SIZING A CO_2 CIRCULATING SYSTEM

Based upon our experience, maximum pumping efficiency and longevity can be achieved without overloading the refrigeration system, provided the pump differential pressure never exceeds 30 PSID. The circulating loop must be carefully designed with this fact in mind, taking future expansion into account, as well.

EFFECTIVENESS OF LOW-CAPACITY VS. HIGH-CAPACITY PUMPS. Many systems require periodic discharge of liquid CO_2 to atmosphere. Instantaneous *liquid* ejection on demand through every use point must be guaranteed. When all drops are activated, the resulting liquid flow out of the supply tank must not encounter excessive resistance between the tank and the discharge points. There could easily be excessive resistance to a flow of liquid in excess of pump capacity, if it first has to pass *entirely through the pump* on its way to the discharge points.

This situation often simultaneously occurs with another adverse condition, pump "wind milling". That is what happens when the pump ceases to cause a flow of liquid, and the flow out of the tank actually drives the pump. In poorly designed pump installations, "wind milling" frequently subjects pumping equipment to very adverse conditions. Whether the motor is turned "off" or "on" makes hardly any difference to the potential severity of pump damage, especially if there is no way for excessive liquid flow out of the tank to bypass the pumping unit.

The pump resists overriding liquid flow, causing (1) *internal pressure drop*, while (2) *being hydraulically driven* at RPM in excess of its own motor speed. The motor, while resisting this transmitted turning force, can also be subjected to undue stress. Resultant pressure reduction within the pump interior easily damages the working parts due to over revving, excessive cavitation, or particles of frozen product ("dry ice") in extreme cases.

"Wind milling" can be eliminated by simply installing relatively large capacity pumps, with outputs always higher than the combined product demand through all the drops. The greater recirculated flow in these designs, requires increased size, expense, and energy utilization in higher-capacity components. However, modern system designs utilize less energy to effect proper liquid feed to the drops. They actually permit the tank pressure to take over during an "overdemand" situation, which allows utilization of a lower-capacity refrigeration and pumping installation.[1] Smaller pumps need lesser-capacity refrigeration systems, since they inject less heat into the liquid. The flow out of the smaller recirculation pump can be calculated more in line with environmental heat absorbed around the circuit, as opposed to being based upon a high flow demand contingency.

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1 See Technical Bulletin "AL-93" for additional information on this and related subjects of concern.

When a smaller pump is used in this fashion, the storage tank is provided with an additional liquid outlet line that carries excessive demanded flow *around* the pump, permitting the pressure in the storage tank to push unobstructed liquid toward the drops. Therefore, as long as there is a proper minimum flow maintained through this kind of loop, during those periods of heavy CO_2 liquid discharge there will actually be times when the pump is not necessarily required to compensate for absorbed heat, or to insure instantaneous liquid ejection out of each drop on demand. The recirculation pump is now better viewed as a piece of equipment which maintains a small, sufficient, "trickle flow", within the system to compensate for minor heat gain and vapor accumulation during minimal-use or no-use periods. The "flow overdemand pump bypass line" is supplied with a check valve, to prevent immediate recirculation back to the tank when the product demand diminishes, and the pump develops measurable differential pressure.[2]

LOW-CAPACITY SMITH RECIRCULATING PUMPS. Most Smith recirculating pumps utilized in the aforementioned manner for low-pressure liquid CO_2, are operated "non-stop", continuously for more than six consecutive hours, requiring that they be run between 750 to 1000 RPM.[3] The following table indicates the average capacities of the usual models, in pounds per minute, when driven at the most commonly-used nominal drive speeds:

MODEL	SHAFT RPM	CAPACITY, POUNDS PER MINUTE
MC-1 NSSAZ	900	16
GC-1 NSSAZ	900	16
SQ-1 SAZ	900	16
	1200	24
	1800	38
SQ-H SAZ	900	25
	1200	35
	1800	54
SQ-HH SAZ	900	44
SQ-HH8 NSSAZ	900	70

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[2] We cannot overemphasize the importance of a proper Engineering study to determine exactly the required balance between continual pump output flow, flow demanded by the drops, and heat gain. Safety should always be a primary concern when designing and utilizing these recirculation systems. Be sure to follow all applicable Federal, State, and local safety regulations.

[3] Other speed ranges might possibly apply in cases where the pump is used only a few hours each time. By our definition, in low-pressure liquid CO_2 recirculation service, if the recommended Smith pump model is in "intermediate" non-stop use (run continuously for no more than six consecutive hours at a time), it may be driven at 1200 RPM, 60 Hz direct-coupled electric motor drive speed. In "intermittent" non-stop use (run continuously for not more than two consecutive hours at a time), the appropriate Smith pump models may be operated successfully at up to 1800 RPM, 60 Hz direct-coupled electric motor drive speed. Refer to the application limit table on the following page. See Technical Bulletins "AL-17A", and "AL-93", for additional information on related aspects of importance. Contact the factory if there are any questions.

In a few cases, the circulating loop requires greater pump capacity than indicated in the aforementioned table. There is a wide selection of appropriate Smith models with higher flow rates, available for these applications.[4]

MATCHING THE PUMP TO THE SYSTEM USE CHARACTERISTICS. Our product line continues to be upgraded as our technology improves over the years. At the present time, Smith Precision provides highly engineered products, which can be modified for maximum performance within the particular characteristics of the actual use conditions. The low-pressure liquid Carbon Dioxide transfer pump product line lends itself very well to this approach, as shown in the following application table. It is very important to coordinate the pump configuration with the "on" time intervals, and recommended RPM ranges. Failure to properly match the duty cycle to the pump RPM, the piping system capacity to the pump capacity, or the differential pressure to the fluid handling characteristics, will result in premature unit failures. This is the case with all models, regardless of their physical sizes, constructional options, or nominal capacities.

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

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

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

PIPE SIZES FOR VARIOUS LENGTHS OF CIRCULATING LOOPS. The pressure drop in the circulating loop must be limited to 30 PSID, *regardless of the model number or capacity of the circulating pump used*. The actual inside diameter of the pipe or tubing utilized is not necessarily the "nominal" size. Therefore, in order to calculate the maximum recommended length of the loop, the *inside* diameter of the piping or tubing must be figured into the equations. Also, although the length of any loop should be kept as minimal as possible, the future requirements should *always* be taken into consideration during initial design. If it is conceivable that the loop will eventually have to be lengthened, the circuit design may have to be modified to offer less flow resistance than first anticipated.

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[4] See Technical Bulletins "AL-3", "AL-93", and Catalog "CP-1", or contact the factory for additional information.

The pressure drop of a circulating loop is directly proportional to its equivalent pipe or tubing length, and almost inversely proportional to the fifth power of the inside diameter of the same. **The following table illustrates this relationship with several typical flow rates. Maximum loop lengths in feet of commonly used pipe, or tubing, are determined by matching the internal diameters with these flow rates. The recommended circuit lengths in the following table already include an allowance for an average number valves, tees, and elbows.[5] For example, if "0.50" i.d. tubing is used for flow rates up to 24 lbs/min, the maximum loop length should not exceed 283 feet, to keep the differential pressure at 30 PSID, or less.**

MAXIMUM LOOP LENGTH (IN FEET) FOR 30 PSID MAXIMUM PRESSURE DROP

INSIDE DIAMETER OF PIPE OR TUBING (INCHES)	POUNDS PER MINUTE CAPACITY OF PUMPS							
	16	24	25	35	38	44	54	70
0.30	42	20	19	9	8	6	4	2
0.40	173	83	77	39	37	27	18	8
0.50	612	283	272	132	127	95	61	28
0.65	2360	1100	1050	501	475	356	229	105
0.75	4650	2160	2070	1020	975	731	470	216
1.00	19600	9190	8700	4300	4080	3060	1970	906

BE VERY CAREFUL WHEN DETERMINING PIPE OR TUBING SIZES. We have been referring to pipe and tubing by *inside* diameters. As previously mentioned, the nominal sizes do not necessarily relate to the actual cross-sectional dimensions that accommodate the liquid flow. For example, "1/2-inch pipe" has neither a 1/2-inch outer diameter, nor a 1/2-inch inner diameter. Soft copper refrigeration-type tubing is sold on the basis of its outside diameter: Its inside diameter is considerably smaller, depending upon the wall thickness specified. Type "K", or type "L" soft or hard copper tubing is sold on the basis of a nominal size which has no relation to either its o.d. or i.d.. It is, therefore, very important when specifying piping or tubing for a circulating loop, to be certain that the real inside diameter is known without question.[6]

[5] This table should only be used as a general guide. A thorough Engineering analysis of the *exact* data specific to the particular system is always required for proper installation design.

[6] Again, the reader is reminded that the above table should only serve as a general guide, due to component variances. Typical examples that illustrate this viewpoint are as follows: (1) *The real inside diameters will not necessarily coincide exactly with those listed in the above table*. If they are different, the next smaller table size should be used as a reference. (2) *Straightforward use of the table assumes that the entire loop length will utilize the same inside diameter pipe or tubing*. This may not be the case in all installations. Many of them must have feed legs of a larger size than the return legs. (3) *An additional factor for "lift" may have to be taken into consideration, when figuring total Differential Head pressure in the pump outlet line*, especially when there is an unusually substantial height difference between the pump and the highest elevation in the loop. See Technical Bulletins "AL-17A", and "AL-93", for additional general information on these and other related variables. Contact the suppliers if there any questions relating to more specific details.

In conclusion, keep in mind that this bulletin is only intended to be used as a general guide for typical low-pressure liquid Carbon Dioxide circulating systems. Due to the many variable influences, which affect the functional aspects of these installations, a thorough engineering study is required for proper system design. Be absolutely sure that the installation will operate efficiently, and *safely*, at a maximum differential pressure of 30 PSID. Install only those components, which are specifically designed and approved for the intended use.[7] Avoid potentially hazardous situations. Be sure to follow all applicable local, State, and Federal safety regulations. Always contact the manufacturers of the equipment used in the installation, if there are any questions. Carefully read and understand all pertinent literature from Smith Precision and other sources such as the other equipment manufacturers, Engineering texts, and related references. Be sure that the proper pump model is to be utilized within recommended parameters. Be sure to follow all manufacturer's recommendations.

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[7] **Smith pumps fall into this recommended category. They are UL listed for CO_2 service.**