Technical Note #6

Water Quality Specification for Power Supplies

Introduction

The cooling water for Alpha Scientific Power Supplies must meet certain minimum specifications in regard to quality and flow rates. Operation outside the specified values will violate the warranty and can shorten the life of the equipment.

Design Criteria

Flow Rate

The flow of water through the equipment removes the internal heat. This heat is caused by the electrical inefficiency of the power conversion process. In order to produce a certain amount of output power, a slightly greater amount of input power is required. This difference is used by the power supply itself. A typical power supply might be 80%-90% efficient, which means that 10%-20% of its input power is dissipated inside the unit. Assuming that all of this heat loss is transferred into the water, the basic formula for temperature rise of the cooling water is:

$$TemperatureRise(°C) = \frac{kilowatts * 3.78}{GPM}$$

Where kilowatts is the power dissipated into the water
(either actual or estimated at 10-20% of output)

Our designs almost always assume a maximum temperature rise of 20°C rise on a 35°C maximum inlet temperature. Substituting these numbers and solving for flow rate gives the following:

$$GPM = \frac{kilowatts * 3.78}{20°C}$$

So,

$$GPM = kilowatts * 0.189$$

In cases where the inlet water is cooler, or the unit is operated at reduced power, the temptation might be to use lower flow rates than calculated above. The flow rate can only be reduced down to the point of minimum differential pressure or until the water flow switch trips the unit off.

Minimum Differential Pressure

Almost without exception, the power supply's internal water circuit is divided into multiple parallel water paths. A certain pressure is required across the unit to ensure proper sharing of the water flow. We have specified 10 PSID as the minimum differential pressure that can be tolerated.

Minimum Static Pressure

As water is flowing through the power supply, a pressure drop is developed, the outlet pressure always being lower than the inlet pressure. Some plumbing systems may connect the power supply outlet to the suction side of a water pump. It is the customer's responsibility to insure that the static pressure of the outlet (or inlet, for that matter) never goes below 0 PSIG. Pressures below zero can cause collapsed hoses, and cause the cooling circuit to become restricted.

Maximum Static Pressure

High water pressure stresses the hoses and fittings. Of particular concern are the seals inside the water flow switch. Most often, the flow switch's pressure rating is the limiting factor on the power supply's pressure rating. We have specified 100 PSI as the maximum static pressure that should be applied at any time. In cases where special flow switches are used (perhaps by customer request), a higher value may be tolerated.

Water Temperature

As stated previously, our flow rates are based upon a 20 degree rise on top of a 35°C maximum inlet temperature. Therefore, the temperature of the outlet water should not ever exceed 55°C. Temperature sensors mounted on critical components protect all of our water-cooled units. These switches are rated at 82°C (180°F) and are designed to turn the unit off in case of overtemperature. The margin between the 55° outlet temperature and the 82°C cutoff is to allow for temperature variations between the multiple water paths and also to account for the heat sink temperature being warmer than the water temperature.

There is no protection against low temperature. It is the customer's responsibility to insure that the unit will never operate with water below the freezing point.

Dew Point

It is very important that the inlet water temperature never fall below the ambient dew point. If this should happen, condensation would form on the water-cooled electrical components inside the cabinet. This could lead to electrical shorts and corrosion of metallic parts.

The dew point is variable depending on the temperature/humidity relationship. It varies according to season, and time of day. Anytime the water temperature is lower than the ambient air temperature, the possibility of condensation exists. It is the customer's responsibility to ensure that condensation does not occur. Water chillers are notorious for producing water below the dew point. We recommend evaporative cooling systems that cannot, by nature, produce water that is too cold. Our warranty does not cover damage due to condensation.

Relative Humidity @20°C	Dew Point °F	Dew Point °C
30%	34.9°	1.6°
40%	41.5°	5.3°
50%	47.8°	8.8°
60%	53.1°	11.7°
70%	58.1°	14.5°
80%	61.7°	16.5°
90%	65.1°	18.4°
100%	68.0°	20.0°

Water Quality

The following table outlines several parameters necessary for the cooling water's quality.

Quality Summary

Parameter	Specification	Recommendation
Resistivity	30kΩ - 2MΩ	100kΩ
Hardness	<100 ppm	<10 ppm
Particulates	<1000 microns	<200 microns
pH	7.0 - 8.5	7.5
Additives	Only pure ethylene glycol allowed	

Resistivity

Water that has resistance lower than the specification has excess dissolved salts. This allows electrical conduction through the water hoses. The electrical current carries with it, metal ions from the components. This is similar to what happens during electroplating processes. This loss of metal will lead to eventual water leaks in the positive area, and clogged passages in the negative area. The effects can be offset be using longer water hoses, thus increasing the effective resistance between components. We designate minimum hose lengths inside our equipment to allow a life span of greater than 20 years, when used with the minimum allowable water resistance ($30k\Omega/cm^3$). The following chart illustrates the case when using a ¼ inch hose. We have established that 5 grams of metal loss would represent the end of life for a ¼ inch hose barb.

Material	Coulombs required to move 5 grams	Microamps required to deliver stated coulombs in 20 years	Minimum hose length in feet A × volts × diameter^2
Copper	15183	24	A = 0.231
Stainless Steel	TBD	TBD	A = TBD

In rare cases where the customer cannot meet the minimum water resistance, or in cases where minimum hoses lengths cannot be met, sacrificial targets can be used in the water system. These are replaceable inserts inside the water system designed to corrode while leaving the permanent parts of the water system intact. We try to avoid using targets, except as a "last resort". Our experience shows that although the positive target does in fact, corrode away, the negative target is subject to clogging. Even at best, the targets would require periodic replacement. The better alternative is to improve the water quality up to the point where targets are unnecessary.

Water that has resistance higher than the specification (hi-grade de-ionized water) is not acceptable. Although this water is very "pure", this is also an unnatural state for the water. The water seeks ions from the plumbing materials and causes corrosion.

Hardness

Water that has hardness greater than 100 ppm has excess mineral content. The ability of water to hold dissolved minerals is somewhat dependent upon the water temperature. Because the temperature increases during the time it's inside the power supply, it leads to the depositing of the minerals inside the cooling paths. These minerals form an insulating coating that inhibits the proper conduction of heat.

Particles

Particles larger than these can “fall out” of the water in areas of low velocity and settle inside the units. Smaller particles are kept in suspension and exit the power supply with the water flow. After long-term exposure to “dirty” water, the power supply could overheat due to clogged water paths. In addition, many types of water flow switches have small orifices, particles can lodge in them and cause malfunction, (either stuck ON or stuck OFF).

pH

pH is the measure of acidity or alkalinity of the water. The ideal water would be slightly toward the alkaline side of neutral, about 7.5

Additives

Pure ethylene glycol is the only additive we allow in the water system. Note that automotive antifreeze contains additives and therefore cannot be used. The only reason for using glycol is for freeze protection. Because glycol does not absorb heat as well as water, a power supply will operate slightly warmer when glycol is used. We suggest no more than a 30% mixture of glycol be used. Following is a table showing freezing points for different mixtures of glycol and water.

Percent by Weight	Percent by Volume	Freezing Point F°
0	0.0	32.0
5	4.4	29.4
10	8.9	26.2
15	13.6	22.2
20	18.1	17.9
25	22.9	12.7
30	27.7	6.7

Materials

Inside our power supplies, a variety of different materials are exposed to the water. These materials have been chosen for their inert properties. They will last for many years in direct contact with the water. In some cases the facility's water quality department may want a listing of these materials, they include:

Copper
Brass
Silver solder
Vinyl Hose
Neoprene
Stainless Steel (316)
Buna N

It is expected that the facility's plumbing system will use many of the above materials. Although not used inside our power supplies, polyvinyl chloride (PVC) plumbing material is compatible with our power supplies.

Certain materials are specifically prohibited from the plumbing system. These include:

Carbon steel
Galvanized steel
Aluminum
Iron

Water Connection Size

Connections to the power supply's water fittings can be by piping or hoses. Two criteria must be considered when selecting the size of the pipes (or hose).

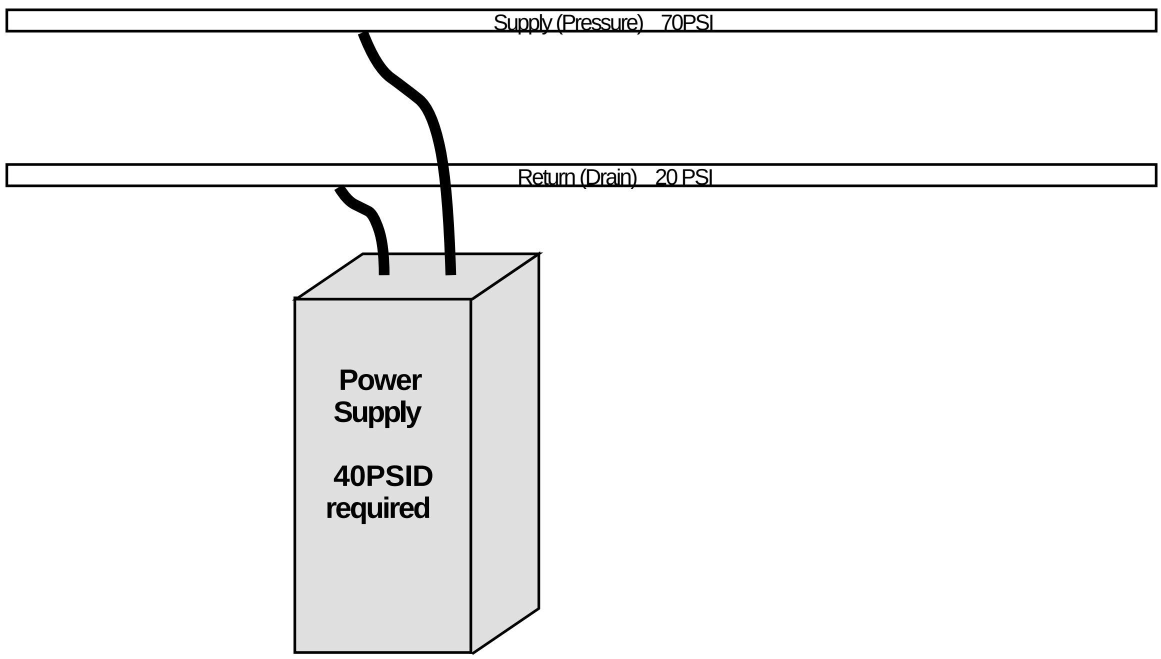
Velocity

The velocity of the flowing water must be less than 10 fps (feet per second). This is necessary in order to minimize plumbing noise and to reduce the effects of water "hammer". Water hammer is the pounding effect that happens when a valve is closed and the inertia of the moving water is suddenly stopped. The following table shows the maximum flow rate allowable for different sizes of piping.

Nominal Size	Actual Diameter	Flow rate (GPM) for 10 FPS
¼ hose	0.250	1.5
¼ pipe	0.364	3.2
½ hose	0.500	6.1
½ pipe	0.622	9.5
¾ hose	0.750	13.8
¾ pipe	0.824	16.6
1 hose	1.000	24.5
1 pipe	1.049	26.9
1¼ hose	1.250	38.3
1¼ pipe	1.380	46.6
1½ hose	1.500	55.1
1½ pipe	1.610	78.8
2 hose	2.000	97.9
2 pipe	2.067	105
3 pipe	3.068	230
4 pipe	4.026	397

Pressure Drop

Additionally, any pipe (or hose) will have a pressure drop from end to end depending upon the flow rate and its length. There are also effects from water temperature, inside roughness of the pipe, and vertical rise, but these effects are minimal for the purpose of this paper. The amount of pressure drop that can be allowed in the connections depends on the amount of system pressure in excess of the amount required by the power supply. In the following example, the pressure drop must be kept below 5 PSI per hose.

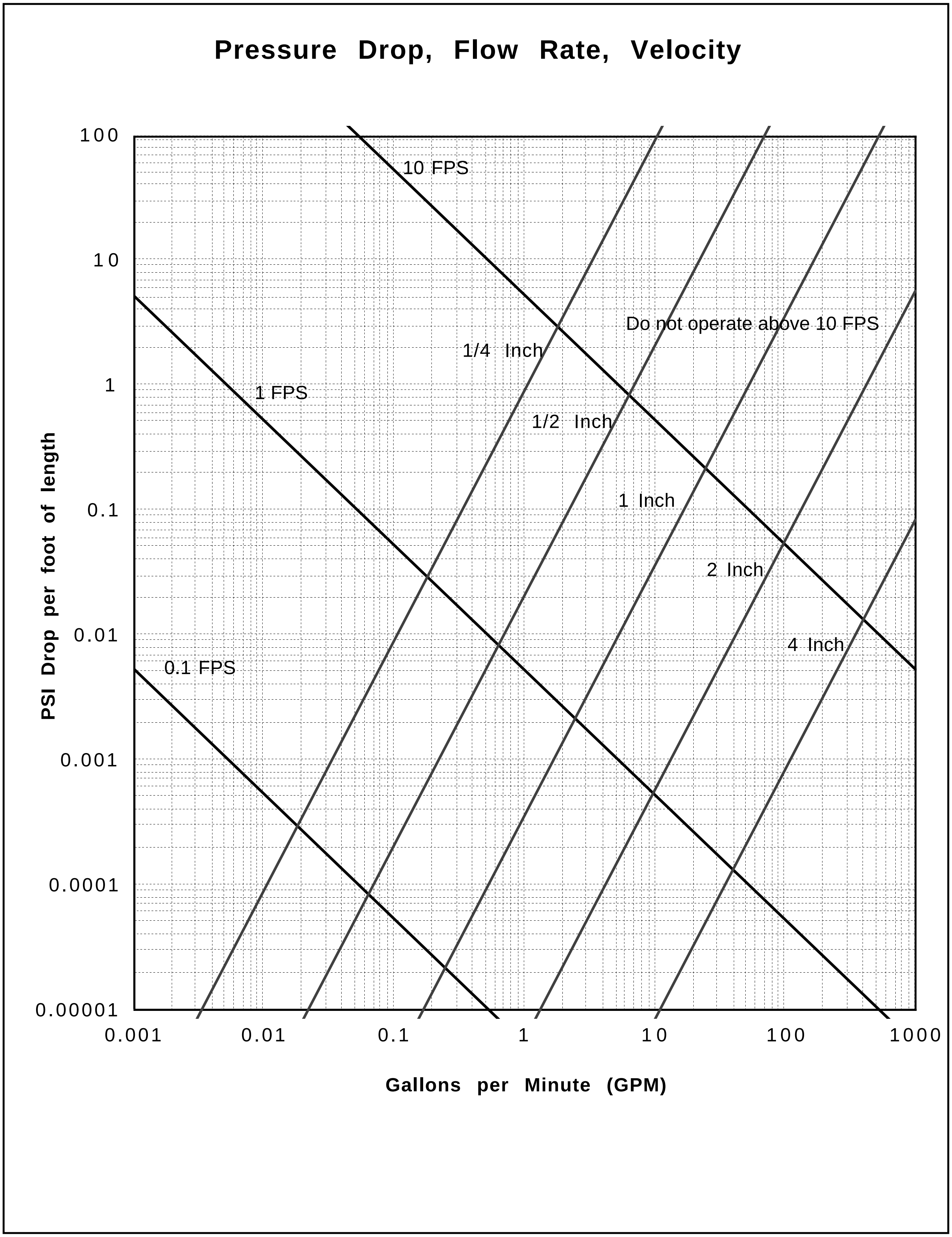


Pressure between Manifolds is 50PSID
Pressure required across power supply is 40 PSID
Allowable pressure drop across hose is 50-40 = 10
Or 5 PSI per each hose

In some cases, the required hose size might have to be larger than the velocity table would otherwise indicate. It is also conceivable that some cases would require larger piping than the power supply's water fittings. In those cases, pipe reducers can be used to connect to the larger hoses.

The following graph shows the relationship between pressure drop, pipe size, flow rate, and velocity.

Graph



Pressure Drop, Flow Rate, Velocity
100
10
1
0.1
0.01
0.001
0.0001
0.00001
0.001
0.01
0.1
1
10
100
1000
PSI Drop per foot of length
Gallons per Minute (GPM)
10 FPS
1 FPS
0.1 FPS
1/4 Inch
1/2 Inch
1 Inch
2 Inch
4 Inch
Do not operate above 10 FPS

Metric Conversions

For those people using metric units of measurement, the following factors can be applied.

To convert from	to	multiply by
GPM	LPM	3.785
GPM	LPS	0.0631
PSI	kG/cm^2	0.07031
PSI	millibar	68.95

Summary

The cooling water used for the power supply is an important part of both the immediate cooling needs as well as the long-term reliability of the unit. The water system should be designed and maintained to provide cooling water within these specifications.

Flow Rate	Per spec plate mounted on power supply
Minimum Differential Pressure	10 PSID
Minimum Static Pressure	0 PSIG
Maximum Static Pressure	100 PSIG
Maximum Inlet Temperature	35°C
Minimum Inlet Temperature	Dew Point
Resistivity	30kΩ - 2MΩ
Hardness	<100 ppm
Particulates	<1000 microns
pH	7.5 - 9.5
Additives	Only glycol allowed

Specific questions regarding this paper, or about power supply cooling can be answered by our engineers.

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