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HVAC Tech Note #1 – December 2002

Reading Pump Head for Fluids Other Than Water at 60 ºF

It is common to estimate pump performance by using a pressure gauge or gauges to measure the pump head in psi, convert it into feet of head, and then refer to the pump curve. The conversion factor normally used is 2.31 feet of head per psi. That conversion, however, is only accurate for water at 60º F. If the water is hot and/or the fluid is a glycol solution, the conversion factor must be adjusted for the fluid specific gravity. If you don't do that, you can be out by several feet of head and will get a false flow reading. For a pump with a flat curve, the error can be a whopper!

For a more detailed explanation, an example, and correction factors, see the 1999 ASHRAE Applications handbook, pages 36.11 and 12.

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HVAC Tech Note #2 – January 2003

Improving the Performance of Small Direct Drive Squirrel Cage Fans

Small direct-drive forward-curved squirrel cage fans are widely used in packaged HVAC units. If you have an installation that's short of airflow, here's a tip that may get you out of a jam. These small wheels have different performance curves with motors of different horsepower, even though the nominal rpm is the same. This is because larger horsepower motors will have less slip, and will run closer to the motor nameplate rpm; higher rpm equals more airflow. Since most fractional hp motors of the type used on these fan wheels are universal motors with the same frame size, a simple motor switch may overcome the shortfall in fan performance. If you can get an OEM fan curve, you should be able to determine this. Check to make sure the wheel does not already have the largest horsepower it is rated for and that the electrical components used to control the motor are adequate for the higher amperage draw of the larger motor.

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HVAC Tech Note #3 – February 2003

Why Do Conventional Expansion Tanks Waterlog?

Conventional expansion tanks trap a cushion of air in the top of the tank; the system fluid and the air are in contact with each other. If these tanks fill completely with water, or ‘waterlog’, there is no room for fluid expansion and the system pressure can increase beyond the relief valve threshold. There are two main reasons why this can happen.

The first is one-pipe gravity flow between the system and the tank. Hot water from the system flows up to the tank and slowly absorbs the air until the tank is filled with water. A sure sign that this is happening is a hot tank. This situation can usually be corrected by installing an airtrol fitting on the tank. These fittings are designed to prevent gravity flow, and provide several other benefits as well.

The second cause is the sight glass that is quite often installed on this type of tank. The top gasket on the glass, being above the normal waterline, dries out and starts to allow the air to get pushed out of the tank by the system pressure. The solution is simple – either remove the gauge glass altogether or valve it off.

These tanks should operate without attention for years with the initial air charge.

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HVAC Tech Note #4 – March 2003

Accurately Setting Heat Anticipators

Many thermostats have adjustable heat anticipators that must be set to match the current in the control circuit to provide reasonable operating cycles of the equipment being controlled. As the control circuit current draw is usually quite low, it is difficult to accurately measure with even a digital clamp-on ammeter. Here's a trick that will allow you to accurately measure the current and set the anticipator even if you are using an old style analog amprobe.

Use some thermostat wire to make a coil that has exactly 10 loops in it. Place the coil in the control circuit and measure the current by clamping the ammeter around the coil. The coil will amplify the current by a factor of 10, so divide the ammeter reading by 10 to get the actual current draw. For example, if the ammeter reading is 9 amps, the correct setting for the anticipator will be 0.9 amps.

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HVAC Tech Note #5 – April 2003

Sizing Check Valves

We've all heard chattering check valves in HVAC systems, and it will almost always be because the valve is too big. All check valves require some minimum pipe velocity to keep the valve disc or flapper fully open. Valves that are too big will be noisy in operation, and will experience premature wear of the moving parts.

The Crane Technical Paper No. 410 lists formulas for calculating the minimum pipe velocity required for full disc lift in different types of check valves. For example, standard threaded swing check valves require a minimum pipe velocity equal to 35 times the square root of the specific volume of the fluid. For water, that equates to just over 4.4 fps, or slightly higher than the design guidelines used for small diameter pipe in HVAC systems. Use a valve smaller than line size to get longer valve life and quieter operation. Quite often there will be some other device in the system smaller than line size, like a pump or control valve. Placing the check valves adjacent to these components will reduce the number of fittings required to accommodate the correct size of valve.

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HVAC Tech Note #6 – May 2003

Air in Water

A significant amount of air can be added to a closed hydronic system with make-up water from a domestic supply. Fig. 3 on page 12.4 of the 2000 ASHRAE Systems Handbook graphs the solubility of air in water based on pressure and temperature. This graph shows that at 50º F and 60 psig an air/water solution can contain about 11% air by volume.

If, however, the water is stored at room temperature in a packaged system feeder tank that is vented to atmosphere (0 psig), the solution will contain less than 2% air by volume. This sharply reduces the amount of air and corrosive oxygen that gets added when make-up water is required for the life of the system. As side benefits, the water stored in the feeder tank can be pre-treated, and there need be no connection between the hydronic and potable water systems, eliminating any potential for cross-connection and the requirement for backflow prevention.

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HVAC Tech Note #7 – June 2003

Automatic Air Vents

Automatic air vents are only truly effective when installed on an air separation device. Air gets carried along in a piping system by water velocity; air separators slow the water down to release the air and get it out of the system. When an automatic air vent is installed in the piping where water velocity is high, the air will get carried right past the vent. These vents will likely only release air when the pump is off. Since almost all automatic air vents will eventually leak, installing a lot of them usually only creates maintenance problems.

Use manual air vents at the high spots for initial purging, and a good quality industrial air vent on the air separator. If automatic vents are used at high spots to make the initial venting easier, they should be valved off during normal operation to avoid potential leaks. This will also prevent them from allowing air to enter the system if it should go sub-atmospheric for any reason.

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HVAC Tech Note #8 – September 2003

Pre-Charged Expansion Tank Hints

Pre-charged expansion tanks contain a factory pre-charge of air (usually 12 psig) that is separated from the waterside of the tank by a membrane. Here are some hints that may help to diagnose and/or avoid problems.

The air charge in the tank has to equal the cold fill pressure required for the system.

There must be no pressure on the waterside of the tank when checking or adjusting the air charge.

Check the air charge on new tanks before installation, as the air may have leaked out. If it has, check the Schrader air-charging valve. It may just need tightening.

Use oil-free air to avoid the possibility of damaging the membrane.

Don't expose small tanks to city water pressure when filling and purging the system.

If you get water out of the air charge valve, the membrane is leaking. Bladders can usually be replaced; diaphragm tanks cannot be repaired and the entire tank must be tossed.

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HVAC Tech Note #9 – October 2003

Erosion in Piping Systems

High water velocities can erode pipe, fittings and components, but it's not the water itself that does most of the damage. The following is from the 2001 ASHRAE Fundamentals Handbook, page 35.4:

> *'Erosion in piping systems is caused by water bubbles, sand, or other solid matter impinging on the inner surface of the pipe. Generally, at velocities lower than 10 fps, erosion is not significant as long as there is no cavitation. When solid matter is entrained in the fluid at high velocities, erosion occurs rapidly, especially in bends.'*

To prevent damage from erosion, keep the fluid in closed systems clean and air-free. Eliminate cavitation in pumps and control valves by ensuring that maximum flow rates are limited to design values and that proper system pressurization is maintained. In other applications where it is not possible to completely eliminate the elements that cause erosion, e.g. domestic hot water recirculation, control the flow to keep velocities low and prevent premature failure of the pipe and fittings.

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HVAC Tech Note #10 – November 2003

Liquid Gold

After water has been in a closed hydronic system for a while, it gives up all its nastiness. The oxygen in the entrained air oxidizes with the ferrous components, and any other contaminants get used up as they form scale or otherwise react with the system. The water becomes 'dead', and in many instances will also have been chemically treated. It may look bad when it's drained out, but as far as the system is concerned, that 'dead' water is liquid gold.

If it's not contaminated in some way, any of this fluid that is drained for service reasons should be put back into the system instead of being dumped and replaced with 'live' untreated raw water. This is particularly important if the system fluid is an anti-freeze solution, or if treatment chemicals in the fluid represent an environmental hazard.

Installing a packaged system feeder for system pressurization will make re-injecting this liquid gold easy – just pour it back into the feeder tank.

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HVAC Tech Note #11 – December 2003

Terminal Unit Piping

There are some simple rules that should be followed when piping terminal units in hydronic systems that use fluid:

Pipe flow from the bottom up so that the water flow carries the air out of the terminal unit; especially important if the water flow passages are large and the water velocity is low, as in heat exchanger shells.

Pipe so that the heating/heated mediums are hot-to-hot and cold-to-cold; for coils, easy to remember as air in/water out. This will maintain the highest average temperature difference between the mediums and allow the terminal to perform at design. This is particularly important for chilled water coils.

When multiple terminals are in parallel, as with stacked coil banks, ensure equal flow through each individual terminal with piping design or flow balancing devices.

Here's hoping that the whole world, you included, has a better year in 2004!

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HVAC Tech Note #12 – January 2004

Glycol

Automobile manufacturers use glycol solutions in their engine cooling systems regardless of where their vehicles are sold for two main reasons – corrosion protection and a higher boiling point. Freeze protection is a bonus. In HVAC systems, freeze protection is the primary reason we use glycol, but there are important guidelines that should be followed for a successful glycol installation.

- Make sure the system is clean before the glycol is installed.
- Use high quality mix water or buy a pre-mixed solution. (If you've got a jug of Prestone at home, read the instructions. They don't want you to mix that with crappy water, either.)
- Use a packaged feeder rather than a raw water connection for makeup and pressurization.
- Follow the manufacturer's recommendations for minimum concentrations. Very low concentrations may not provide adequate inhibitor strength.
- Check the concentration, pH, and inhibitor strength annually.

These are the main things; for an excellent technical article with more detail on the use of anti-freeze in HVAC systems go to www.raypak.com/commframe.htm.

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HVAC Tech Note #13 – February 2004

Single Phase Motors

Most people don’t like to use single-phase motors over about ½ hp for various reasons, but sometimes there’s no 3-phase power available. Some manufacturers of variable frequency drives (VFD’s) now have small, reasonably priced micro drives designed for single-phase input power that can solve this problem.

All VFD’s produce a 3-phase output to the motor, even if the input is single phase. This means that in addition to acting as the motor starter, a single phase input micro drive also acts as a phase converter, allowing the use of preferred 3-phase induction motors in a lot of applications. In HVAC, there is also the added benefit of easily allowing fans and pumps to be ‘trimmed’ to match the system requirements (assuming, of course, that the system in question is balanced). This saves energy and improves performance by reducing system differential pressures.

If you do this, ensure that the manufacturer you select is familiar with this application, as the VFD will have to be over-sized.

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HVAC Tech Note #14 – March 2004

Thermostatic Steam Traps and Water Hammer

Most thermostatic steam traps are balanced-pressure traps. They have a bellows filled with an alcohol/water mixture that has an atmospheric boiling point lower than water. As the steam pressure in the trap changes, however, the boiling point of the mixture in the trap bellows changes with it. These traps will always discharge condensate at about 20 ºF lower than the temperature of the steam at the inlet to the trap.

If the steam pressure/temperature is high, say 10 psig and 240 ºF, the traps will discharge condensate at about 220 ºF. This condensate will flash back to steam in atmospheric condensate return lines and cause problems, one of them being water hammer.

So, if you've got thermostatic traps and water hammer, try turning the steam pressure down. All that's required in most steam terminal units is 1 psig (215 ºF).

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HVAC Tech Note #15 – April 2004

Water Velocity and Heat Transfer

In terminal units like wallfin element and coils that have finned tubes, the effect of water velocity on heat transfer is minimal. According to the 2000 ASHRAE Systems Handbook (page 32.4) the heat output of finned-tube element varies little over the range of 0.5 to 3.0 fps (in a ¾" copper element, 3.0 fps is about 4.5 USgpm). They go on to say, however, that at velocities below this range, output is difficult to predict accurately and that small changes in actual flow have a significant effect on output. The minimum recommended tube water velocities in the same handbook for heating coils is 0.5 fps (page 23.4) and for chilled water coils 1.0 fps (page 21.6).

Problems can arise in terminal units that have low design water velocities that are further reduced by modulating control valves. A 'hair-trigger' response can result at low loads when minor changes in flow, either because of a load change or a change in delta P across the branch, cause dramatic changes in the terminal output.

It's a good idea to be aware of how low the water velocity might actually have to be in any terminal unit that has variable flow.

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HVAC Tech Note #16 – May 2004

Non-Freeze Steam Coils

'Non-freeze' steam coils (which, believe me, *can* freeze) have a tube-in-tube design. The inner tube is designed to distribute the steam evenly along the length of the coil. The outer tube collects the condensate and returns it to the manifold. Most manufacturers use a 3/8" inner tube, and offer either a 5/8" or 1" outer tube.

This type of coil is commonly used in applications where the entering air temperatures are low and the temperature rise and condensate loads are high. If a 5/8" outer tube coil is used in these applications, there is very little room between the inner and outer tubes to handle the high condensate loads. Condensate can back up and prevent steam from getting all the way down the coil.

If you have a high load on a non-freeze steam coil, use a coil with a 1" outer tube. It will be more expensive, but it will work better.

For a more detailed article with specific recommendations, go to www.usacoil.com/newsletters/mar.pdf.

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HVAC Tech Note #17 – June 2004

Balancing DHWR Systems

The flow required in branch returns of domestic hot water recirculation (DHWR) systems need only be high enough to overcome the thermal losses in the piping. Unfortunately, these systems are rarely balanced and some branches overflow while others get almost no flow.

In the branches that overflow, high water velocities erode the fittings. In some cases, erosion can even occur in straight runs of pipe immediately downstream of connectors if the fitter has not properly reamed the edges of the tubing.

The branches with inadequate flow may not have hot water immediately available, and users may have to run the water for a while. This time lag can be aggravated if the plumbing fixtures have flow restriction devices like low-flow aerators.

Automatic flow limiting valves can solve these problems by controlling the flow in DHWR branch returns to low values, e.g. 1.0 USgpm in ¾" tubing, water velocity less than 1 fps. The system will be balanced, with hot water readily available at all points (saving water and energy), and the low velocity will not cause any erosion.

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HVAC Tech Note #18 – September 2004

One-Pipe Gravity Heating

In the early days of hot water heating, they didn't use circulating pumps. Flow was achieved by gravity – buoyant hot water flowed up through large pipes into large radiators. There it was cooled, became more dense, and dropped back to the boiler in the basement. No moving parts!

We don't design gravity circulation systems anymore, but it is possible to get unwanted heat transfer in modern systems because of gravity flow. In fact, this can happen within a single pipe. Buoyant hot water can flow in one direction along the top of the pipe, with cooler water flowing in the opposite direction along the bottom of the pipe. If this happens, heat transfer will continue from a terminal even if the control valve is closed – very mysterious.

Prime conditions for this are high water volume terminal units at the same or higher elevation than the mains, with large diameter feed pipes and the control valve on the return. Example – a run of 1-1/4" wallfin element. It can usually be prevented by installing a check valve in the vertical riser to the terminal, or by moving the control valve to the supply side.

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HVAC Tech Note #19 – October 2004

Tempered DHW Recirculation

Thermostatic mixing valves are used to temper the supply of domestic hot water to plumbing fixtures. In many installations, a recirculation pump is installed to keep the temperature up in the entire system during periods of low or no demand.

If all of the piping is well insulated, it will take some time during periods of no demand for the water temperature to drop in these systems. Because the temperature is not dropping, the mixing valve will not be required to admit any hot water and the valve will not be 'working'. These valves perform better and last longer when they are 'working' all of the time.

It's a good idea, therefore, to leave the insulation off a stretch of the recirc piping somewhere where it won't cause a problem. The minor loss of heat from this pipe will require the valve to modulate during periods of no demand to meet its setpoint. This simple step will improve the operation of the system and extend the life of the valve.

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HVAC Tech Note #20 – November 2004

A Slow Death

A leak of one drop per second represents a loss of about 200 US gallons of fluid per month (about 2.6 million drops!). It's not hard to imagine having a leakage rate of that magnitude in large systems that have lots of valve packing, pump seals, and mechanical piping connections. In addition to the cost of the fluid, that can add up to a lot of wasted energy in any system where the fluid is being heated or cooled.

There is another impact in closed systems – a slow death from corrosion and scale caused by raw water makeup required to maintain system pressurization. Raw water makeup, with its oxygen and other undesirables, is usually the only source of contamination available to closed hydronic systems. That's why it is so important to keep closed systems tight, and to quickly detect and repair leaks when they inevitably develop. Unfortunately, small leaks can be very hard to detect.

Packaged system feeders provide excellent leak detection; if the fluid level in the reservoir is going down, the system is taking fluid. A packaged feeder also gives the operator control over what is used for makeup fluid, which can be a big advantage in areas where the raw water supply should not be used for makeup.

Our thanks to David Whitfield (Johnson Controls Edmonton) for sending me a note on the impact of leaks and providing the basis for this tech note.

And, we hope that you have a safe and happy holiday season.

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HVAC Tech Note #21 – December 2004

Pressure Loss in Closed Systems

Closed hydronic systems lose pressure for one of three reasons:

Venting air – this is normal in systems with automatic air vents, primarily during startup

Leaks – this is not normal and should be avoided (see HVAC Tech Note #20)

Fluid is drained for service or some other reason.

Because water and other fluids used in closed systems are incompressible, a very small loss of fluid can result in a complete loss of pressure. For example, in order to add 1% more water to a full, closed vessel, you would have to apply a pressure of about 3,000 psig. Conversely, if you were able to accomplish that, you could drop the pressure in the vessel from 3,000 psig to 0 psig be releasing only 1% of the water. Note – do not try this at home!

The cold water in a freshly purged and filled heating system will be about 2-3% dissolved air by volume. Added to that will be any trapped free air that was not caught by the purging process. These systems, then, may require as much as 3-5% of their total volume made up to get through the venting process.

Once all of the air is vented, the pressure loss and requirement for makeup fluid in a tight system should be very low. However, loss of pressure for whatever reason can cause several undesirable things to happen, so it's important that adequate pressurization be maintained.

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HVAC Tech Note #22 – January 2005

Sequencing Parallel Natural Draft Boilers

Although it is becoming common for boilers to have dedicated (primary) circulators, there are still parallel boiler systems that have primary only pumping, which means all of the boilers are flowing all of the time. If the system is also variable flow (mostly 2-way control valves), it's possible that during periods of low demand the flow through any boiler may be lower than is required to handle the full boiler output. With low mass boilers, this can create all kinds of problems like noise, high limit trips, and even physical damage.

If the boilers have stage or modulating firing it is a good idea to bring all of the boilers on at low or part fire before any boiler is staged to high fire. By the time it is necessary to have any boiler on high fire the demand and the flow should be up and every boiler should have adequate flow. And, since any unfired natural draft boiler that has constant flow is radiating heat up the flue when it is off, staging the boilers this way shouldn't make the plant less efficient.

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HVAC Tech Note #23 – February 2005

Troublesome Condensate Transfer Pumps

Many small condensate transfer units have pumps that are designed to return condensate to low pressure steam boilers. Accordingly, they are rated at 15-20 psi (35-45 ft. head) discharge pressure. In many installations, however, they are only pumping condensate up a few feet to another vented tank through a piping system that has a low head loss. If they are not throttled they will run way out on the pump curve and over-pump.

When this happens, there will be trouble. The operating cycles of the pump will be very short, sometimes lasting only a few seconds. This can put a lot of stress on the mechanical and electrical components. There will also likely be cavitation that can destroy the pump impeller. Limiting the flow on these pumps to the design value moves the operating point back up to the sweet spot on the pump curve. The operating cycles will be the proper length, the pump will quiet down, and maintenance requirements should be reduced.

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HVAC Tech Note #24 – March 2005

Keep it in the Shade

The efficiency of air-cooled condensing equipment can be improved by locating it so that it is shaded. ARI rating conditions for central system condensing units typically used in residential applications are at 95 °F air temperature entering the condenser. If the air entering the condenser is reduced to 85 °F, the total cooling capacity increases by about 7% and the compressor power required drops by about 4%. Conversely, if the air temperature is 105 °F (not unusual for roof mounted units) the total cooling capacity decreases by about 7% and the compressor power increases by about 13%. *(These numbers are based on published performance for a Carrier model 38AK008 condensing unit at 45 °F SST.)*

It's well worth it, then, to think about the location of this type of equipment and take advantage of any shade available. It may even make sense to provide shading if no natural option exists. The equipment will also last longer running in less severe conditions.

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HVAC Tech Note #25 – April 2005

Rangeability & Turndown Ratio

Modulating control valves have an operating characteristic called 'rangeability factor'. The rangeability factor of a control valve is the ratio of the maximum flow to the minimum controllable flow. This characteristic is measured under laboratory conditions with a constant differential applied to the valve only. A rangeability factor of 10:1 indicates that the valve alone can control to a minimum flow of 10%.

The installed ability of the same valve to control to low flows is the 'turndown ratio', calculated by multiplying the rangeability factor times the square root of the valve authority. Hence, a valve that has decent rangeability but poor authority will not have good capability to control down to low flows, and may only be able to provide 'on-off' control over a good part of its flow range.

Many globe style HVAC control valves do not have high rangeability factors; a major manufacturer lists values from 6.5:1 to 25:1 for their range of globe valves from ½" to 6". Most characterized ball control valves, however, have very high rangeability factor (usually >150:1), making them a better choice for some HVAC modulating control applications.

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HVAC Tech Note #26 – May 2005

Charging Pressure System Tanks

This tip will work for any pressure demand water system and may be particularly helpful to anyone who has a system like that in a cottage. These packages typically have a pump, a pressure switch, and a pre-charged pressure tank, sometimes referred to as a drawdown tank. It's not uncommon for some of the air charge in the tank to be lost over time through minor leaks in the air charging valve and/or migration through the diaphragm.

In order to maintain consistent water pressure, maximize the drawdown capacity of the tank, and minimize pump cycles the air charge in the tank should be adjusted to about 2 psi below the cut-in setting on the pressure switch. To check this, start with the system up to pressure and the pump off. Slowly draw water from the system while watching the pressure gauge and note the pressure when the pump starts – the cut-in pressure. Then, shut the pump off and draw or drain water until there is *no pressure on the water side connection to the tank (very important!)*. You can then check the pressure of the air charge in the tank using a tire gauge and adjust it if necessary.

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HVAC Tech Note #27 – September 2005

Equalizing Sump Water Levels

If two or more sumps (cooling towers for example) are installed in parallel it is common to have equalizing lines connecting them so that they all operate at the same water level.
The only differential pressure available to push water from sump to sump is the difference in the sump water levels. In some applications this static head differential may only be on the order of a few inches of water column before the water level in the high sump reaches the overflow outlet. For example, a 6' length of 2" steel pipe with a ball valve installed between sumps will only flow about 30 USgpm from one sump to the other if the difference in the sump water levels is 4". If equalization lines are not properly sized to handle the required flow at low differentials, the high sump may flood and lose water (and possibly chemical) out the overflow. This can be an expensive problem. Increasing the size of the equalization line, including the entry and exit openings into the sumps, will keep the sumps close to the same level.

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