour/day period.

Positive displacement pumps are ideal in these operations, *because of their versatility*: as the prevalent conditions may change pressure, viscosity, and density within the system, and are responsible for different fluid characteristics from site to site, it is often not practical to utilize a pump which by its own innate design must contend with very narrow margins of application. The Smith pump is not affected by these observed variances in liquid qualities as are other non-positive displacement types, especially when supplying liquid CO_2 during very long uninterrupted intervals.[1] The unique three-piece state-of-the-art Smith mechanical seal assembly designed specifically for these types of applications, is noted for its high service longevity and extremely low product seepage potential.[2]

Given these *continuous* use parameters, we recommend that Smith CO_2 pumps be used at a speed range between 750 and 1000 RPM, and that the maximum differential pressure be kept lower than 40 PSID. This insures that they will not require excessive cooling effects from the pumped fluid, that they will not inject excessive heat into the system, and that they will last a reasonable amount of time before repairs are required (8000 - 16000 hours, average).

If the pump is to be left running for less than six hours at a time, then it can be operated faster. See Bulletins "AL-3" and "AL-17A" for additional information on drive speeds matched with "on" intervals.

In a system requiring periodic discharges to atmosphere, it is desirable to take advantage of the tank pressure as much as possible, to push the liquid CO_2 through the discharge points.

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[1] Unfortunately, commonly-used mathematical models give the impression that the flow and storage conditions in question will always remain constant. In reality, low-pressure refrigerated liquid Carbon Dioxide when handled under average conditions continually reveals its variable nature.

[2] See Catalogs "CP-1", "CP-9", and other Smith literature for additional information.

The purpose of the pump, then, would be to maintain a nominal flow within the system, to prevent orifices from blocking with "dry ice" during atmospheric discharge. Also, the pump circulation compensates for heat gain, and vapor formation, especially during the intervals when no product is being used. It is therefore not necessarily a good idea to size this pump for more output than the combined discharges of all the "drops". A very low capacity unit could probably be used to circulate the liquid, and if "overdemand" occurred infrequently, the tank pressure would be able to take over temporarily, without any ill effects. This assumes that the installation is properly designed and utilized.

As for any such recirculating system, *a thorough engineering study is initially required.* The system should always comply with all applicable safety codes and regulations. The design must allow, among other things, for the circulated liquid to pass as close as possible to the discharge point(s), so that the higher temperature of the liquid will prevent dry ice from blocking the atmospheric discharge orifice(s). Blockage from frozen product, aggravated by excessive debris accumulations, can prevent efficient operation, and are usually the results of improper consideration given to the design, which must take many contingencies into account.

(3) BYPASS LINE WITH A CHECK VALVE.

One such "contingency" concerns the potential product demand during atmospheric discharge, which is above the rated output of the circulating pump. This occurrence would attempt to turn the pump, independently, of its motor. This kind of energy utilization, and interference with the motor, causes an internal pressure drop. Since the liquid handled is already at, or very near, its boiling point, a substantial amount of vapor displacement could easily occur within the pump during this time, while it were being driven by a flow of liquid. In a highly aggravated situation, the pump could actually be run much faster than the rated speed of the motor. These conditions, "wind milling", can be extremely detrimental to pump longevity.

In order to protect the pump from this "wind milling", during an overdemand situation, there should be a supply line bypass around the pump, with a suitable check valve that prevents immediate recirculation to the tank, when the overdemand subsides. Ideally, this supply line bypass would come out of a separately-dedicated tank outlet, as opposed to the pump inlet line, to prevent the possibility of pump cavitation during an unusually prolonged overdemand episode.

Also, should the check valve leak, the pumped fluid would not immediately recirculate back to the pump inlet. In this manner, the absorbed heat would harmlessly dissipate in the supply tank. Resultant vapor formations would not be directed into the pump. Likewise, any vapor, which is returned to the tank through the return leg of the loop, should also be able to dissipate within the supply tank, *without affecting the liquid fed into the pump.*

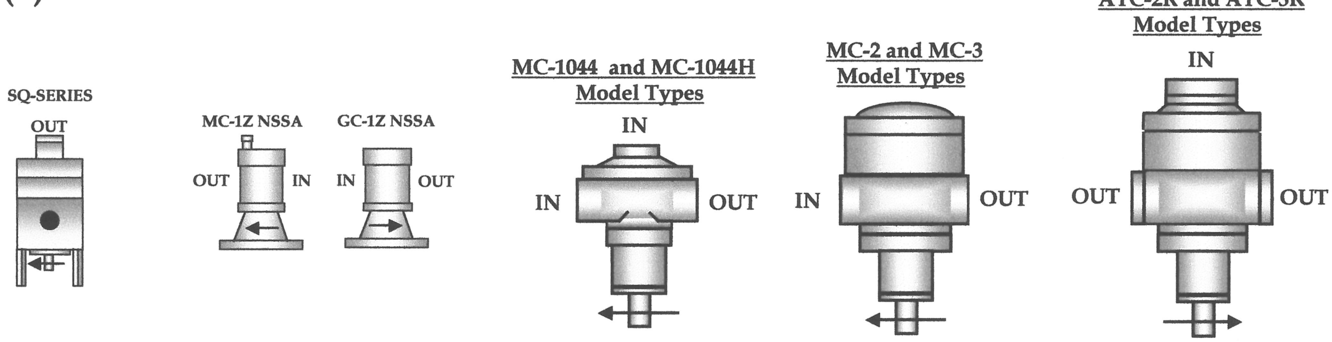
(4) THE RETURN LEG.

The return can be either piped back to the vapor or liquid phase within the cold storage tank. If the return enters the vapor phase, in an installation that utilizes atmospheric discharging, there should be a check valve installed in the return leg. This will prevent flow reversal during an overdemand situation, and keep tank vapor from being drawn through the last use points.

However, in many cases it is desirable to take advantage of the temporary flow reversal potential, which would momentarily convert the system into two feed lines, with much less flow resistance, during a temporary high surge situation where the flow is greater than the pump capacity. The return leg, then, would enter the supply tank liquid phase at a point far removed from the outlet to the pump. There would be no check valve in this line.

A further advantage would be that the subcooled liquid in the bottom of the supply tank would normally precool the "warm" return liquid before the heat entered the vapor phase. This would have the beneficial effects of potential energy savings in running the tank refrigeration system, as well as maintaining a more constant and predictable liquid quality.

(5) RECOMMENDED SMITH MODEL TYPES.

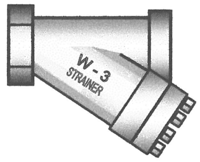


Smith pumps which are used under the aforementioned conditions, with CO_2, must be labeled specifically: "For CO_2 Liquid Only". They have no optional modifications, as do many other models which we produce. They must be of the "SAZ" type, and *whenever possible, "NSSAZ", <u>without exception</u>.* As previously mentioned, even with these "heavy-duty" models, in "continuous recirculation service", the differential pressure must be less than 40 PSID.

The speed range must remain within 750 to 1000 RPM. Speeds and differential pressures out of these ranges can only apply in "noncontinuous duty", in spite of what may be inferred from the pump label plates or the catalog descriptions, which are meant for general market comparative purposes only. The units will certainly develop more than forty PSIG differential pressure, and certainly function at speeds above 1000 RPM, but will not last a reasonable amount of time unless our recommendations are followed, correctly. Not only are the drive speeds and pressure differential limits critically important, but also the quality

of the liquid supplied to the pumps, which should not contain excessive amounts of particulate debris.

(6) STRAINERS.



There should always be a properly-sized strainer, correctly installed in the pump inlet line, which is capable of trapping particulates at least as small as .006 - .008".[3] The strainer should be inspected and regularly cleaned at frequent intervals. Care should be taken to insure that pressure evacuation does not cause the formation of dry ice crystals that block-off the strainer element, particularly when the pressure is relieved from, or very near to, the pump.

In spite of the fact that the liquid Carbon Dioxide is "food-grade" quality, or that it is manufactured by "distillation", there should still be a strainer in the pump inlet line. This is because there are any number of several potential pollution sources, all of which could cause problems not only with the pump, but with the other equipment using the product handled. There is virtually no way to prevent some contamination in an average recirculation system. Eventually, even with a strainer in the installation, the build-up of these substances will reach beyond tolerable limits, and will have to be removed. Knowing when the very fine debris has built-up excessively, before it does irreparable damage, can be determined by periodic inspections.[4]

(7) GEAR BACKLASH MEASUREMENT.

The pump should be periodically inspected and properly maintained. If used in an average manner, the first parts which should be periodically checked and replaced, are the gears. A typical inspection may be made once the pump has been safely isolated from the system, and carefully depressurized as per established safety codes and procedures. The gears will be exposed if the gear end cover is removed from the pump body. Upon reassembly, the old casing face sealant must be removed, and new sealant adequately applied.[5] The gear end play, diametral clearance, and backlash, are all critical measurements essential to proper pump functioning. A periodic inspection must be made to determine the condition of the gears, bushings, and the other parts, before the pump breaks-down.[6] The interval for

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[3] See "Booklet A (AL-36)", and Bulletins "AL-17A", "AL-40" and "CP-6", for additional information. Strainers should be cleaned frequently to maintain unobstructed flow into the pump. Do not blow-off the strainer to clean the screen. *The strainer screen must be physically removed from the strainer for cleaning.* Be sure to keep an extra strainer screen on hand in case the one in use becomes damaged.

[4] See Bulletin "AL-1" for additional information. Consult with the other equipment manufacturers and fabricators.

[5] See Bulletins "AL-1", "AL-58", appropriate service manuals, and other literature from Smith Precision, for additional information on this and related maintenance aspects.

[6] See Bulletin "AL-19", "AL-20", or "AL-21" for more detailed information on the recommended periodic inspection procedures for the particular pump model in question.

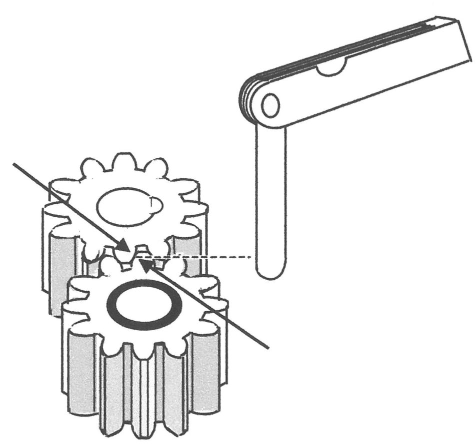
these inspections must be determined by the personnel at the site, since every installation is different, and presents variable demands upon the equipment.

It is therefore necessary for the first inspection to be done very early, for example, after one or two months of use. If the inspection reveals no measurable wear, double the interval, and check again. If the second inspection is negative, double the interval once more, and so forth, until wear is noticed. At that point, the parts are replaced. The preventive maintenance interval has now been determined. Comparison of visual inspections indicates any rapid build-up of fine debris as mentioned, earlier. This inspection procedure as suggested is specifically intended for pumps used in CO_2 service; other services may require different techniques. Contact the factory if there are any questions.

Usually, if the gear ends have worn against either end of the chamber formed by the housing and corresponding cover, this is very easy to see, and is excessive wear. Likewise, if the gears have contacted the diameters of their respective bores, this can easily be visualized, and as such, usually constitutes excessive wear. However, the free play between meshing gear teeth does not lend itself to visual inspection as readily, and is the first area to see normal wear. In most cases, it is the lack of timely gear replacement, which causes the visible casing wear patterns on the pocket ends, and diameters.

The "gear backlash" should always be measured with a simple feeler gauge. This will indicate the extent of working part wear in the complete pump assembly. If this measurement is beyond the maximum, install a new set of gears, and measure the backlash, again. If the indication is still too excessive, replacement of other parts is necessary, or an exchange pump is required.[7] If the indication is within tolerance, the unit can be reassembled with the new gears, and used until the next scheduled inspection. In this way, the system should not be plagued with surprise breakdowns. The required repairs, and/or modifications, can be made in an opportune manner. Gear backlash measurement, in accordance with the periodic inspection plan as previously mentioned, should be in line with the following table:

PUMP TYPE	* BACKLASH, NEW	* MAXIMUM
MC-1Z NSSA	.004 - .008	.016
GC-1Z NSSA	.004 - .008	.016
SQ-1Z SA	.004 - .008	.016
SQ-HZ SA	.004 - .008	.016
SQ-HHZ	.004 - .008	.016
SQ-HH8Z SA	.006 - .012	.020
MC-1044 SERIES	.006 - .012	.024
MC-1044H SERIES	.006 - .012	.024
MC-2,3,4, AND 5 SERIES	.006 - .012	.024
ATC-SERIES	.006 - .012	.024
TC-SERIES	.006 - .012	.024



[7] See Bulletins "AL-1", and "AL-3", for a more detailed explanation of the Smith pump "Exchange Plan".

** NOTE: "Backlash" measurements specified, here, are determined with gears installed in the pump, by inserting feeler gauges between all meshing gear teeth combinations, simultaneously, in one housing. This actually determines the total "play", or "free working clearance" by taking up all the slack in the working parts in the particular housing, at the same time. This is not the same measurement as determined with the gears in a special "backlash fixture". Contact the factory for more details on these or other models used in CO_2 service.*

(8) DEBRIS.

Excessive amounts of debris continually recirculating and pulverizing can easily enlarge the working clearances, and cause rapid wear, in any pump. Debris can be a very detrimental factor to service life, with pumps in liquid CO_2 recirculation service, especially if the duty cycle is continuous. It is very important to do everything possible to minimize the contamination of the system, and to strain the liquid before it enters the pump. However, in spite of the standard precautions, there is always the possibility that every time the storage tank is filled, from an external source, impurities may enter, in the form of moisture, dust, etc.. These can become highly pulverized abrasive particulates and ice crystals, concentrated in the supply tank, and literally floating on top of the liquid phase. If the liquid level drops enough, or if there is a high turbulence condition, the debris can pass into the pump inlet line. Continual passage through the pump allows it to work its way into the minutest of working clearances, where it can be extremely abrasive to the gears and shafting.

At this point it is fitting to mention that any working part capable of wearing out eventually, does generate particles. It is important to consider the relative amounts of particulate generation caused by pumps and other equipment used in these systems, as well as the "reactivity" of said debris. Smith pumps are noted for low particulate generation, and were purposely designed with minimal working parts that have large product-cooled, self-lubricated, load-carrying areas, as well as a unique low-wear three-piece mechanical seal. The minute quantity of debris produced by these parts, in operation over a long period of time, is essentially inert, and of a nonabrasive nature. Circulating substances from other sources, including piping, fittings, sealants, etc., as well as the other handling equipment, which contaminate the fluid, can be completely different, and potentially detrimental, as previously stated.[8]

(9) CARBONIC ACID.

If the frictional stress by particulate matter, or by any other condition which inhibits liquid cooling effects, is excessive, corrosion of exposed internal surfaces may take place, as well. This is due to the fact that one common contaminant is moisture. Moisture freezes and

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[8] Contact the other equipment manufacturers and CO_2 suppliers for more detailed information about potential long-term product contamination.

forms particles of water ice which can mix with the other impurities often found in recirculation systems.

If the debris takes up critical working clearances, some of the fine ice particles melt and chemically combine with the Carbon Dioxide to form carbonic acid. This problem becomes aggravated if the liquid level in the tank is unusually close to the bottom, of if there is high turbulence, allowing the ice particles floating upon the liquid phase to be carried by the liquid flow into the pump. The acid, which is relatively weak at atmospheric pressure, becomes a potential problem under the storage pressure conditions of the "low-pressure" transfer system (usually between 220 - 310 PSIG). It can produce rust-like abrasive particles in the lines, and can be responsible for locking-up the pump, as well as causing critical damage to other components in the system.[9]

(10) FILTERS.

Sometimes, the use of a filtration device is in order, to eliminate contaminants. When the particles are as fine as clay, or talc, they cause a particularly difficult set of problems. The working surfaces of the internal moving pump parts can polish themselves away in a very short interval, especially when the abrasives measure less than .001" across their widest area.

One realistic way to remove these microscopic particulates is by filtration. "Filtration", as opposed to "straining", is a method by which extremely fine, or "microscopic" particles are removed. "Filters", as opposed to "strainers", are rated in "microns", not "mesh size". Particulates which must be "filtered", can pass right through the strainers that are normally used, which trap relatively large particles, measuring several thousandths of an inch across. "Strainers" are often mistakenly referred to as "Filters", and this can cause some confusion about the proper device required.[10]

A recommended strainer can be installed *before* the pump. However, the placement of the filtration device is more critical, due to its vapor-trapping and pressure drop characteristics, not found in recommended strainers. In order to prevent cavitation, it would therefore be installed in the pump *outlet* line, not in the inlet line. It would be necessary for the ultra-fine abrasives to go through the strainer and through the pump, first, before being trapped in the filter. In extreme cases, it might even be necessary to "sacrifice" a pump, in order to adequately remove particulate contamination, and to prevent abrasive damage to subsequently replaced pumping equipment. Another way to reduce subsequent damage to

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[9] Check with other manufacturers of equipment used in these installations, for additional information on effects of acid and contamination. In this case we are discussing the pump, but care should also be taken not to jeopardize the rest of the recirculating system. Be sure to exercise all standard safety precautions.
[10] To help illustrate the difference, if there were, for example, a strainer in a theoretical mesh size fine enough to trap the aforementioned "microscopic particles", it would plug-up quickly from lack of sufficient surface area exposure to the flow, unless it were of an unusually large, impractical size.

the equipment is to insure that there is always plenty of "Net Positive Suction Head" pressure in the pump inlet line.[11]

(11) STATIC HEAD UPON THE PUMP.

The amount of "static head" upon the pump can be a great benefit to it by minimizing cavitational potentials. Also, in a sense, extra "NPSHA" can compensate for internal wear, and other unforeseen conditions, which would cause some of the liquid to boil on its way through the unit. This factor is much more critical in a continuous use application, and should always be given special attention.[12]

(12) SIZE AND SHAPE OF THE SUPPLY TANK.

The type or style of cold storage tank can actually affect the availability of gravity head pressure. For example, a "vertical" cylindrical cold storage tank, as opposed to a "horizontal" one of identical shape and capacity, would present three advantages. First, and foremost, (1) it would raise the amount of available gravity head pressure, by increasing the liquid level above the pump; (2) it would require less floor space; and (3) it would possibly allow for greater refrigerative efficiency, due to the enhanced symmetry of the vapor phase area, the lesser liquid surface area, and the increased distance to the bottom of the tank.

However, on the opposite side of the coin, a vertical tank (1) lends itself more to the formation of whirlpools in the liquid phase ("chorialis acceleration") and (2) has a greater probability of liquid access connections in excessively close proximity. These could cause pump cavitational problems, due to heat gain in the return flow, running back into the liquid phase, which might not dissipate sufficiently before entering the pump, again. On the other hand, with a horizontally-aligned tank, the return leg can usually be piped back to liquid, but *at the end opposite from the pump supply connection.* This eliminates the possibility of immediate recirculation without sufficient heat dissipation (which leads to eventual vapor-locking). Another related problem which can cause vapor-locking has to do with the placement of the recirculating pump, itself.

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[11] "Net Positive Suction Head (NPSH)" is one of several terminologies that express pressure in units of *vertical liquid column height.* In this particular case with the Smith pump, we are referring to the resultant difference between the natural vapor pressure in the supply tank, and the measured liquid pressure in the pump inlet while it is running. By factoring in the pressure head of the stored liquid above the pump centerline, *less* the value of the resistance to flow through the pump inlet line, there must be an "additional pressure factor", or "positive energy" *above* the tank vapor pressure, which will continually fill the intake transfer cavities completely with "solid liquid". In other words, the acceleration of the liquid mass when the pump first starts, and its continuing flow into the pump, should be *positively* "force-fed" or "flooded", by energy primarily derived from gravity, to *prevent excessive boiling, or " cavitation"* while handling low-pressure liquefied Carbon Dioxide, which is at its boiling point. Therefore, in consideration of *all* contributive factors, the "<u>Net</u> Positive Suction Head Available (NPSHA)", delivered to the pump inlet ("suction"), should be higher than the "<u>Net</u> Positive Suction Head Required (NPSHR)" by the pump to perform its function. This figure helps to determine how high the tank should be above ground level.

[12] See Bulletins "AL-3", "AL-17A", "Booklet A (AL-36)", and others, for additional information.

(13) PLACEMENT OF THE PUMP.

We have always recommended that the pump be situated as close to its supply source as possible, and preferably, right under it. The size of the inlet line should be at least the size of the pump inlet connection. In general terms, the horizontal run of the inlet line should not exceed 10-12 Ft.. If these recommendations are not followed, the pump will cavitate. This will occur for two reasons: (1) the product handled is a liquefied gas at its boiling point, literally "looking for an excuse" to open-up into vapor; (2) the product handled is refrigerated in order to keep the vapor pressure down within more practical limitations. If something happens to disrupt the maintenance of colder-than-ambient temperatures in the pump inlet line, and/or if some occurrence causes excessive resistance to flow in the inlet line, and/or if the column of liquid in the inlet line is excessively long upon initial acceleration toward the pump, excessive amounts of vapor will continually pass through it.

It is quite obvious that the way the pump must be supplied with liquid is not the same as would be the case with dielectric coolants, oil, or water. The more continuous the use conditions are, the more critical the placement of the circulating pump becomes. Also, for the same reasons mentioned above, it is important that each pump in service have its own line, each from a dedicated separate outlet in the supply tank.

Common intake manifolds may be used with pumps in other liquefied gas services, especially if these pumps are used intermittently, and if the liquid in question has a small amount of lubricity. In the case of low-pressure liquid Carbon Dioxide transfer, this is not so: the highly "polarized" nature of this fluid, its artificially maintained temperature, and its continuous usage, make it an "exception to the rule".

In a sense, the placement of the pump is actually affected by the fact that CO_2 is a comparatively "dry", and "abrasive", liquid. Unlike petroleum derivatives, for example, it does not wet the parts it contacts; it simply "washes on" and "washes off". The pump must be close enough to its supply source to always take full advantage of the cooling, or "refrigerative", effects of the CO_2. As it passes from the inlet to the outlet, the pump uses horsepower, to do work, to build pressure upon it. This work can be quantified as injection of heat, or "BTU's", over a certain time period.

The liquid must absorb this heat at a sufficient rate to compensate for work accomplished and all resultant frictional factors. If there is a disruption in the liquid's ability to properly perform this function, the pump will be cavitating, and be exposed to rapid wear and lock-up situations. This is why the inlet line must be relatively short, and each pump in use must have its own dedicated tank outlet.

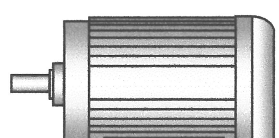
(14) "LIFT" IN THE OUTLET LINE.

Static head in the inlet line is important; just as important are the "lift" and "negative head" characteristics present in the outlet lines. A more valid case can be made for the influence of negative head, or the "falling of liquid", in the return leg, within systems where the total flow eventually returns to the cold storage supply tank. However, it is a good practice not to count on full recuperation of lift loss, from flow return. Due to the realities of heat gain potentials, wear factors, and pressure differences around the loop, some of the differential pressure across the pump may, or may not, be gained back as the liquid in the return leg drops the same distance that it had to be lifted. The maximum amount of recommended lift, or vertical distance between the pump centerline and the highest point in the loop, depends upon the resistance to flow characteristics when the system is functioning. The maximum recommended differential pressure across the pump is 40 PSID. *The maximum system design differential pressure is 30 PSID.* The head gain per foot is 0.43 PSIG, at the average temperature of 0°F.. If head losses from flow and lift in the system are much over 90 Ft., the differential pressure is excessive for "continuous duty", as we have defined it, and excessive for running the pump between 750 and 1000 RPM.[13]

Also, another factor which can affect the amount of allowable lift in a CO_2 recirculation system is simply the safety settings of the required relief valves. We cannot overstress the importance of safety when handling liquefied gases, such as CO_2. Obviously, it is not recommended to attempt to build a pressure higher than that which is considered at a safe level by the safety regulations that apply, in your area. Our pumps, by virtue of their positive displacement nature, are quite capable of building much more pressure than that which we recommend, and by the same token, can momentarily build a very excessively high differential head, of sufficient proportions to open safety valves and/or subject the system to excessive pressure.

The "bypass valve", properly installed, prevents accidental over-pressuring, and at the same time provides a means where the excessive pressure can be discharged, harmlessly, right back to the cold storage supply tank. Previously, it was stated that the maximum differential pressure for continuous duty, RPM 750 - 1000, should not exceed 40 PSID. In a properly designed, average system, the back pressure should easily be under 30 PSID, and the bypass valve can be set for approximately 10 PSID above that. It would never open during normal operation of the system, but only be there as a passive safety device, providing a means whereby the pump could keep on running during an abnormal outlet resistance incident, without blowing a safety valve, without creating a potentially hazardous situation, and without subjecting itself to excessively rapid wear. This is of even greater importance in a fire prevention system, which can depend upon proper pump functioning to save equipment and lives.

(15) HORSEPOWER OF THE MOTOR.



Sometimes, the motor is not considered as a safety item, as is the bypass valve. However, the electric motor should be set-up to shut down the pump, if a potential problem exists.

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[13] See "Booklet A (AL-36)" and Bulletin "AL-17A". Contact the factory for additional information about matching speeds with differential pressures and use intervals. It is very important that these factors comply completely with the factory recommendations, because CO_2 is somewhat of an exception to the vast majority of liquefied gases handled by Smith pumps, covered in the product line catalogs.

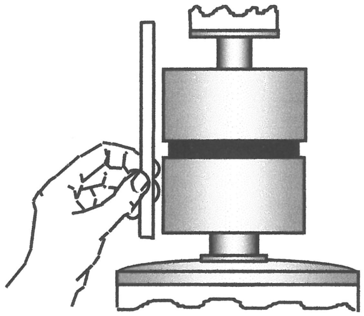
For example, when the correct motor is used, and connected to the power properly, should the differential pressure accidentally go up too high, the excessive torque demand would simply activate the circuit breakers which would turn off the electrical supply, stopping the motor before any damage were done. As a further measure of safety, the motors should be supplied with internal thermal overload protection, as are the totally-enclosed, fan-cooled, fractional HP motors which we usually recommend for Smith pumps in these systems. Since the motor is a safeguard measure, if the thermals should ever trip, an investigation should be done to determine whether certain problem factors exist. The most obvious ones, other than simple motor failure, include: (1) a low voltage condition, (2) improper electrical connections, (3) improper alignment with the pump, (4) excessive differential pressure, (5) pump starvation due to inlet line restriction, (6) vapor build-up due to improper return too close to the pump outlet, (7) pump "wind milling", (8) insufficient static head on the pump, (9) excessive amounts of debris in the system, (10) ice in the system, (11) motor running backwards, (12) excessive pipe thread sealant or tape inside the pump, (13) excessively long inlet line, (14) high turbulence in the supply tank, (15) liquid level too low in the supply tank, (16) excessive heat gain in the system, (17) extreme changes in tank pressure. There are other related problems. Contact the factory for additional information if required.

(16) FLEXIBLE DRIVE COUPLINGS.

The condition, or even the style, of the coupling that connects the pump and motor shafts, could have a detrimental effect upon the motor and the pump. The flexible drive coupling is very often overlooked, even when the pump is replaced. It is quite often removed and replaced "as-is", sometimes without using a puller. Hammering upon the coupling to remove and reinstall it will not only damage the coupling itself, but can also damage the pump as well as the motor.

There are many styles and brands of drive couplings, and an equal variety of price ranges. Even though the coupling is technically called a "flexible drive coupling", the key term, "flexible", does not necessarily mean what the literal interpretation of the word implies. Regardless of what claims may be made by the coupling manufacturers, the pump and motor shafts *must always remain in very close alignment*. In other words, even if the coupling is designed for up to 1/8" misalignment, or more, without being overstressed and damaged, the pump and motor shafts must still be aligned as close as possible, checking both "angular", and "parallel" differences. Ideally, the alignment would be adjusted for an equal dimension from all measuring points. Appropriate gauges, or indicators, and a straight edge, would be used for this purpose. It would not be uncommon in a typical installation with a base-mounted pump, to shim the motor for proper positioning. The manufacturer's recommended distance between coupling halves must be checked and properly set as an adequate compensation for friction and end play. Once this operation is complete, make sure the shafts turn freely by hand. Always double check the alignment after the piping has been installed in the pump, as it is possible that the force exerted during installation has affected the alignment.

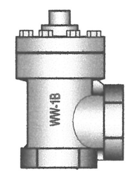
The VC-Series Smith flexible drive coupling has been specifically designed for use with our product line. It consists of two metal hubs with pins, turned concentrically with the bores, and a hard rubber, or inert plastic disc, between them. The coupling halves are designed to be used as a reference point for angular and parallel alignment. The positioning of the pump and motor shafts, with our coupling, must stay within .015" of "perfect", and there should be a slight gap (approximately .010" total) between the two halves and the insert.



Fast coupling wear indicates misalignment of pump and motor shafts. Misalignment or the continued use of a worn coupling insert, can be responsible for rapid pump wear, continual seal leaks, and noise. The proper way to align the Smith drive coupling is shown in the sketch. (See Bulletins "AL-1", and "AL-3").

The correct use of flexible drive couplings protects the motor as well as the pump. Of equal importance in pump protection, is the proper installation of the differential pressure bypass system, as mentioned previously under point number 14.

(17) THE DIFFERENTIAL PRESSURE BYPASS SYSTEM.



The type of bypass valve used in the return line can not only provide an easy way for the operator to keep differential pressure at a constant level if necessary, but *it is also a safety item.* It allows excessive supply leg pressure to stay within the confines of the piping by simply discharging back immediately to the cold storage tank. Should the main flow circuit become blocked for any reason, an external bypass valve, properly installed and adjusted, automatically opens, and the overpressure is relieved internally, not externally, without causing the pump to cavitate. The bypass system compliments, and in our opinion is just as important as, the external discharge safety relief valves on the storage tank, and the hydrostatic relief valves at key points throughout the system, as required by safety codes. We can never overstress the importance of maintaining safety at as high a level as possible with these CO_2 recirculation installations. The proper use of the bypass return system enhances the accident prevention characteristics. It also prevents the pump and motor assembly from overstressing, under abnormal conditions.[14]

[14] This valve should always be included in the installation, regardless of whether the pump utilized has an internal bypass relief valve. See "Booklet A (AL-36)", and Bulletins "AL-3", and "AL-17A" for further discussions of the importance and proper functioning of the bypass valve and its return piping system.

(18) CONCLUSION.

In conclusion, as with any liquefied gas transfer system, always be sure to read carefully, and follow specifically, all manufacturer's and fabricator's instructions, as well as pertinent safety codes. Among the many safety recommendations regarding the use of Smith pumps in these systems, the following are among the most important (see the specific manufacturer's instructions for more complete information) :

Never use a Smith pump for any other service, or in any other way, than originally specified by Smith Precision Products Company, Inc. **Do not "dead-head" the pump. Do not allow it to go "hydrostatic". Avoid rapid blow-down situations. Do not allow the pump to fill with water. Avoid water ice expansion within the pump. Depressurize the system carefully, and properly isolate the pump or remove it from the installation, before disassembling the pump for any reason. Avoid "wind milling". Do not pound on it. Do not overstress the pipe connections, or the mounting feet. Clean casings thoroughly before reassembly, and use an appropriate sealant between the sealing faces (see Bulletins "AL-3", "AL-17A", "AL-58" and appropriate service manuals, for additional information). Contact the factory if you have any questions. Also, contact the other manufacturers of equipment used in the system, regarding any of the abovementioned situations, and be sure to read their literature.**

Low-pressure liquid Carbon Dioxide recirculation, as opposed to other kinds of liquid transfers, is a unique, comparative case, because (1) concentrated vapor can cause asphyxiation by displacement of air in a confined, poorly ventilated, area; (2) it must be continually refrigerated to keep the pressure lower than it would normally be at the average temperature of its surroundings; (3) it is handled at *below freezing temperatures* **allowing for condensation, formation of ice deposits, and potential significant contraction of pipe lines when initially charged; (4) any debris, impurities, or moisture, entering the storage tank when it is filled, tend to concentrate in the transfer system, and eventually build up in the tank; (5) rapid "blow-down" of system pressure can drop the temperature in the immediate area far enough to freeze the product, which can cause piping and strainer screen obstructions; (6) recirculating particulates will be pulverized to microscopic size and form "coatings" on all exposed internal surfaces; (7) the liquid does not "wet" the parts it contacts, and from a certain perspective can be said to be "abrasive" and "dry"; (8) as such, careful attention must be paid to matching slow pump speeds, with required differential pressures, and "on" time intervals.**

As has been shown in all of the aforementioned, there are, indeed, various unique, important aspects, involved with the application of Smith pumps for this kind of low-pressure liquid Carbon Dioxide transfer. If all pertinent use and safety factors are properly taken into consideration when the system is designed, and while it is being used, the pump will give long, trouble-free service. When a pump needs to be changed-out, the use of the "Smith pump Exchange Plan", is a very customer-convenient means to readily acquire a replacement pump, guaranteed as new, for less cost than a new one.[15] Although this "exchange program" is quick, easy, and relatively inexpensive, it is not the answer to

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[15] See Bulletin "AL-1".

continual use of the equipment under poor conditions. Smith pumps may seem to function "normally", and even appear to be "lasting reasonably long", even though they are used in a non-recommended manner. Labor costs and maintenance difficulties being as problematic as they may be, it is many times all too easy for a typical user to just "let things go", simply replacing his Smith pump with an "exchange unit" every time it wears out. Far too many piping systems appear to have initially related to cutting corners and reducing initial cash outlay, or look like they have been modified over the years in a haphazard manner which causes extremes of heat gain and back pressure.[16] Never lose touch with the realities of these situations. In spite of what may be said about other alternatives, in most cases it is *practical* to recirculate liquid CO_2 with a positive-displacement Smith pump, used in the correct manner. However, the simple, rugged construction of the Smith pump, and its ease of replacement, were never intended to eliminate the logical application of "preventive inspection/maintenance", and "proper installation".

For example, typically within its specified limitations, in a given period, a pump can be working against high to nominal differential pressures. Another similar type of variable occurrence is that tank pressures are not constant all the time. Thirdly, corresponding to the aforementioned, there can be continual temperature differences. It cannot be assumed in such a system that the density and viscosity values of the pumped liquid will remain constant. This illustrates the need for a pump whose performance is essentially unaffected by these inconsistent liquid qualities. Obviously, there is a valid case made here for the positive displacement nature of the Smith circulating pump, which by necessity, has to be "flexible" in these applications, and eventually, may have to be upgraded to match these and other changes. The users should, therefore, make themselves aware of any detrimental pumping condition, as soon as possible. A simple inspection, done in time, will easily reveal potential wear conditions upon the pump. This gives the user ample time to repair or modify the pump assembly, and to correct any installation problem, *before it becomes critical to system function.*[17]

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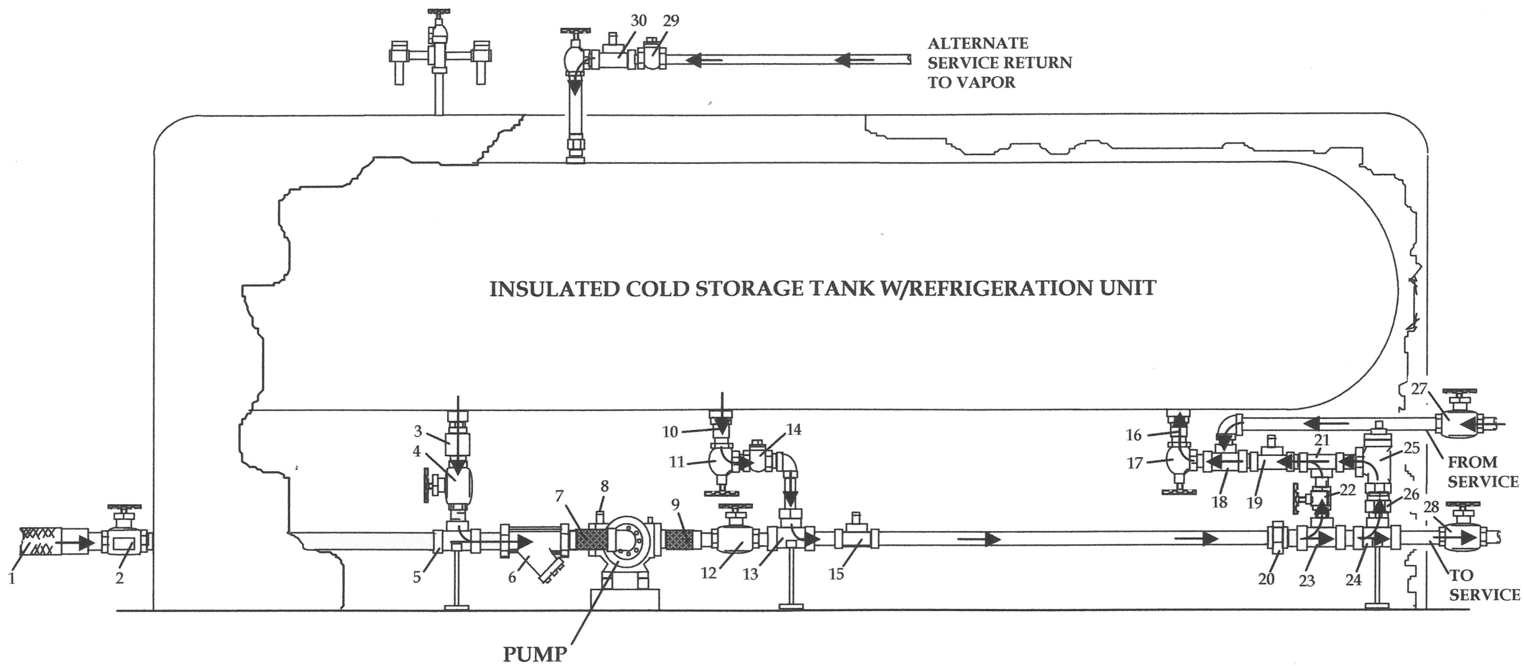
[16] See Bulletins "AL-3" and "AL-17A" for more complete details on remedies for, and causes of, pump failures.

[17] There is a procedure for visually determining whether the pump will function properly in its present condition, and if not, whether it can be repaired in the field. This procedure must be done in sequence, in the prescribed manner. It varies only slightly from one model, to another (consult service manuals, or contact the factory, for additional information). Always properly depressurize and isolate the pump, or remove it from, the piping system. Never reuse excessively worn pump casings. Upon reassembly, always carefully remove the old casing face sealant, and reapply an approved sealing compound in the recommended manner. Review pages 5 - 6 in this bulletin, "AL-97", and "GM-1".

NOTE: When the Smith pump is running normally, under average conditions, *the balanced loading upon the gear set actually keeps the gears from contacting the casings.* (See Catalog "CP-3", Bulletin "AL-1", "AL-3", "AL-17A", and other descriptive literature, for more details on this, and related subjects). *In order to avoid accelerated internal casing wear and parts deterioration, always be sure that the pump is utilized exclusively for handling the liquid under the conditions for which it was intended, as indicated on the serial tag, and as further detailed by exact factory recommendations.* Highly abnormal conditions, or lack of timely periodic maintenance, even when handling the appropriate indicated fluid, will lead to wear patterns which are easily visible during these inspections.

BASIC LOW-PRESSURE LIQUID CO_2 RECIRCULATION PUMP AND SUPPLY TANK SYSTEM



This drawing is an example of an early low-pressure liquid CO2 cold storage facility, showing the basic installation of the pump, as well as the beginning, and the end of the service piping. The theories and premises illustrated here, are still very much applicable, today. Of course, no single piping diagram can possibly be used in all cases. However, this drawing still serves to generally illustrate the best way to set-up the continual transfer system piping around the storage tank for low-pressure liquid Carbon Dioxide. Please refer to sheet "AL-3", and other engineering references, for proper pipe sizes. Always use approved pipe, tubing, fittings, valves, meters, tanks, pumps, etc., to construct the continual transfer system. Contact the suppliers if there are any questions. There can be many variables, including the recommended shelf life of the system components.

The installation illustrated, above, may look somewhat complicated, but it is not costly and there is a very good safety or convenience reason for every item shown. Obviously, there are other types and styles of valves which can easily be substituted for those illustrated. Other changes have been recommended by safety authorities over the years. We recommend that the weight and stress of the piping system be properly taken-up by the tank or free-standing supports (not necessarily exactly as shown in the above drawing). The pump should not support the total piping system. Be sure that there is no undue stress on the pump casing (or any other system component) during or after installation. Avoid application of excessive angular force which might tend to misalign the pump with the motor.

Avoid any potentially hazardous situations. For more current information as required, please refer to handling equipment manufacturer's data, and the applicable local, State, and Federal codes and regulations. Obviously, modifications to this installation as shown above, must be made to suit safety requirements, and service conditions. This drawing is not intended to be taken literally. It is as complete as possible, but does not show everything that could be desired by all users. The storage tank, for example, is of the horizontal type, but vertical tanks are just as satisfactory if mounted as high above the pump level. Arrows indicate the direction of flow as follows:

TO OPERATE THE RECIRCULATING SYSTEM: Liquid CO2 flows out of the cold storage tank through the coupling 3 , shut-off valve 4 , tee 5 , Smith strainer 6, flexible connector 7, and into the Smith pump. The pump develops the necessary recirculation differential pressure, and pushes the liquid through the loop, through the flexible connector 9 , shut-off valve 12, tee 13 , tee 15 , union 20, tee 23, tee 24, shut-off valve 28, back from the service through shut-off valve 27, tee 18, shut-off valve 17, and coupling 16. The shut-off valve located at position 2 is left closed. The shut-off valve located at position 22 is also normally left closed, but can be opened initially for a few seconds to allow the pump to purge itself of vapor before building pressure. An alternate routing of the loop return is into the vapor phase of the cold-storage tank through the check valve 29, tee 30, and the accompanying shut-off valve. Positions 8, 15, 19, and 30, are for hydrostatic relief valves which must be installed on the pump and between any two valves which if closed, could trap liquid between them.

THE DIFFERENTIAL PRESSURE BYPASS VALVE: If the pump builds-up an excessive pressure, the bypass valve 25 , opens, allowing enough of the liquid pumped to return to the storage tank The bypassed liquid passes through the tee 24 , union 26 , Smith bypass valve 25 , tee 21 , tee 19 , tee 18, shut-off valve 17 , and coupling 16 , to the cold-storage tank.

THE EXCESS FLOW DEMAND PUMP BYPASS LINE: Should there exist an overdemand situation in systems where CO2 is discharged to atmosphere, in stead of "wind milling" the pump, additional flow beyond the pump's capacity simply flows out of the tank through the coupling 10 , shut-off valve 11, check valve 14, tee 13, tee 15, union 20, tee 23, tee 24, shut-off valve 28, and on to the use points in the loop.

TO FILL THE COLD-STORAGE TANK: Connect the liquid hose 1, and the vapor return line (not shown). The delivery tanker pump, or the auxiliary ground pump, fills the cold-storage tank through the delivery hose 1, shut-off valve 2, tee 5, shut-off valve 4, and coupling 3. Shut-off valve 12 is closed during this operation. The system pump shown could also be used to fill the tank, if required. In such a case, valves 4, 28, and 27 would be left closed. The pump would pump the liquid through the delivery hose 1, shut-off valve 2, tee 5, strainer 6, flexible connector 7, flexible connector 9, shut-off valve 12, tee 13, tee 15, union 20, tee 23, shut-off valve 22, tee 21, tee 19, tee 18, shut-off valve 17, coupling 16, and on into the cold-storage tank. If the operation cannot be shut-down during tank filling, a separate liquid connection (not shown) is used, which allows the recirculating pump to continue operating while the storage tank is being filled simultaneously.

SMITH PUMPS

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