Where's The Chilled Water?

TURNQUIST

About The Author

Plus a little extra ....

Jim Turnquist began his involvement with chilled water cooling and air conditioning systems in the late 1960's, working for a distributor of Servel's water-cooled absorption chillers. He had a first hand introduction to the newly developed gas-fired, air-cooled, absorption cycle chillers when they were introduced. Over the next 30 + years, Jim devoted his time specializing in this technology and has become an expert on designing, installing, servicing, repairing and maintaining these chillers. In the late 1990's, Jim provided consultation for a new company who was developing new absorption cycle technology for chilled water systems and he even assisted them in the writing of their product manuals.

Jim's purpose for the writing of this book, is to provide an open door to anyone who may have even the smallest interest in chilled water cooling, to expand upon its effectiveness in today's world and to hopefully excite some hydronic heating people to cool their heels, with a little temperature reversing logic. This book, if you care enough to buy it and read it, provides years of factual field experience and some other neat things which cannot be found in any publication. This book stands alone, being specifically tailored & opinionated to chilled water cooling systems.

And that's a fact, J Israel Turnquist, Author.

Singularly responsible for this book's good and bad content, and maybe even a few smiles you may find along the way.

Other Books by this author; "Thirty Years of Gas-Fired, Air-Cooled, Absorption Cycle Cooling". 520 pages. Everything, Anyone, would ever care to know or learn regarding Servel™ Chillers.

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COVER

Courtesy Of;

The Hundreds
Of Satisfied Customers,

Who Are Enjoying Their Comfortable

Hot Water Heating Systems !

And Those Who Have Found

A New & Exciting Experience

In Chilled Water Cooling Systems !

JIT Productions

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INTRODUCTION

Radiantologists[1], like no other persons, know that the science of Hydronictology[2], has existed for ages. Hydronticists[3], first mastered the application of hot water being applied as an efficient and effective heating source. Radiantologists have now taken Hydronictology to a new and exciting level. Through the design and addition of numerous new Radiant Heating Devices (cement, wood, tile, carpet and metals), Radiantologists have developed a method of incorporating Tubing (specially designed and manufactured tubing I might add) into these devices to create a New and Exciting World of Radiant Panel Applied Heating.
The Question Still Remains ..... "Where's The Chilled Water ?"

Radiantologists and Hydronticists, like no other persons in the HVAC Industry, know and understand the importance of; 1- A Good and Proper Application. 2- The necessity of a Properly Designed System. 3- The requirement for a Properly Sized Piping (tubing) System. 4- The requirement for a Properly Sized Pumping System. 5- The requirement for Properly Sized and Applied Flow Control Items. 6- The requirement of Properly Installing a System, as Designed, and as Recommended by a Manufacturer. 7- And last, to Properly Maintain any Installed System.

Boy, it sounds to me like you've just installed a "Chilled Water System" ? So .... why aren't you installing Chilled Water Cooling Systems ?

There are a lot of manufacturers today who are producing stand-alone chilled water cooling units. These Units (Chillers), only require water piping (copper/pvc), gas piping (some chiller types[4]) and electrical wiring to be connected to them, and then to their load zone distribution systems. Hey, that sounds like a boiler's requirements to me. There are also many manufacturers today who are producing stand-alone air distribution devices (no duct work). Every year, new and exciting air distribution units are introduced which offer; 1- simplicity of design. 2- ease of application and connection. 3- diversity and flexibility of use. 4- aesthetic pleasure for the consumer. SO, ... "Where's The Chilled Water ?"

1- Rá-dee-an-tol-ô-gists; radiant wetheads who know what they are doing.
2- Hï-dron-ik-tol-ô-gee: the ability to put hot water to work for a useful purpose.
3- Hï-dron-tì-cists; first wetheads to discover hot water's useful purpose.
4- There are two (2) basic chiller types; Electric Chillers (no gas) and Gas-Fired Chillers with minimal electrical needs.

DEDICATION

THIS BOOK IS DEDICATED TO THE RADIANT INDUSTRY

THIS BOOK IS DEDICATED TO
THE RADIANT PANEL ASSOCIATION
AN ORGANIZATION WHICH PRIDES THEMSELVES IN PURPOSE,
FUNCTIONALITY, AND ENDLESS EDUCATIONAL PROGRAMS,
FOR YOU AND ME, TO BE THE BEST WE CAN BE,
IN TODAY'S, HEATING AND COOLING INDUSTRY.

THIS BOOK IS DEDICATED TO THE "EMRPA".
THE EASTERN MICHIGAN RADIANT PANEL ASSOCIATION.

NO WHERE IN THIS WORLD HAVE I MET SO MANY NICE INDIVIDUALS,
WHO ARE WILLING TO SET ASIDE BUSINESS DIFFERENCES AND COMPETITION,
FOR THE BETTERMENT OF ALL, HAVING A COMMON INTEREST,
IN A GROWING AND EXCITING INDUSTRY.

THIS BOOK IS DEDICATED TO YOU,

THE WETHEADS OF THE WORLD !

Chapter 1- "Where's The Chilled Water ?"

Chilled water cooling systems were among the first systems used for comfort air conditioning. In 1915, Willis Haviland Carrier, along with other investors, started the Carrier Corporation and became one of the first companies to produce and manufacturer large tonnage, water cooled, absorption chillers. In 1939, Arkla-Servel introduced their first absorption chiller. Many of these first chillers were operated by steam. There are many companies manufacturing large tonnage, water-cooled chillers today and many of them operate by natural gas, steam and even hot water.

In the early 1960's, the Bryant® Corporation introduced the first small tonnage, gas-fired, air-cooled chiller to the HVAC industry. These chillers were available in 3, 4 and 5 ton sizes. Two other companies also manufactured small tonnage, gas-fired, air-cooled chillers during the 1960's; The Whirlpool® Corporation and Arkla® Industries. Thousands of these chillers were installed in residential homes and small commercial office buildings. By 1975, only Arkla® Industries were continuing to manufacture these chillers.

Today, there are many companies who manufacture and produce large tonnage chillers and small tonnage chillers which are totally operated by electric power. Electric operated chillers can be of the water-cooled variety and they can also be air-cooled. Large tonnage chillers are typically water-cooled, while small tonnage chillers can be either water-cooled or air-cooled. Small tonnage water-cooled chillers are typically used for special purpose dedicated cooling systems (e.g. process cooling, computer rooms, etc.). The cooling unit can be incorporated right with the air distribution system or water circulation system and they can be located in or near the area (load zone) being cooled. Air-cooled chillers must be located outdoors and chilled water piping must be installed from the chiller to the load zone.

Small tonnage chillers being adapted for comfort air conditioning were not a popular item for contractors initially, due to first costs. The high initial purchase cost made these chillers prohibitive (or contractors just didn't want to pay this much). The contractors, who did purchase and install these small tonnage chillers, knew the secret of chilled water cooling and they liked being specialists in a competitive world. Just like hot water heating systems which can really shine through load zone diversity (multiple zoning), these contractors were among the first to offer their customers cooling diversity through zoning.

Chilled water systems, just like hot water systems, offer you and the consumer more application and installation variables than any other type of system and at a very competitive cost. Radiant Heating Systems are among the most expensive systems to purchase and install. So, why are so many people getting involved with radiant, when the same people lash out at chillers, saying they cost to much and there is no way I can sell them ?

Radiantologists, have a unique belief in their heating products and systems like no other segment of the industry. They love the fact that they are unique and they believe in radiant systems. They, like their customers, know that a good radiant system can offer a special comfort. This is exactly what makes radiant popular and it is exactly why Radiant Heating is growing year by year. True Radiantologists, are selling a system, they are selling a concept, they are selling comfort.

So, ... "Where's The Chilled Water ?"

Hydronticists and Radiantologists have stayed away from air condition for many reasons. One of the most popular reasons being, "I don't install duct work". Another reason is having to deal with refrigerant piping, refrigerant types, vacuum pumps and all that specialty stuff which air conditioning systems are made of, Right ? Wrong! Today's chillers are available as stand- alone, totally self-contained products, which only require water piping, gas piping (gas-fired chillers) and electrical wiring. All the same components any good hot water radiant system would require. Hydronticists and Radiantologists have an exceptional advantage over other air conditioning contractors when it comes to chilled water cooling. They understand water piping systems and distribution, while other contractors typically understand air distribution systems.

Part of the decrease in the popularity of chilled water cooling systems and chillers for residential and small commercial air conditioning has been due to application and installation issues. This is because more "AirHeads" have been installing chiller systems, than "WetHeads" have. Isn't it time to switch this around? The bad side of this scenario is, that improperly applied and installed systems will not work right, they will not last and they do have frequent service/repair issues. Then to make matters even worse, guess who or what gets the blame for the problem? The Chiller! More specifically, the particular brand name of the chiller and the manufacturer who worked so hard to produce a good product.

SO, ... "Where's The Chilled Water?"

One of the main reasons why Hydronticists and Radiantologists have not gotten interested in chilled water cooling systems, is that no one has taken the time to talk to them and to provide them with good information about this unique and versatile system. While the radiant industry and radiant associations in the industry do acknowledge the existence of chilled water cooling, the majority of their time and information is devoted to hot water heating systems. While radiant panel cooling has had some investigation, the limitations and system installation requirements have not excited people enough to get on the band wagon. BUT, there are other chilled water cooling options available and no one is better suited to design and install these systems than Hydronticists and Radiantologists. Yes, when it comes to water, be it hot or chilled, the Wonderful World of Hydronics offers the best for all.

I realize that there are many radiant contractors who are 100 % satisfied with the work volume they have and in trying to be the best they can be with the work at hand. But, there must be just as many other radiant contractors who would like nothing more than to expand their business and grow. What better way to become a complete, well rounded Hydronticist, than to offer your customers the best of both worlds? A great hot water radiant heating system and a great chilled water cooling system. Then, to add in a neat plus on the positive side, once you've installed these two great systems, you've also installed a third system. Yes, through some simple applied piping, valves and controls, your customers now have their own forced-air heating system to take the chill out of the air in early spring and late summer.

If I have heard it once, I have heard it many times over and over again. If any customer has any gripe at all regarding their radiant heating system, it's the spring and fall minor heating requirements which typically require total mass heating from a radiant system.

It's slow to respond at first start-up, and once it is heated up, it can create some heating over-ride issues before it cools down. Many contractors have stated that the air-conditioning contractor, who installed the air conditioning system, even installed a furnace too, just for this purpose. It doesn't make since to me, when there are so many better options available and especially when you're the person who should be making the profit.

SO, Have you decided yet?

What are you waiting for?

"Where's The Chilled Water ?"

OK, so you still need some more convincing. You're still worried about that almighty duct work system, are you? Maybe it's still the un-known world of chilled water cooling and all those neat new self-contained air distribution systems? Well, some one once said that "Knowledge is Power", and if it's chilled water power your still lacking, you have nothing more to do than to turn the page and turn on the power.

Whether you consider an electric operated chiller or a gas-fired chiller, the world of chilled water applied systems has more similarities than it has differences. Also, if any differences were to exist, the majority of them will exist in the chiller product itself and not in the applied piping system or the air distribution system (load zone areas). The rest of this book will provide information on chiller types, air distribution types, some hydronic basics, some water pumping basics, some chilled water engineering and designs and some typical application and installation information which is generic for all chilled water applied systems.

YES, Here's the Chilled Water Cooling System !

Chapter 2- Chiller Types & Air Distribution Systems

Welcome, to the Wonderful World of Chilled Water Cooling. It is now time, to turn on the power and gain some important knowledge about chilled water cooling systems. Hopefully you are reading this page due to a sincere interest to increase your knowledge about these systems and to become a complete, well-rounded contractor for heating[1] and cooling. If you're a Hydronticist or a Radiantologist, and you have been successful doing so, you will definitely notice right away that there are great similarities between hot water systems and chilled water systems. Consider this, they're only separated by a few degrees of water temperature.

This chapter will introduce you to two (2) chiller types; an electric operated chiller and a gas-fired chiller. I will point out the similarities and differences of these two chiller types, highlighting the similarities which all chiller systems have in common. While the method of producing the chilled water can and will vary by a chiller's method of operation and its manufacturer, the application and installation of the applied chilled water cooling system will be identical. Chilled water cooling systems are applied by utilizing some style (s) of an air distribution system (s). While the differences between chiller types is small, the differences between air distribution styles is much larger. Many, many companies manufacture and produce similar air distribution systems and they also produce manufacturer specific and dedicated systems. Many air distribution systems due require large and intricate duct work systems, but there are many air distribution systems which are smaller, stand-alone systems which do not require any duct work. Many of these systems will be shown and discussed.

Yes, there are some advantages, sometimes, for the utilization of a duct work applied system. What, you don't do duct work ? That's ok, sub-contract that part, but retain your right to control the whole job. P. S. Be sure to source out your sub-contractors and ask around if necessary regarding who's good and definitely who's bad in the area. Remember this, and you typically don't have to tell this to a Radiantologists, the low bidder is not normally the best investment. You will get what you pay for.

1- This statement in no way implies that you need heating education and this book certainly will not provide any. Its intent means that you are a well-rounded heating contractor and this book is intended to add cooling to your scenario.

Chiller Types: Electric & Gas-Fired

Figure 2.1 below, shows two chiller types; a typical electric chiller and a typical gas-fired chiller. Listed below the figure, there is an outline which shows some similarities and differences in these chiller's specifications and design.

Figure 2.1 5 Ton Chillers

Multi aqua® Electric Chiller

SERVEL® Gas-Fired Chiller

SPECIFICATION	Multi-aqua®	Servel®
Cooling Capacity	60,000btuh	60,000btuh
Primary Energy Source	Electric @ 5701 watts	Nat. Gas @ 96.5 mbh
Voltage/Min Circuit Amps	208/230-1-60Hz/ 47.3 amps	208/230-1-60Hz/9.88 amps
Chilled Water Supply/Return	44° F / 54° F	45° F / 55° F
Water Flow Rate; Max/Min	14.4 GPM / 9.0 GPM	15.0 GPM / 12.0 GPM
Chilled Water Pump	Included in Chiller	No pump in Chiller
Piping Connections; Supply/Return	1" Supply / 1 ¼" Return	1" Supply & Return
Pumping Head / Chiller PD	50 Ft Hd / 1.85 Ft Hd PD	NA / 13.0 Ft Hd PD
Antifreeze Requirement	10 % Propylene Glycol Minimum mandated requirement	20% Ethylene or Propylene Glycol minimum mandated requirement
Refrigerant	Freon R 22	Ammonia

Pictures and Information Courtesy of;
Multi-aqua® - Miramar, Florida and **Robur** – Evansville, Indiana

There are a few chiller specifications which are interesting to take note of due to some minor differences between the two chiller types;

1- Take note of the minimum and maximum acceptable water flow rates. The typical industry standard for a chilled water flow rate is 2.4 gpm per ton of cooling. Some chiller manufacturers, by chiller operation and design, do allow for some variances in a chiller's water flow rate. Over the years there have been four (4) different gas-fired chiller manufacturers and all of them mandated a 2.4 gpm flow rate per ton of cooling capacity as the minimum acceptable flow rate. The important logic here is to always refer to a manufacturer's installation manual for a proper flow setting.

2- Take note that the electric chiller has a water pump in the chiller, which means that a piping system's design and size must be engineered around this pump's available foot of head. The gas-fired chiller, having no water pump, allows for the designer to size and purchase their own pump, properly sized for the designed system. Most manufacturers also allow for removal of a factory supplied water pump and then a separately purchased pump may be properly sized for the designed system.

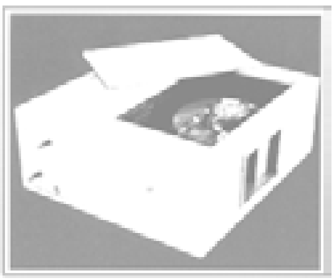
3- Take note of a chiller's antifreeze requirement. Light load conditions, low ambient conditions, and if anything should cause a reduction in the chiller's mandated and minimum water flow requirements, there is a potential for a chiller to produce water temperatures lower than 32° F. This of course could cause freezing in the chiller's evaporator and it would cause a freeze rupture. Most manufacturers state in their installation manual that, "NO CHILLER SHALL BE STARTED OR OPERATED UNLESS THE WATER SYSTEM HAS BEEN FILLED PROPERLY *AND* THE PROPER PERCENTAGE OF ANTIFREEZE HAS ALSO BEEN ADDED". Also, ***All*** antifreezes are not created equal, and many times, a manufacturer will specify a specific type of antifreeze due to its protection ability, its heat transfer properties and its inhibitors which keep a system clean. The antifreeze types which I have seen most often, as being manufacturer recommended are; **DOWTHERM®**[2] **SR-1** (ethylene glycol) **and DOWFROST®** (propylene glycol).

4- These 3 issues; improper water flow rates, improper water pump application (sizing), and improper antifreeze products (even no antifreeze at all), have caused more problem issues for manufacturers than almost any other item.

2- **DOWTHERM® SR-1** and **DOWFROST®** are registered trademarks of the Dow Chemical Company - Midland, Michigan.

Air Distribution Systems

Every chilled water applied cooling system will require a forced-air distribution system to properly circulate the cooled air throughout the load zone area (s). This could be applied by several air distribution types and styles (a.k.a. fan coils or air handlers); 1- is a typical single air handler which may be applied as a vertical up-flow device, a vertical down-flow device or a horizontal device. These air distribution systems are normally applied like a typical furnace system requiring a considerable amount of duct work. 2- a single stand-alone, self-contained blower unit (fan coil) which requires no duct work. These units are available in many different styles and types. These units are also not typically applied as a single zone, although they can be. They are typically applied in multiples to take advantage of the diversity in load demand and to offer the high efficiency and savings which is common from a multi-zone chilled water cooling system. Here are some pictures of some different air distribution devices and a short explanation of their use and application. More information on air distribution systems may also be found in the application chapter.



Horizontal Air Handler

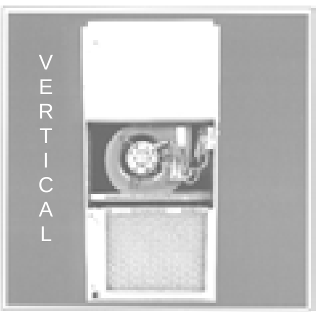
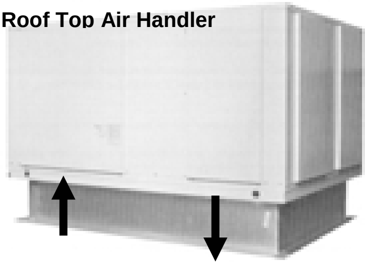


Figure 2.2

Chillers are not manufactured or available in as many sizes as typical air conditioning systems (Freon, forced-air systems). Typical chillers sizes average in the 3, 4 and 5 ton range, and some manufacturers produce 7.5 ton and 10 ton chillers. From this point, capacity sizes jump dramatically and many times, multiple chillers are manifolded to meet specific capacity requirements. Typical small tonnage chiller applications (3, 4 & 5 ton), typically mean a single air distribution system. Two of the most common used air handlers[3] are shown in Figure 2.2. The air handlers pictured, also have the option of having a chilled water coil and a separate hot water coil in the air handler. All you have to do is to connect the piping and sub-contract the duct work. Note: This will not be your typical application.

2- Pictures Courtesy of Magic Aire® - Division of United Electric Company LP - Wichita Falls, Texas



Roof Top Air Handler

Figure 2.3

If you ever decide to charter into the forbidden world of sub-contracted duct work systems, you may be interested in knowing that there is a Roof Top Air Handler[4] available and its size ranges from 2 to 20 tons (800 to 8,000 CFM). This same manufacturer produces many styles and types of single stand alone fan coil units too. As shown in Figure 2.2, and more will be shown.

Multiple Zoning through specific and dedicated fan coil units.

Radiantologists and Hydronticists know that the best and most efficient hot water heating system, is one which can truly address a proper load demand, per load zone area, and as the load varies due to occupancy, use, heat loss factors and ambient conditions. This same scenario follows for a good chilled water cooling system and this can only be best addressed by Multiple Zoning (multiple fan coil units). The good side of this great application scenario is, that there are many styles and types of fan coils which require absolutely no duct work. Yes, you can pocket all the profit. Let's look at some specific styles and types of these fan coils.

Floor Mounted, Wall Exposed, Louvered Top Fan Coil Unit

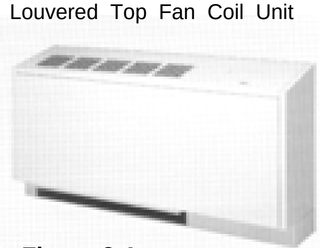


Figure 2.4

Many contractors have seen this style of a fan coil unit[5] (a.k.a. convectors) in office buildings, churches and schools. They are a very utilitarian device, but they do lack some aesthetics which make them a little un-popular for residential use, especially in high end marketed homes. Not to worry, there are other options. But, you may just be working on a job where this style of a fan coil could be a viable option. This fan coil's operating controls are self-contained and thermostatic control can be internal or external.
Yes, you can just connect the piping.

4- Picture Courtesy of Magic Aire® - Division of United Electric Company LP - Wichita Falls, Texas
5- Picture Courtesy of Magic Aire®

Figure 2.5 shows some more convector[6] styles and types which you may or may not have seen before. These are very popular and highly used devices.

Coil # 1 Coil # 2 Coil # 3 Coil # 4

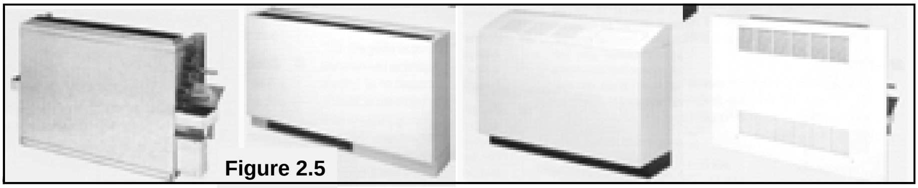


Figure 2.5

Fan Coil # 1 is a Wall Recessed device which is totally hidden with only air louvers added for air circulation. # 2 is a Floor Mounted, Wall Exposed device with a flat top and a louvered inlaid air outlet grille. # 3 is identical to # 2, but it is a Slanted Top style with stamped louvers right in the cover panel. # 4 is identical to # 1, but it has an added manufacturer's face panel with supply air and return air louvers stamped into the panel. These fan coil units are typically available is sizes from, 0.5 to 3.0 tons (200 to 1200 CFM). Yes, the aesthetically pleasing fan coils are coming.

There is another type of fan coil which also has some style variations, and it is called a Ceiling Hideaway Fan Coil[7]. Figure 2.6 shows these fan coils.

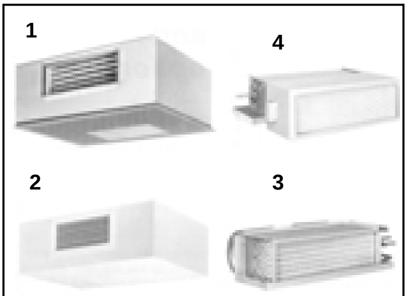


Figure 2.6

These fan coils may be located above a dropped ceiling, or they may be incorporated into a closed ceiling (service/repair access required). # 1 and # 2 are identical, except that # 1 has a manufacturer's external panel on the under side. # 3 and # 4 are identical, except that # 4 has a manufacturer's return air/filter plenum added. These fan coils are typically available in sizes from, 0.5 to 3.0 tons (200 to 1200 CFM).

Many times ceiling voids are used as a duct work system (always check codes for use and application, and be sure to consult a manufacturer's installation manual).

6- Picture Courtesy of Williams, "THE COMFORT PRODUCTS PEOPLE", Colton, California.
7- Picture Courtesy of Williams.

Now Cometh the Aesthetics

In an effort to sell new air conditioning systems, chillers and typical Freon systems, many manufacturers are now producing fancy and aesthetic pleasing fan coils to promote and increase unitary sales. More and more in today's world of energy efficiency and load zone demands, people are beginning to address the simple fact that homes, offices and many other cooling/heating applications, do have different heat loss factors. There is no better way to be the most effective contractor you can be, and to give your customers the best of all worlds, than to offer them a multiple applied load zone system. So, there's only one thing you still lack to fulfill this requirement, an aesthetically pleasing fan coil. Here it is.

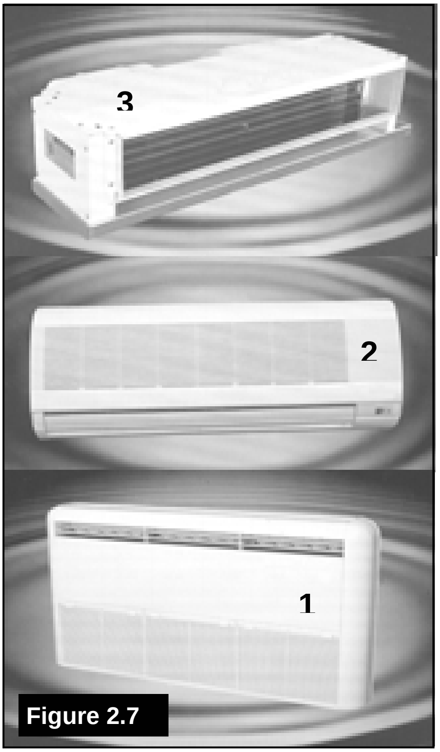


Figure 2.7

These neat fan coil units are manufactured by **Multi aqua®[8].** With fan coil # 3 being the only exception (a ceiling hideaway unit), the other two fan coils offer a unique slimness in design and pleasing curvature to their exterior. # 1 is a Universal Mount Fan Coil which would typically be located on the wall of a room, at or near floor level, or hung from the ceiling. This fan coil does not protrude out into the room as much as others do and it is certainly acceptable for residential cooling applications. # 2 is a High Wall Fan Coil which is to be located 6 to 7 feet above floor level. It too offers a pleasing decorum. Sizes range from 0.5 to 5.0 tons (200 to 2000 CFM). Many manufacturers of these neat new fan coil styles, also offer the option of having an electronic remote control station, which controls the entire operation of these fan coil units.

Oh No, not another remote control ? Yes, another remote !

8- Picture Courtesy of, **Multi aqua®** - Miramar, Florida

Have I Gained Your Interest Yet ?

There are many other manufacturers, besides those which I have shown, who manufacture and produce air handling systems and stand-alone, self-contained fan coil units. If you have gained any interest at all in researching this potential business endeavor, being a great cooling contractor as well as a great heating contractor, you're going to have to do your home work. The neat reality today, is that most of us now have the ability to research the world from our easy chairs at home. The world wide web is loaded with information just waiting for you to log on and get started. Search engines will take any word or words and then you only have a million or so web sites to search, to find exactly what you are looking for.

Oh, just in case you are interested in some more information regarding the manufacturers which I have noted in this book, all their contact information and research information (www) may be found in the acknowledgment section in the back of this book.

You now have an idea about chillers (electric operated and gas-fired). You have seen many styles and types of air distribution systems which are appropriate for any chilled water applied system. The next step, is to identify some reality applications, to see which ones are best suited for a chilled water cooling system and to identify those which you really do not want to get involved with. Chapter 3 will do just that. Recognizing a good, better and best application.

I must apologize for the deliberate deletion of any information on radiant panel cooling. I have not yet had the chance to venture into this world of cooling. But, if you are interested, I do have some www sites which you may visit to learn more on this subject. See below. Also see, Page VII, main index, back of book.

Radiant Panel Cooling Web Sites:

www.redec.com
www.edwards-eng.com
www.greenengineer.com
www.hydronics.org
www.twapanels.ca

www.sterlingheat.com/htm1/radheatcool.htm
www.ashraejournal.org
http://epbl.lbl.gov/thermal/hydronic.htm
www.radiantpanelassociation.org
www.havefun

Chapter 3- Application Recognition

What is the best and most appropriate application for a chilled water cooling system? This is a question which has plagued the contracting industry for many years, and especially when it comes to residential cooling applications and small commercial applications. First let me state that there is no bad application. Bad to many contractors' means it costs too much and I can't sell it. There are applications where chilled water cooling is not an option. This is mainly due to the available sizes of chiller units. Also, as the size of the chiller (cooling requirement) increases, so does the application potential (multiple zoning). Good chilled water cooling applications have one word which stands out as its best definition, ***"Multiples".*** This chapter is going to provide some information on many various applications where a chilled water cooling system has been successfully applied, and it will especially highlight applications where Hydronticists and Radiantologists should start re-thinking about being a cooling contractor as well as a heating contractor. Increasing your bank account's bottom line. Cooling 101.

Small Residential Cooling Systems

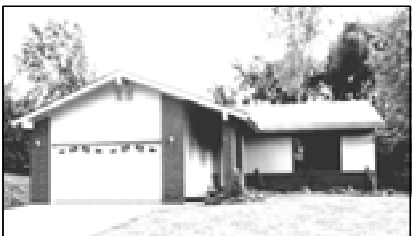


Figure 3.1 1700 sq. ft. residential home

While this 1700 square foot home is not a high potential application for a chilled water cooling system, don't tell this home owner. A 3 ton chiller has been providing cooling for this home for over 10 years now. The same outdoor unit has also been providing for this home's heating requirements too. Some manufacturers produce combination chiller/boiler units for total applied comfort systems. The hot or chilled water is circulated through a horizontal fan coil in this home's crawl space. This entry is provided to give you a chiller's basic starting point for an application. Typically 3 tons of cooling capacity and larger.

FIG 3.2 3000 sq.ft. Home

This 3000 square foot older home requiring a 5 ton cooling system increases the application potential for chilled water applied cooling system. Then, to add in another plus, the entire inside of this home was being completely re-modeled right down to the wall studs. It was a 3 level home and the home owner wanted a heating/cooling system for each level of the home. Yes, a hydronic applied system was the answer.

The installing contractor located a chiller and boiler outside the home and connected their piping by 3-way seasonal change-over valves. The supply and return piping circuits were then run to 2 air-handlers; a 4 ton vertical air handler in the basement (first and second floor) and a 2 ton hideaway fan coil in the third floor which was a high attic space with peak sloped ceilings (business loft). The second floor air handler was omitted due to limited installation space. After the system had been in operation for 6 to 8 months, and as re-modeling continued, the home owner now decided that he wanted warm floors in the kitchen and the two bathrooms. The heating system (a hot water system) was converted to a constant flowing circulation system, and secondary pumping loops were installed to provide hot water heating of the floors for the kitchen and bathrooms. Through the use of floor temperature sensors, a secondary pump (per applied loop) circulated hot water through a loop until a proper floor temperature was obtained and then the pump would shut off. The use of lower temperature hot water (140° F) made this adaptation easy. Note: When chilled water coils are being used for both cooling and heating, the hot water temperature can be reduced considerably.

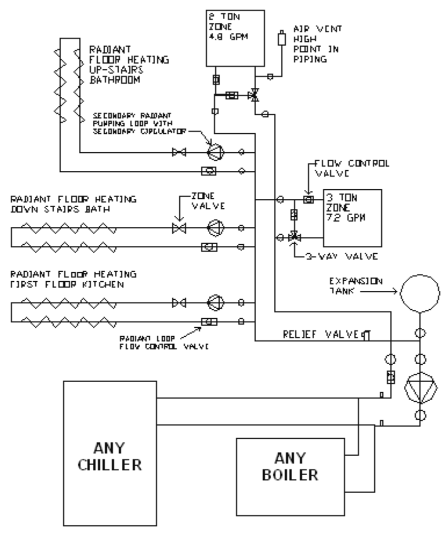
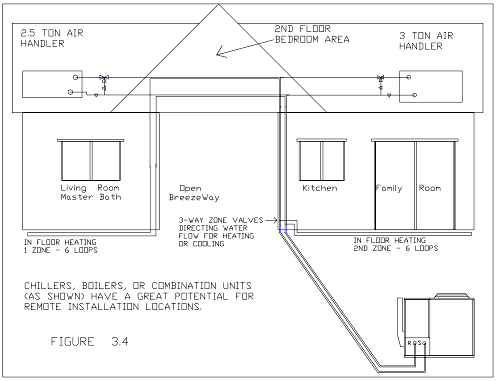


Figure 3.3 Radiant In-Floor, back-ended

This application may not, and most likely will not be typical for Hydronticists and Radiantologists, but it does highlight the diversity and flexibility of a hydronic applied system. Figure 3.3 shows a simple drawing of this application's layout. If you look at this drawing good, you can plainly see that most of this system's installation requirements relate to water piping and water circuit controls. Who is better suited to install this type of a system than hydronic people? I'm sure that there is someone out there who would be willing to do some duct work for you.

The next residential application to be shown was a two-fold designed system. Radiant In-Floor Heating for the home and a Forced-Air, Chilled Water Cooling system for the home.



The drawing in Figure 3.4 doesn't do justice to the size and unique design of this home, but it does offer some unique concepts for the adaptability and flexibility of a hydronic applied system. This home is divided into two parts by an open breezeway and access to either side requires the use of a stairway to the second floor, or exiting a door across the breezeway.

An outdoor boiler and a chiller were installed and located approximately 75 feet away from the home and underground piping was run to and into the home. In-floor radiant heating was installed for the home (cement slab floor with a 6 loop manifold system per side). Horizontal air handlers were installed in two attic spaces and flexible duct work was used for the air distribution system.

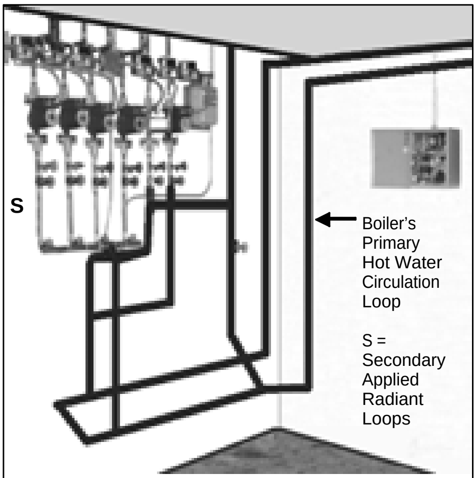


Figure 3.5 A Radiant Baseboard System

Another application was a home on a lake which had an existing radiant baseboard heating system (Fig 3.5). The home had no cooling system and the owner was looking to install one. Also, the age and condition of the hot water boiler was being questioned. The contractor suggested a chiller system to the owner, adding in that he could get a unit which could provide both, hot water for heating and chilled water for cooling. The new system was installed outdoors freeing up floor space where the old boiler use to be and it gave the home owner another usable room.

A simple main hot water circulation loop (primary loop) was run into the home and the existing secondary radiant loops were adapted to the new primary loop. Cooling was provided for by an air handler in the homes attic space.

Up to this point, every application has had a common application factor; forced-air, duct work applied, air distribution systems. This is mainly due to two reasons; 1- was the availability of aesthetic pleasing, self-contained fan coil units at the time, and 2- the knowledge of a contractor regarding the availability (existence) of good fan coil options.

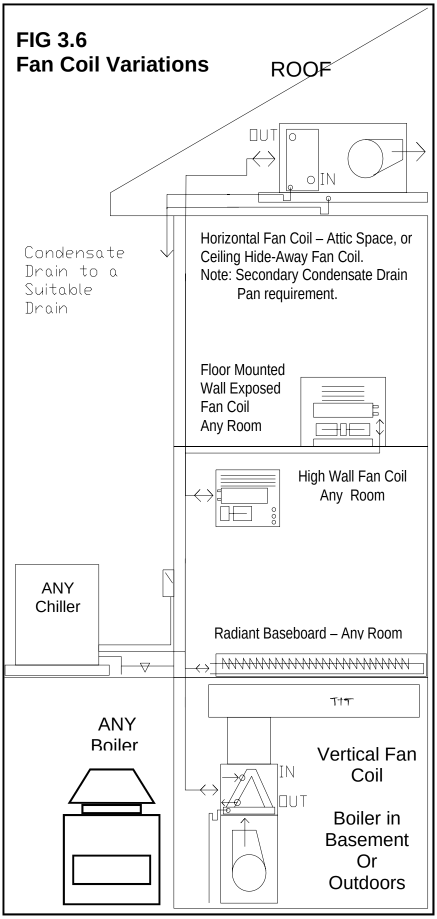


FIG 3.6
Fan Coil Variations

Figure 3.6 highlights the use of many types and styles of air handlers and fan coils. You have already seen many of the various devices which are available today and, I am sure that there are a lot more out there which some simple and easy research could locate.

Any of the applications which have been shown, could just as well have been applied through the use of stand-alone, self-contained fan coils. Can you avoid having to have duct work all the time, absolutely not? But it can be minimized and sometimes totally eliminated.

You have the knowledge and know-how to install a great hydronic heating system. You now have a better understanding of the application potentials for a chilled water cooling system. What if you had an application requirement which couldn't be 100 % radiant heating and that was all that you did? I'm sure this occurs from time to time.

Would you just give the job away, because you don't do duct work?
If you were a hydronic cooling contractor too, you wouldn't have to throw away any job potential, or the extra profit which could be had.

"Where's The Chilled Water ?" It's in the bank !

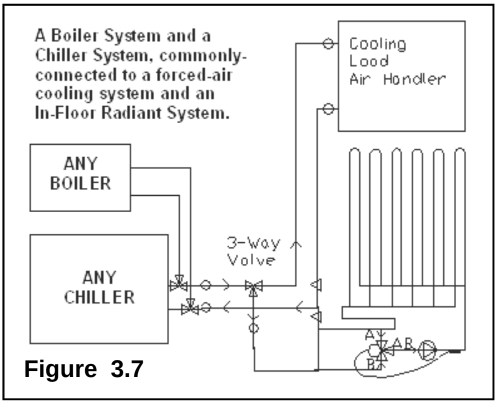


Figure 3.7

If you do decide to get involved with chilled water cooling systems, you will have many application options available to you. One being, installing each system independently of one another. Why you would want to, is not understandable to me, because installing them as one connected system would give you three (3) systems;

1- a hot water heating system. 2- A chilled water cooling system. And 3- a forced-air heating system. As shown in figure 3.7, 3-way valves can be easily adapted for a system's seasonal operation (boiler operation or chiller operation). Another 3-way valve can direct the hot water supply or the chilled water supply to the proper seasonal load. Please excuse my radiant layout drawing, I'm still learning. The cooling load could be a single applied air handler (not), or it could be as many individual smaller fan coils as required. Your radiant system could also be a single manifolded system, or multiple zones. You're the designer, you're the installing contractor, and it's your call. Finally, some simple added controls can provide for forced-air heating if needed.

You already know radiant systems; you just need some more designing and engineering logic for applied chilled water cooling systems. That's exactly what the rest of this book is going to do. It will provide you with typical chilled water system requirements (Cool Hydronics 101). Some information on Water Pumping, including pump sizing and pumping variations. Information on system designing and engineering. And last, information on typical installation requirements for chilled water systems. Yes, there are many, many similarities for all hydronic applied systems.

But, before we venture into these topics, I want to provide you with just a little more general information on application potentials. Many contractors limit their business to residential applications; some contractors do both residential and small commercial, some do strictly commercial and some do large commercial applications only. Chilled water cooling systems do have a place in all of these areas. Here are a few more pictures of some great chilled water cooling applications and they are all radiant applicable too.

Maintaining the Aesthetics

Figure 3.8

Figure 3.8 shows two older homes which most likely had steam heat and no cooling system when they were built.

Some where in time, both of these factors will have to be addressed and possibly several times. There is no better way to destroy the aesthetic pleasure of a neat older home, than to consider a massive duct work cooling and/or heating system. Some companies today, are even manufacturing old style steam radiators again to regain some lost aesthetics. Boy, just imagine the fun a good chilled water cooling/hot water heating contractor could have in a home like these.
P.S. I meant installing a system. Yes, I wouldn't mind owning one myself.

Residential Homes, Now We're Talking Residential Homes?
They look more like mansions to me. Just imagine the load variables here.

Figure 3.9

No home is without its own particular aesthetic beauty. Yea, I'd take one of these too. These homes are typically applied by 2, 3 or even more individual cooling systems. The may have radiant heating or the typical forced-air furnace systems, or worse, furnaces on top of radiant. Hey, "Where's The Chilled Water ?" Imagine, one larger manifolded chiller system could have been used and applied through an energy efficient, multiple load, zoning system.

Now we are starting to enter the ideal world of chilled water cooling systems. Remember the definitive word, **“Multiples”.** Multiple exposures, Multiple heat losses, Multiple rooms (lots of them), Multiple chillers and Multiple load zones. Any time any chiller system can be applied by two or more load zones, the total efficiency of the cooling system increases and so does operational cost savings. Did someone mention payback periods?

No contractor increases their business or potential growth by being satisfied with the work at hand. You must be a visionary, capable of seeing not only the forest, but the trees too. Look beyond the scope of the norm, dare to be different, dare to be better than the norm, dare to be able to say, “I Know Where The Chilled Water Is”!

If you’re a commercial contractor too, or strictly a commercial only contractor, I have some more great application ideas for you too. Multiple offices, Multiple apartments, Multiple motel (hotel) rooms, Multiple class rooms and one of the best scenarios, Churches which have Multiple un-used (un-occupied) rooms. As the number of applied load zones increases, so does a load demand diversity factor. Due to heat loss variables, occupancy and use, no large multiple load zone system will typically have all zones demanding cooling at the same time. This is where a multiple chiller system can really shine. Multiple chillers can be staged to evenly match any given load demand at any given time. If multiple load zones can offer great savings, just imagine the great increase in further savings which may be obtained through a multiple and staged cooling system.
Where does it end? A visionary has no end!

Multiple Offices and Multiple Apartments

While it may not be the norm, it is very highly appropriate. Both these buildings use hot water heating and chilled water cooling.

Figure 3.10

Partial hot water and forced air. All hot water heating and a unique fan coil.

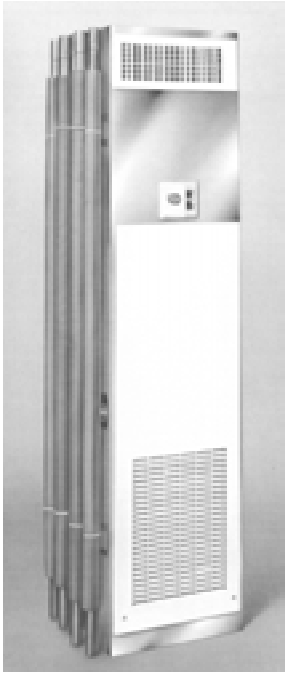


Figure 3.11
Stack-On Fan Coil

As shown in figure 3.10, the office building pictured on the left is using a combination of radiant heating and two applied roof top forced-air heating systems. Each 15 ton roof top unit also has a chilled water coil which is adapted to a multiple and staged 15 ton chiller system. For this particular application, the multiple is only related to the chillers.

The high rise apartment building shown on the right in figure 3.10 is using all hot water for heating and all chilled water for cooling. Both of these items are being applied through the use of a really neat stand-alone, self-contained fan coil unit. This fan coil unit, a Stack-On Fan Coil[1], is shown in figure 3.11. These fan coils are available as two-pipe units (one coil for both hot water and chilled water), or as four-pipe units, using an independent coil for each process. They are also available as wall hide-away units (must be incased in a wall covering), or as a free standing unit, completely covered by a manufacturer's finished exterior. This is a great fan coil option for multiple level applications, especially if upper and lower levels have the same identical floor plan (one fan coil right on top of another). Multiple Chillers, Multiple Loads, Multiple Fan Coil Options and a chilled water cooling system, the more you know the more you'll grow.

The Epitome of Diversity, Efficiency and Savings

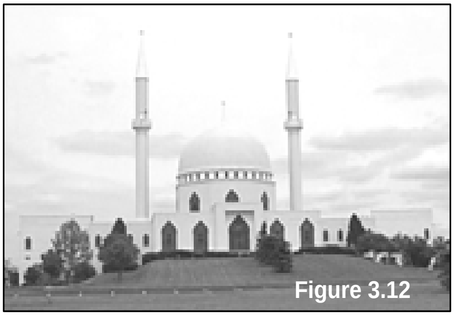
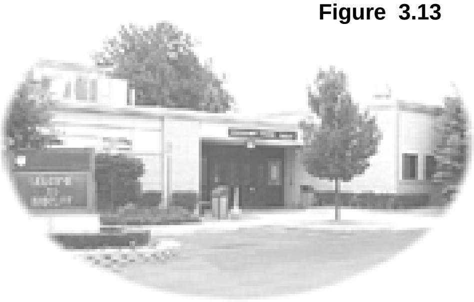


Figure 3.12

This beautiful church has close to 60 tons of applied air handlers throughout the building (8 or 9 AH's). It also has a 30 ton manifolded chiller system which cools the entire building. No, not all at the same time. All areas in the church are not used, all at the same time. Each area, when used, receives its share of the chilled water circulation system for its required occupancy time.

1- Picture Courtesy of Williams, "THE COMFORT PRODUCTS PEOPLE", Colton, California
This is one of the neatest and most service friendly fan coils I have ever seen.

Figure 3.13



There is also a very high potential for load zone diversity in schools (colleges). These buildings have many areas which are occupied all the time, some of the time and none of the time. Only a Multiple and Diversified Chilled Water Cooling System can offer such versatility and flexibility of design and application.

You’ve seen it used over and over again for hot water radiant systems, and Hydronticists and Radiantologists alike, have gloried in their ability and knowledge to offer their customers the most comfortable, efficient and effective heating systems.

So, why in the world, wouldn’t you want to offer your customers, one of the most comfortable, efficient and effective cooling systems too?

“Where’s The Chilled Water ?”

Hopefully, In Your and Your Customer’s Future !

Chapter 4- Cool Hydronics - 101

So, you've decided to enter this unique realm of Chilled Water Cooling. Whether you're an experienced Hydronticist or Radiantologist, whether you have only some limited experience, or even if you're a beginner, there's sure to be something in this chapter which will get your mind working. This chapter covers some important basics of hydronics as it relates to chilled water cooling systems. It does not cover everything hydronic, but the information included in this chapter has provided me with 30 years of pleasurable chilled water cooling experiences. Throughout these next chapters, you will undoubtedly say to yourself many times, Hey, these are the same requirements which hydronic boilers and radiant systems have. **Bingo !**

Throughout the rest of this book (chapter 4 and on), I will be using a numbering logic for the specific topics and subject matter being discussed (e.g. X.x - X = the chapter number, while .x = the topic's number). In a sincere effort to reduce repetitiveness and redundancy, I may find it necessary at times, to refer you back to a specific topic.

4.1 Getting Started

The basic starting point for any chilled water cooling system is to do (or have someone do) a load calculation to determine the required size of the cooling system (chiller's size). You then have to choose the air distribution system's style (type and number of load zones). Now enters the hydronic basics. Having a proper chiller and the chosen fan coil (s) (air handler or handlers), you must design and install the piping system which will deliver the chiller's cooling capacity to the applied load zone (s).

One other item which must be considered up-front is the method of water pumping for the designed system. Many manufacturers supply water pumps in their chillers while others may not. Also, even if a manufacturer does provide a water pump, there is absolutely no reason why you must use that pump. Water pumping variables for chilled water cooling systems will be discussed fully in chapter 5.

Once a proper chiller size has been chosen, you will now have the starting point for designing your applied and installed system. GPM = Gallons Per Minute. Every chiller, if it is to perform properly, will have a manufacturer's rated GPM requirement per chiller's size.

4.2 GPM - Gallons Per Minute

Chilled water cooling systems have a fairly standard GPM industry requirement; ***2.4 GPM per ton of cooling capacity.*** While this may vary a little by manufacturer and/or chiller type (electric chiller or gas-fired chiller), it is an important value to remember. It is also very, very important to ***always consult a manufacturer's installation, operation manual*** to determine the proper total GPM requirement for a given chiller size. Many manufacturers list this as two (2) entries; Maximum GPM and Minimum GPM. ***The important value to note here, is the Minimum GPM.*** This means there must ***never*** be less than the minimum flowing through the chiller when it is operating.

Just like a boiler, which is never fired without water in it and water flowing through it, a chiller has the same requirements. Chillers, like boilers, also have a means of controlling this factor. A manufacturer installed water flow switch in the chiller, or a mandated field applied requirement for adding a water flow switch. This prevents chiller operation under a no flow condition. Some chiller's have a post operational period at the end of their cooling cycle. This may be an operational pump down period for an electric chiller and it is definitely a post operational cool down period for gas-fired chillers. Water flow is normally ***mandated*** during this period. Always consult a manufacturer's literature.

Special Note: Most chillers, especially gas-fired chillers, have a water flow requirement which many designers and installers totally over look. Even with a full water system, even with a properly set GPM flow rate, it does not mean that the chiller's operation is proper. Look at any designed and installed piping system. Note all the valves which are controlling water flow through the system. Then ask yourself, could any of these devices cause a reduction in a chiller's minimum mandated flow rate during system operation? If the answer is yes, than something is wrong. No chiller's mandated and proper flow rate should be changed in any way when the chiller is operating (this includes the post operational period too, if applicable). A chiller's mandated flow rate, per manufacturer and chiller size, must be set properly and it must be constantly flowing through a chiller when it is operating.

Chiller manufacturers will also provide you with a second chiller value which must be incorporated into the system for designing and installing the chiller. A Ft. Hd. Value (foot of head).

4.3 Ft. Hd. - Foot of Head

Everything through which water flows (piping, valves, etc.), creates a resistance to flow due to the movement of the water (friction). The hydronic industry has created two (2) values for dealing with this factor; **Ft. Hd and PSI** (pounds per square inch, a.k.a. psig = pounds per square inch gauge). Each value has been assigned its own rating and not by chance either.

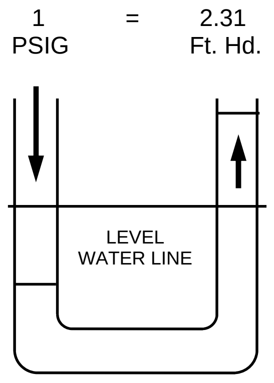


Figure 4.1 Ft. Hd. & PSI

By using a U-tube, water was added to create an equal water level line in both tubes. Then, one (1) pound of pressure (1 psi) was applied into the opening of one tube. When this was done, the water in the tube on the other side rose up 2.31 feet. This test gives us the **Formula:**

1 PSIG = 2.31 Ft. Hd. This formula is used over and over again for pipe sizing, valve sizing and water pump sizing. Also, all manufacturers of chillers and air distribution devices (fan coils and air handlers) will provide a rating value for their products based on its operational and performance requirements (specified GPM flow rate).

Everything through which system water flows (chiller, fan coil (s), air handler (s), piping and valves) must be calculated into a system's design, to ensure that; 1- the manufacturer supplied water pump, or 2- the separately purchased and installed water pump, is capable of moving a proper GPM flow rate through the designed and installed system. The problem which can occur from time to time, is that some manufacturers (chiller and/or air handler) may provide you with a Ft. Hd value, or it may be a PSI value. Ft. Hd. values are what you require and it is your job to convert PSI values to Ft. Hd. values.

4.4 Chiller & Fan Coil Values

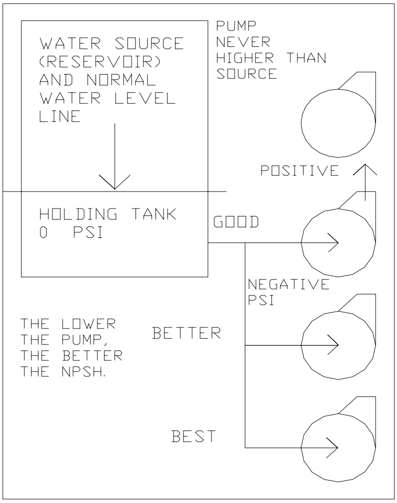
If a manufacturer provides you with a Ft. Hd value, you are basically all set. If they provide you with a PSI value, it must be converted to a Ft. Hd. value. This is where the above formula comes into play. For any known Ft. Hd. value or PSI value, they can easily be converted from one to the other. Take any known Ft. Hd. value (50.0 Ft. Hd.) and divide that value by 2.31 (50.0 ÷ 2.31 = 21.64 PSI) and you will have the PSI equivalent value. Take any known PSI value (5.6 PSI) and multiple that value by 2.31 (5.6 x 2.31 = 13.0) and you will have the equivalent Ft. Hd. value. Note: Water pumps are typically purchased by two (2) operating values; A GPM value and an operational pressure value, Ft. Hd.

4.5 Chiller Systems & Water Pumps

Some chiller manufacturers provide chilled water pumps right inside of the chiller, while others do not provide a pump at all. This factor will create two (2) system designing issues; 1- If the manufacturer does provide a pump, they will also provide you with this pump's total pressure capability, Ft. Hd. This value may also be provided in two (2) different ways; A- as a total Ft. Hd. for the pump, or B- as an available Ft. Hd. for the pump. A- Means that you must deduct the chiller's operational Ft. Hd. from the total value. B- Means that the manufacturer has already deducted the chiller's value and the available value is what you have to design your piping system around (Note: fan coils are considered as part of the piping system). 2- If the manufacturer does not provide a water pump, then it will be your job to properly size and purchase a water pump. For this requirement, you must use the manufacturer's Ft. Hd. value of the chiller in your pump sizing calculations.

4.6 Open Loop verses Closed Loop

Over the years of manufacturing, most chillers were designed as ***Closed Loop Systems.*** This simply means that every part of the water circulation system (chiller, fan coil (s), piping, valves, etc.) operated as a "Positive" pressure system. There have been some chillers which were designed as ***Open Loop Systems.*** This simply means that in some part of the chiller, the closed piping loop was "Opened" (special cooling tank area and water reservoir holding tank) and this created a three (3) pressure zone operational chiller; 1- a positive pressure to and into the chiller. 2 - a zero pressure zone in the special cooling tank. 3 - a negative pressure zone in the piping where an applied water pump must suck water out of the holding tank.



If you ever run across an "Open Loop Chiller", or a New Purchased Chiller is designed this way, there is a very important water pumping requirement which must always be remembered. No water pump, may ever be installed Higher than the operational water level in the holding tank. Lower than yes, and the lower the better, but never higher. There is a special definition for this operational requirement too. It's called NPSH (Net Positive Suction Head). This simply means, that the water holding tank must provide a natural, gravity flow of water to and into the water pump.

Figure 4.2 Proper Pump Location.

4.7 NPSH - New Positive Suction Head

When any water pump is being applied to an open system, there are several installation and application requirements for the pump, to ensure proper pump operation and proper system (cooling) operation. You already know the most important requirement, “Always install a pump lower than its water source”. Here are some more factors to ensure good and proper operation; 1- ***Never*** down size piping from the water source to the pump. 2- ***Never*** install a strainer in a pump’s suction line. 3- Even if a pump is lower than the water source, ***Never*** raise any supply piping to the pump, higher than the pump. 4- ***Always*** minimize the number of piping installed items in the pump’s supply line (valves, fittings, etc). 5- ***Always*** keep the pump’s supply piping as straight as possible. 6- ***Always*** install the water pump as close to the water source as possible. **“IF”** , these rules of the road are followed, any installed and applied pump should have an NPSH requirement of 10 feet or less.

In the chapter on water pumps, I will point out a particular pump style which can typically have high NPSH requirements and it is not a good choice for “Open Loop Systems”. We now have our chiller, our chosen fan coil (s) (air handlers understood) and our chiller either has a water pump in it or you have to size and purchase a pump. Most of these pumping requirements will be discussed in other chapters, but there is another basic factor which needs to be understood. Pressure Drop values.

4.8 Pressure Drop Values

Pressure drop values are used for many reasons; 1- setting water flow rates. 2- pipe sizing. 3- valve sizing (special flow control devices) and more. You already know the pressure values (Ft. Hd. & PSI); you just need a little more information on their use and purpose.

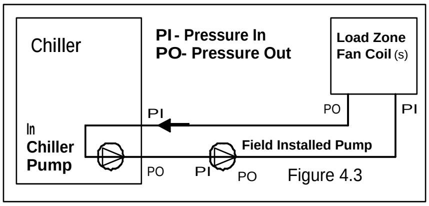


Figure 4.3

Pressure readings may be taken at any point of a piping system and many important operational factors may be determined; 1- the GPM flow rate through a chiller (field installed pump applications). 2- the GPM flow rate through a load zone (s).

3- The pumping capability of a water pump. 4- The total PD of the entire water circulation system. Note: A chiller with a pump in the chiller, uses a special flow rate setting method. You cannot read a chiller’s PD across a pump too. Referring to Figure 4.3, the pressure in value will always be higher than the pressure out value (Note; the water pump is the only typical exception to this rule).

Any given flow rate will create a drop in pressure as water flows through an item (chiller, fan coil, piping, etc.). As the flow rate increases, so does the PD. PD values are typically read as PSI values, but manufacturers normally provide Ft. Hd. values. You must do the conversion (e.g. a 5 ton chiller's gpm flow rate requirement is 12.0 and the manufacturer lists the chiller as having a 13.0 Ft. Hd. PD with this flow rate. 13.0 ÷ 2.31 = 5.6 PSI). If this chiller had a pressure in reading of 12 PSI, and the flow rate was set proper at 12.0 GPM, the pressure out reading would read 6.4 PSI (12 PSI - 5.6 PSI = 6.4 PSI). This same logic follows for fan coils too, and you must use the manufacturer's GPM and Ft Hd values for the fan coils.

Any operational water pump will have a pressure in reading and a pressure out reading. For a pump, the pressure out will always be higher than the pressure in. This is the pump's job, to create a high enough pressure to continually move a proper GPM flow rate through the system. For a pump, pressure out, minus pressure in, equals the pump's total capacity (all flow devices normally wide open). It also provides the total PD of the designed and installed system (all flow devices set). More information will be provided in the water pumping chapter. We now need to start thinking about the designing of the piping system. While this will be discussed in its own chapter, there are a few new basic terms you need to know.

4.9 PD Calculator

There is a real neat device available which can really simplify your life for working with Pressure Drop Calculations. Also, when a manufacturer provides a GPM value and Ft. Hd. Value for this gpm, it is normally for typical equipment operation as specified by the manufacturer. But, the manufacturer also provided you with a Minimum and Maximum GPM value which is also appropriate for the chiller's operation. The problem is, you do not have a Ft. Hd. Value for these other GPM values. A PD Calculator can solve this problem easily. You can take the manufacturer's known and provided values, enter them on the calculator wheel, and you can find other Ft. Hd. (PSI) values by simply moving up or down the GPM portion of the wheel. The PD Calculator I use is called, "The System Syzer® Calculator" which has been produced by B&G (Bell & Gossett) a division of ITT Fluid Handling Corporation[1].

1- A large portion of my success over the years has been due to great information and products provided by B&G. Especially their great local distributor/representative. There's no equal to a knowledgeable supplier.

4.10 Friction Charts & Equivalent Length Formulas

Every designed and installed piping system must have a starting point and this was one of the first items I mentioned, the GPM Flow Rate Requirement. A ***Friction Chart*** lists many different flow rate factors (GPM) and it provides an appropriate pipe size for a given flow rate. As the flow rate increases, so does a pipe's size. This pipe size increase accounts for several potential operational issues; 1- it keeps the flow rate velocity to a minimum for a given pipe size to prevent water flow noise in the piping. 2- higher than normal flow rates through a small pipe will also cause erosion in the pipe. 3- to keep the PD value at a low and acceptable value for a given pipe size. In every appropriate row (GPM per Pipe Size) this chart will provide a pressure drop value for them and for a particular piping material type (copper, pvc, iron, etc.). This pressure drop value may be listed as Ft. Hd., or it could be listed as PSI. Also, these values will be for 100 feet of a given pipe size. This chart is used to design and size the piping system and eventually to be added into the pump's sizing calculation.

Every designed and installed piping system will also have many other items besides the piping itself (elbows, tees, valves, strainers, etc.). All these items create a resistance to water flow too. Each item must be accounted for as to its PD value for the designed system and they must be added into a system's total PD calculation. Unlike piping, these items do not have their own PD values. Each item style, per a given pipe size, is assigned an ***Equivalent Length Value,*** meaning that item equals X feet of a particular pipe size (e.g. a 1" 90° elbow, has the same PD as 3.0 feet of 1" pipe). Your job is to convert every item to an equivalent length of feet (per a given pipe size) and then add it into you system's PD calculation. There is one item which is used in piping systems and its PD value cannot be obtained from this chart, Zone Valves.

4.11 Zone Valves & Cv Ratings

Today's air conditioning systems have a higher potential for constant air circulation within the load zone areas than they ever had. This is mainly due to the electronic gadget age. Computers, printers, copiers, televisions, increased lighting, and on and on. The bottom line is, that there really isn't any location any more, which may be considered as being ideal for locating and mounting a central thermostat. Heating/Cooling loads and heat loss factors vary more than they ever have. This is one of the biggest reasons why a multiple zone system can be so highly efficient and effective. You cannot have a cooling system with two or more zones and constant blower operation without over cooling one or more areas.

The days of circulating water constantly through all load zone coils are basically gone. But, because we ***cannot*** install just any type of a valve which would decrease system flow, it will be necessary to install by-pass valves (3-way zone valves) which either supply a coil or by-pass the coil. These valves have a PD rating all of their own. This is due to valve sizing (namely internal flow ports) which can be smaller than the valve's pipe size connection. These valves are designed around typical flow rates for a given size pipe. Then they are assigned a ***Cv Rating*** based on their design and a given flow rate (GPM).

Example: A valve having a Cv Rating of; Cv 5.5 means, when this valve has water flowing through it at a rate of 5.5 GPM, a 1.0 PSI PD will be created across the valve. It is very important to note Cv ratings for any valve which you may be considering the use of in your system. A System Syzer® Calculator can provide other PD's for other GPM's. One big issue which arises all too many times, is the cost of the valve. Yes, smaller valves are cheaper, but they are also trouble. Down Sizing never accomplishes any good. Always try to limit a valve's PD to 2.0 PSI or less.

4.12 Down Sizing - The Fatal Mistake

Down sizing is rationalized by many as a necessity for being able to make a little extra profit on a job. It is also rationalized by some as a physical requirement due to various connection sizes on chillers and fan coils. Well, at least they're partially right on this point. The main issue which arises for this problem is that the system was designed and engineered properly, but at the time of installation, the installing contractor made some changes and the job's general superintendent didn't catch these minor changes (not).

Yes, for any given designed system, the piping system's size may be larger than a chiller's connection point and/or a fan coil's connection point. But, the piping system's size was designed around a water pump's capabilities (in-chiller or system sized by designer). Any changes and/or deviations in the field will increase a system's total PD and the pump may no longer be capable of moving a proper GPM through the system. Down Sizing, if needed and required at a chiller and/or fan coil, must be done right at the device, by one reducing item and as close to the device as possible. ***No appreciable length of piping should ever be down sized.***

Field installed valves can create a similar problem. If the right size valve is not used and smaller and/or cheaper valves are used, oops, there goes the PD again. This is especially important for 3-way valves which have Cv ratings (e.g. a 3/4" valve could have 2 or more Cv ratings based on the internal port sizing, and they not only vary for a valve's size, but also by manufacturer).

4.13 The Farthest Zone

Almost every installed chiller system today will be adapted to two (2) or more fan coils. One of the installed and applied fan coils will be farther away from the chiller than any of the others. This fan coil will have the longest run of piping to get the chilled water from the chiller, to and through this fan coil and to provide a proper GPM flow rate through the coil. This fan coil will be designated as the Farthest Zone, meaning it and its water circulation piping loop, has the largest PD requirement of the entire applied system. If a water pump can circulate a proper GPM flow rate, from the chiller, to and through the farthest zone, and back to the chiller, there will be proper flow through all the other middle zones.

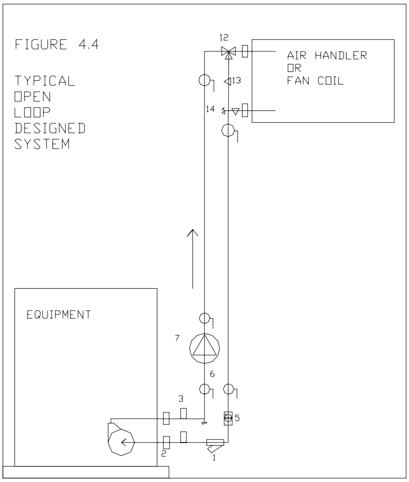
Special Note: There could be exceptions to this rule. A middle zone, due to design and application, may at times have a higher PD requirement than the farthest zone. The important item to remember is you must always use the zone with the highest PD requirement, and this will normally be the farthest zone. The farthest zone logic is used for sizing a water pump.

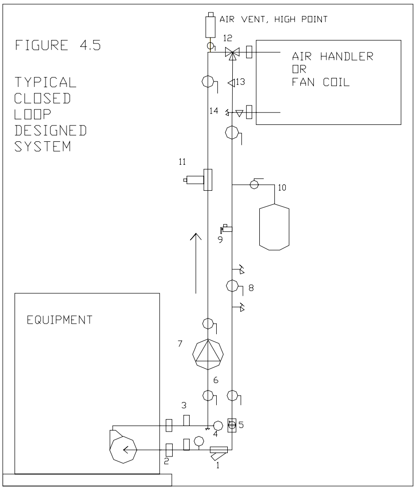
4.14 Pressure Drop & Antifreeze

Every chiller manufacturer that I know of requires some percentage of a good quality inhibited antifreeze to be added to the water circulation system. Antifreeze products are heavier by weight than water is and this can also vary by the antifreeze's type (ethylene glycol verses propylene glycol). This factor is referred to as viscosity. A water pump has to work harder to move a water/antifreeze mixture, than it does for pure water. This typically means that a larger pump will be required for antifreeze mixture systems. This can also vary by the percentage of antifreeze which will be used in the system. This factor can be calculated into a water pump's sizing by using manufacturer provided calculation charts, or you could have a good pump supplier calculate this need for you. Calculation charts and more information may be found in the designing chapter.

4.15 Typical Piping System Requirements

Every installed and applied chilled water cooling system will have many items included in the field installed piping system, other than the piping and general directional fittings themselves. Figures 4.4 and 4.5 show drawings of two (2) typical applied systems; 4.4 is a typical open loop system and 4.5 is a typical closed loop system.





By design and application, each system will have many items added into the piping circuit and, as is easily noticed in figure 4.5, a closed loop system's requirements are much greater than an open loop system. In finishing up this chapter on hydronics 101, I just want to provide a simple list of these items. Why they may or may not be needed in a system, and whether or not some of them may be code required.

Item 1- Strainer: Strainers can be useful in water systems for filtering debris, but they should never be used in lieu of a good cleaning and flushing. Be sure to purchase strainers which are easily cleanable and don't forget isolation valves for cleaning. Some manufacturers even provide strainers right in their equipment. While not necessarily mandated and/or code required, they can be advantageous for a system. Strainers have a PD value which must be calculated into system designing.

Item 2- Unions: Unions allow for the easy dismantling of piping for servicing and repairing of equipment and fan coils. It's especially handy too, if isolating valves have been installed.

Item 3- Thermometers (or Wells): Having some means of accessing the operational chilled water temperatures of a system can be really important at times, especially if one is trouble-shooting the system. Fixed thermometers and thermometer wells typically penetrate into the flowing water stream. This creates a PD issue which must be addressed for some piping circuits (smaller piping may require up-sizing to account for wells). Pete's Plugs® can be used in lieu of wells and they are adapted to side outlet tees.

Item 4- Pressure Gauges: Pressure gauges are not normally required on “Open” loop systems, but there should always be at least one gauge on a closed loop system. Ideally this one gauge should be in the lowest pressure zone area of the piping system (suction inlet area of the water pump). Pete’s Plugs® can be used in lieu of more gauges and they may be located at all the areas noted in figure 4.3 for taking PD readings.

Item 5- Flow Control Valve: Every system will require at least one (1) flow control device for setting the proper GPM flow rate of the system. “IF” any applied water pump has been sized properly (or in the case of a manufacturer supplied pump, the piping is sized properly), the water pump will be providing a greater GPM than required. The flow control valve will be closed down to a point where an accurate and proper flow is established. Some manufacturers make special flow control devices which have pressure taps right on the valve for easy setting and adjusting of flow rates (e.g. B&G Circuit Setter®).

Item 6- Service Ball Valves: Many codes require valves for isolation of equipment when servicing and/or repairs are required. Many good contractors even install extra valves for isolation of other potential servicing needs (pumps, strainers, etc.). Who knows, you may be the person who has to service and/or repair something one day?

Item 7- Water Pump: Every system will have a water pump. It may be a manufacturer supplied pump as shown in figures 4.4 and 4.5 (pump in equipment), or it may be a properly sized and purchased pump which has to be located in the system’s piping circuit.

Item 8- Fill Valve Assembly: Open loop designed chillers typically have the water/antifreeze mixture added right into the chiller’s reservoir holding area (special design tank which created the open system). Closed loop systems do not have this ability and they will require a means of filling the system. As shown in figure 4.5, this is simply a ball valve with a boiler drain on either side of the valve. It will be fully explained in the installation chapter.

Item 9- Relief Valve: This is not required on an open system due to its open reservoir area, which in itself, acts as a relief/expansion area. Closed loop systems, on the other-hand, do not provide for relief and/or expansion and per code, a relief valve must be installed.

Item 10- Expansion Tank: By code, an expansion tank is required on all positive pressure closed loop systems. Even chilled water systems, which could be exposed to minor expansion due to the ambient of the day, must have an expansion tank. Expansion tanks for chilled water systems are typically smaller due to the reduced potential of a high water temperature factor.

Item 11- In-Line Air Separator: Closed loop systems must have some means of air removal from the piping system. Some systems, due to size and length of piping, are more adequately handled by using an in-line air separator which typically removes air at a faster rate. An independent air vent may be adapted directly to the separator, or the separator may be part of an expansion tanks application. Small automatic air vents are also typically installed at high points of the piping system. ***Special Note:*** Air separators and air vents ***are not used for "Open" loop systems***. The open reservoir area allows for air removal. High point air vents can be detrimental to open systems by allowing air to enter the system during system off periods.

Item 12- 3-Way Valves: Most chilled water applied cooling systems are going to be multiple zoned systems which will require a 3-way zone valve at each fan coil (supply water to and through the coil or to by-pass the coil). Each flow circuit of the 3-way valve will have a different flow resistance factor and each circuit will require its own flow control valve (∇).

Item 13- Flow Control Valve: One FCV installed for the fan coil's flow circuit and one FCV installed for the 3-way valve's by-pass circuit.

Item 14- Boiler Drains: Many codes require some means of draining the equipment and/or other items of a system when servicing and/or repairing is required. Some contractors like to install them because they know that they may be the servicing contractor. The two (2) boiler drains installed for the fill valve assembly are not part of any code requirement. They are specific use items related to the filling and/or maintaining of a full system.

Item 15- Automatic Fill System: Although not noted in figure 4.5 for the closed loop system, there is an automatic water/antifreeze filling system now available for chilled water systems. This is a stand-alone system which acts just a city water make-up system. This system provides a fluid pump, pressure regulation, pressure reducing valve and fluid holding tank. All you have to do is keep the holding tank full of its water/antifreeze mixture.

Special Author's Comment: *Some people have criticized me for my simplicity. They say that there is a lot more to this than I have cared to acknowledge. They are absolutely right. But, why in the world would you or I want to make anything more difficult or confusing than it needs to be.*
IF 2 + 2 = 4 gets the job done, then why turn an easy method into this;
$1^2 + (1 \div 2) + (50\%/1) + 0.125 + 0.675 + 1.2 = 4.000$

Ok, we have finished the general introduction for chilled water systems, a. k. a. Hydronics 101. Chapters 6 (Designing and Engineering) and Chapter 7 (Installation) will expand upon this chapter and much more information will be given for the application and requirements of the topics discussed in this chapter.

But, before we get down to the nitty-gritty of chilled water cooling systems, I want to discuss one other very important aspect of every installed system, The Water Pump. Knowing how a water pump functions and how water pumps may be applied is a very, very important part of every applied system.

Chapter 5- Water Pumping Basics

Many people do not know that water pumping has its beginnings traced back to Ancient Times[1]. Back then, water pumping was called "Aquadirecticating"[2]. Ancient Hydronticists, called "Cavaquaductors"[3], were among the first humans to start harnessing water for a useful purpose. It wasn't until many years later, when two Indian Tribes; The Hydronawanchie[4] Tribe and The Radiawaturchie[5] Tribe, finally found water's true purpose. There was a natural hot spring located on the land of the Hydronawanchies and the Radiawaturchies could not have access to it. So the head Hydronticist of the Radiawaturchies went to the Hydronawanchies and proposed a deal. The Radiawaturchies installed hot water heating under all of the Hydronawanchies teepees for access and to gain use of the hot springs.

Thus began the era of hot water heating. Today we have a much better method of controlling and directing water's useful purpose, the Water Pump. Also, through the adaptation of an electric motor (which just happened to be discovered by a distant relative of the Radiawaturchies[6]) we can now control the flow rate of the water too. End of a neat and short history lesson. Are you a believer[7] "?"

The "First Water Pump Invented"?

If you're really interested in some history of water pumping and more information than one may really care to read, type these "four words" into your computer's search box, hit go, and get ready for thousands, upon thousands of sites with some neat, and some not so neat information.

1- This enlightening and inspiring information came to me in a dream one night. It seemed so realistic and true I just had to pass it on to you.

2- A-quâ-dí-rêc-tî-ká-ting; the control of water's flow and direction.

3- Câv-â-quâ-duck-toors; cave dwellers of the water.

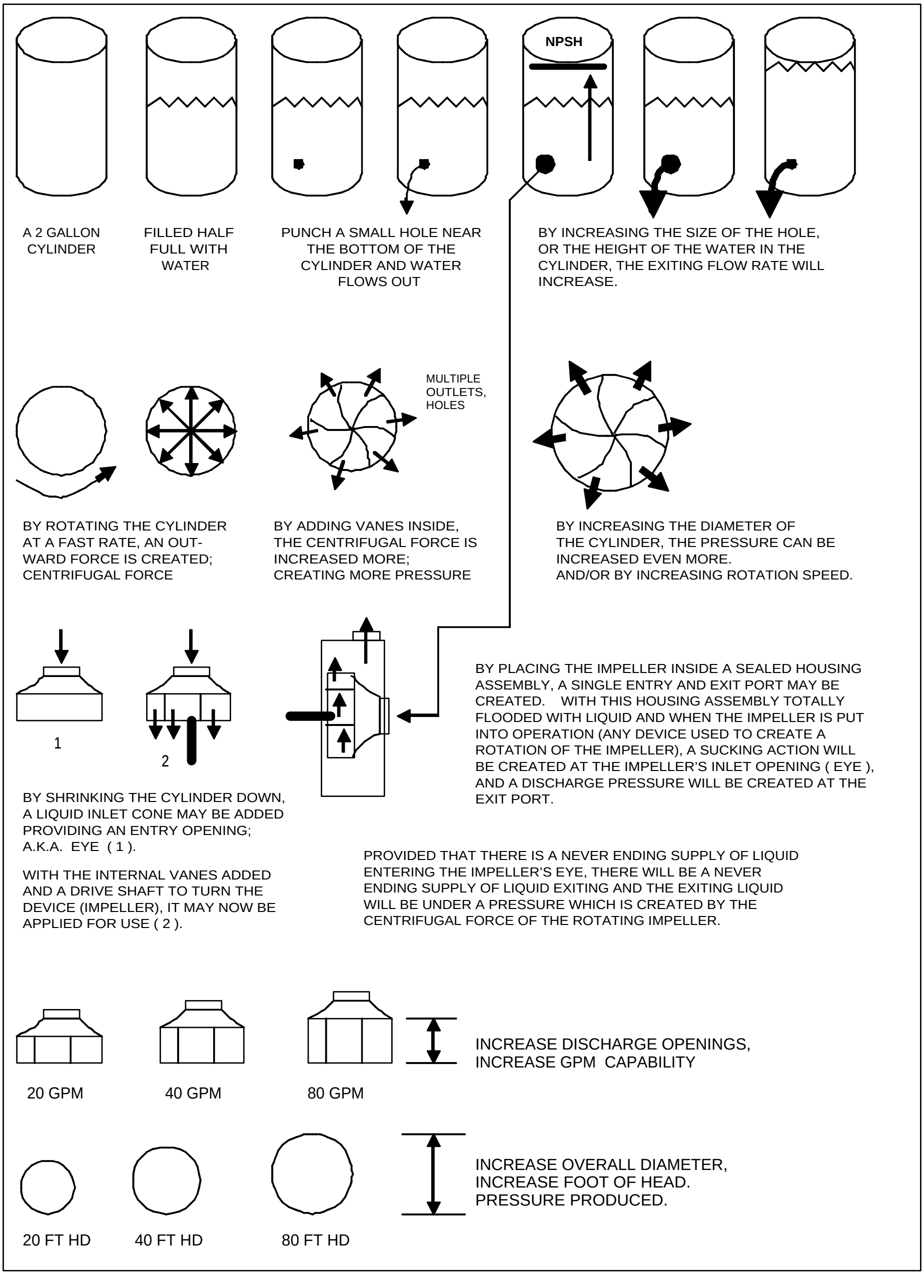
4- Hí-dron-â-wân-cheé; dwellers in the land of the water.

5- Rá-deé-â-waä-tür-cheé; dwellers in the land of the underground.

6- NOT !

7- Many times, a short anecdote can help to break the monotony of tedious reading. Be they truth or fiction, hopefully they will create a smile. I'm a believer, are you ?

The Plain & Simple Basics:[8]



8- Yes there is a lot more to this pumping thing, but do you really need to know all that? And, does it really matter? I guess if you were going to be a water pumping specialists, The answer would be yes.

5.1 Water Pumping - Assessing What We Know

At this point we have learned several factors, formulas and requirements for chilled water cooling systems and almost all of them will have a direct impact on a water pump's proper operation for any applied system. Let's review a short list of these items;

1- Water Flow Rate Requirements; Typically 2.4 GPM per ton of cooling capacity.
2- Some chillers come with a water pump in the chiller and some do not.
3- Water flow through the chiller is mandatory when the chiller is operating.
4- The flow rate must be set correct per chiller size and per manufacturer specifications.
5- The water flow rate must be constant. No system device shall reduce flow through the chiller when it is operating, including post operation if applicable.
6- Chillers with a pump require proper sizing of the piping system, based on the size of the manufacturer supplied water pump.
7- Chillers with no pump require a proper sizing of the piping system, based on an industry produced flow friction chart and a pump must be properly sized for the system too.
8- Operational pressure (Ft. Hd.) is required from a water pump to properly circulate the system's water flow requirement.
9- Ft. Hd. (Foot of Head) and Pressure (PSI or PSIG) have a relationship; 1psi = 2.31 ft. hd.
10- Any known Ft. Hd. Value or PSI Value can be converted from one to the other.
11- Antifreeze is required in every chiller system, based on a manufacturer's minimum to maximum acceptable percentages.
12- All antifreezes are not equal. Only a good inhibited product may be used, and it must be specifically designed for HVAC heat transfer systems.

Now Comes The Fun ....

Water pumps come in many different shapes, styles and sizes, and all of them could have a place in a chilled water cooling system. Also, water pumps may be applied and used in many different ways. This is the neat side of hydronics and it provides us with the great ability to design and engineer fantastic flexible and versatile hot water heating systems and chilled water cooling systems. The more you know and understand about water pumps, can only increase your success.

5.2 A Pump is A Pump ..... Wrong !

Water pumps are available in many different configurations, from small, to medium, to large. Also, many types of pumps are available for high speed operation (typically 2800 - 3450 rpm's) and some are for low speed operation (typically 1150 to 1725 rpm's). Some pumps mount right in the piping circuit (piping supports the pump), while others must be floor mounted (some type of a base support system). Pumps are available for operating on several different electrical power supplies (typically used voltages are; 110volt, 220volt and 460volt). Some pumps use single phase power, while others may require three phase power. Depending upon a pump's installation location, a special motor may be required other than a standard motor (drip proof, totally enclosed fan cooled, or an explosion proof motor). It is going to be your job to choose a pump or pumps, which is best suited for your system's design and operational requirements.

5.3 Popular Pump Styles for Chilled Water Cooling Systems

Figure 5.1 shows some of the most popular water pump styles which are used for chilled water cooling systems.

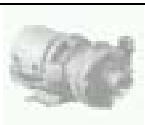
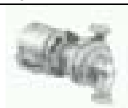
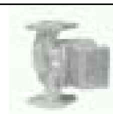
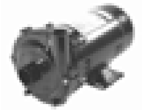
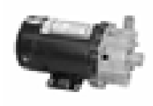
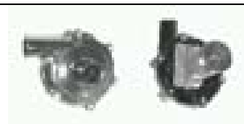
 1: Base Mounted Close Coupled 1725 RPM	 2: Horizontal In-Line with Bearing Assy 1725 RPM	 3: Vertical In-Line Close Coupled 1725 RPM	 4: Circulator In-Line High RPM

Figure 5.1 Typical Pump Styles

 5: Manufacturer Pump 3450 RPM 12gpm@50 Ft Hd	 6: Manufacturer Pump 3450 RPM 12gpm@30 Ft Hd	 7: Manufacturer Belt Drive Pump Some Gas-Fired Chillers Back Side - Front Side

Each style of pump has some pros and cons for its choice and use. Many of these same pump styles are also popular for hot water heating systems too. Let's examine each one and outline some of its good and bad points[9].

1- Base Mounted Close Coupled; (close coupled means the impeller mounts directly to the motor's shaft). This pump is typically offers low to medium GPM flow rates[10]. Three phase motors offer a quieter operation too.

9 - See special note at the end of pump descriptions.

10- Low GPM = < 30, Medium = 30 to 60, High = >60. Low Ft Hd = < 30, Medium = 30 to 60, High = > 60. Typical small chilled water cooing systems 3 to 50 tons.

It is a low RPM pump with low head capacities and its water flow inlet port (suction inlet) is directly into the eye of the impeller. This pump is much cheaper than a base mounted pump which has separate motor and bearing assembly which are connected by a drive coupler. These pump styles are typically used for medium to high GPM systems (50 to 100 GPM +) which have low Ft Hd requirements (20 to 35 Ft Hd). There are some 3450 rpm variations of this pump style which offer much higher Ft Hd capacities (75 to 100 Ft Hd +).

2- Horizontal In-Line Pump; This pump style is quite popular due to its initial cost and its flexibility of installation (location point). It has a separate motor and bearing assembly which is coupler connected allowing many independent and isolated repairs without entering the water circuit. The bad side of this pump is two-fold; 1- It requires special mounting precautions due to its weight, serviceability and maintenance. The side mounted motor does require independent support sometimes. 2- This pump can typically have a high NPSH requirement and it should not be located far from the water source for open systems. This pump offers medium to high GPM's and low to medium Ft Hd capacities.

3- Vertical In-Line Pump; This pump is basically a combination of Pump 1 (close coupled) with the mounting versatility of Pump 2 (in-line mounting). Because all in-line pumps use the water piping as a supporting mechanism, piping support and any extra weight required supporting will be a very important installation issue.

4- In-Line Circulators; Many chilled water cooling systems will be applied in a GPM range of 7.2 to 24 GPM and having low Ft Hd requirements. These small, high rpm circulators can be, and have been, a very popularly used pump for small systems. The bad side if any, is that they are typical throw away pumps. But, considering their low cost, ease of service and being very light weight, they're a bargain which is hard to pass up. If used and applied right, they will provide exceptional service.

5 & 6- Manufacturer Supplied Pumps; Both of these pump styles have the same style motor, just different pumps. Pump 5 is a 3/4 HP motor with a large diameter impeller to provide a low GPM with a medium to high Ft Hd. Pump 6 is a 1/2HP motor with a smaller diameter impeller. It provides a low GPM and a low Ft Hd. Both motors are 3450 rpm operational which allows for downsizing of the pump. This offers a manufacturer a little more ease for locating the pump in their chillers.

7- Belt Drive Pump; Over the years, a few gas-fired chiller manufacturers used this pump style as an in-chiller pump. It was a belt drive, specific purpose pump. I am showing it, only because you may run across one of these pump styles one day. The manufacturer's literature must be referred to for this pump's use and operational requirements.

Special Note: The bad points (cons) which I have noted for these pump styles are related more to their use and installation, than they are to the pump itself. All pump styles have specific installation, location and use criteria[11] which must be followed for good and proper pump operation. Many of my bad points highlight the abuse of these criteria.

5.4 The Heart of the Pump

Every water pump has a heart. That is, every water pump has an operational device inside the pump which does the pumping of the water. The pump's Impeller.

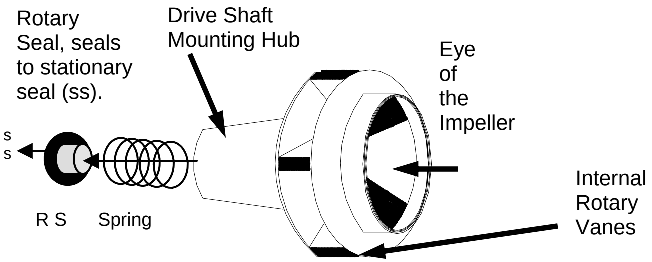


FIG 5.2
Typical Impeller

The Impeller provides spring pressure to rotary seal and holds it tight to the stationary seal.

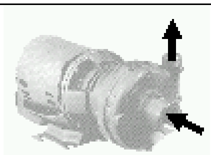
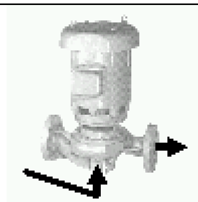
An impeller is connected by one of two methods for a pump's operation; 1- the impeller is connected directly to the motor's shaft (close coupled). 2- the impeller is connected to a bearing assembly's shaft (motor to B. A. uses a special drive coupler). The impeller is located inside a closed housing (a bolted and gasket housing). This housing has three (3) openings; 1- a water inlet port (water into the eye of the impeller). 2- a water outlet port (normal discharge port). 3- a drive shaft opening (motor's shaft or B. A's shaft). 1 & 2 are sealed connections to the piping system, but 3 requires sealing too and this is provided by a pump seal kit[12]. Seal kits are basically three items; 1- a stationary seal (typically rubber loaded) which fits into a machined port opening. 2- a rotary seal which slides over the drive shaft (more appropriately, a clean and smooth shaft), and 3- a pressure spring to apply pressure to the rotary seal which touches the stationary seal during its operational rotation. The impeller, when slid onto the clean smooth shaft, will push on the spring and hold it in position when the impeller is bolted to the drive shaft.

11- Tip; Want to avoid pumping problems, try something new. Try following a manufacturer's application and use literature.

12- All seal kits are not created equal. Depending upon the fluid type being pumped, a special seal may be required. It is always best to notify a pump supplier regarding the fluid type for the system (e.g. glycols and percentages).

The size and design of an impeller, is the key to a proper GPM flow rate and the operational pressure which will be produced when the pump is operating. Typically as the GPM flow rate increases, so will the opening of the rotary vanes. Also, as the overall diameter of the impeller is increased, so will the pressure production (Ft. Hd.) increase. When an impeller is operating, a sucking action occurs in the eye of the impeller (a vacuum). Proper operation mandates a flooded impeller housing and a proper flow of water into the impeller's eye. Closed loop, positive pressure systems are not normally a problem (provided a positive pressure is maintained). Open loop systems can be a problem as noted in 4.7 Net Positive Suction Head (NPSH). Any operational condition which causes a low vacuum to be created in the eye of the impeller, will cause water vapor bubbles to be created. As they move through the impeller to a different pressure area, they can collapse (minor explosion) and this will damage an impeller. This function, when it occurs, is called cavitation. As noted in 4.7, there are many ways to prevent this potential. Also, some pump styles do not favor open systems, due to a higher than normal NPSH requirement.

When is the last time you had a creamy rich and thick milkshake? Remember the fun of trying to suck it up through a small straw. I use to get so mad, I wanted to invent a special, easy draw straw, just for milkshakes. This is basically the same factor that a pump under goes, when it is not being supplied with a proper inlet flow of water. Remember how your cheeks and mouth could really start to hurt badly, when you really had to suck very hard. Well a pump doesn't have those feelings; it just finds a way to self-destruct (impeller pitting, leaking seals, bearing assembly problems).

 **1 Base Mounted**	**Figure 5.3** **Inlet Flow Patterns** Directly into the Impeller's Eye for a Base Mounted Pump	 **2**	2- Vertical In-Line has an in-direct flow inlet. Water has a flow change of 90 degrees = higher NPSH

As shown in figure 5.3, pump style 1, which provides a direct water inlet flow right into the eye of the impeller, will have a much easier suction factor than pump style 2. Pump 2 requires water inlet flow to make a 90 degree turn just prior to entering the impeller's eye. This makes this pump style higher in its NPSH requirements, than pump 1.

Also, if pump style 2 is not located close to the water source (open systems), it is destine to self-destruct. Answer! Know your system's design and operating requirements, and then consult a good qualified water pump supplier.

5.5 Pumping Applications & Variations

Water pumps may be used and applied in many various ways. Every Hydronticist and Radiantologist has been involved with many pumping applications and pumping variations for hot water applied heating systems. Many of them are similar to chilled water systems and many are not used for chilled water systems. Here are the most popular pumping applications and variations for chilled water cooling systems.

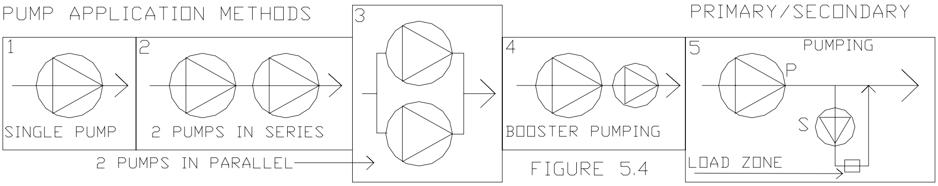


FIGURE 5.4

Figure 5.4 shows five (5) popular water pumping methods which are commonly used for chilled water cooling systems. **1-** is a single water pump being installed and applied as the sole means of fluid circulation for the entire system. Very popular for small tonnage, single or multiple load zone systems. **2-** is two, equal size water pumps, being installed and applied as series flow pumps (one pump, pumps directly into the second pump). Series pumping increases total pressure output capacity (Ft. Hd.). Series pumping offers 2 basic advantages; 1- pumping redundancy and back-up, should one pump happen to break down, and 2- increased operational pressure. A low GPM system having a high Ft Hd, may be best applied by two smaller and cheaper pumps installed in series[13]. **3-** is two, equal size pumps, being installed and applied as parallel flow pumps (equally piped and manifolded, with a common supply and a common discharge). Parallel pumping increases total GPM requirements. Advantages; 1- redundancy and back-up, and 2- increased operational GPM. A high GPM system having a low Ft Hd, may be best applied by two smaller and cheaper pumps installed in parallel. **4-** is two, different size pumps, being installed and applied as series pumping. This has also been called booster pumping, because the second smaller pump is boosting the total Ft Hd. This pumping method is typically used because someone screwed up during the sizing of the first pump. But, it does have a useful purpose too.

13- Pump manufacturers make many pumps which are called standard production pumps. These are normally easier to purchase, easier to get parts for, and they offer the best cost factor. Series pumping, using stock pumps, can save a lot in the long run verses special ordered or special cut impeller pumps.

Many combination systems, hot water heating and chilled water cooling, can have one applied water circuit with a higher Ft Hd requirement than the other circuit (heating being the typically higher PD circuit). Many times, the easiest way to handle this need, is just to add a booster pump to the higher PD circuit. This pump can normally be a standard shelf stock pump, small in size and easy to install. **5-** is a single pump being installed and applied as a primary circulating pump which can provide for the ***"Equipments"*** total needs. But, the designed system has one or more load zones with special pumping requirements (e.g. lower than manufacturer mandated flow rates or, due to design and use, water flow through this zone may actually be reduced and/or stopped[14]. A secondary applied pump, sucks water out of the primary loop, moves the water through the secondary applied loop and then back into the primary loop. The nice part of this method, is that the flow rate of one loop is not affected by the flow rate of the other loop. Cooling capacity can be, but not the loop's flow rate.

The next chapter, Chapter 6 - System Designing & Engineering, will expand upon these water pumping methods and many other items which were discussed up to this point.

Note on a Mechanical Room Wall,
Using a black magic marker, and in big words, the following was noted;
"Turn on second pump, when outdoor temperature drops below 30".

The building owner thought he had two identical size pumps, installed and applied in parallel. One would operate the entire building and one was to be a stand-by in the event that one should fail. What he had, was two identical smaller pumps, and if both were not operating, the total GPM of the building was not being provided. The note on the wall was written many months after the original installation. The installing contractor thought he had pulled a fast one. He had, it took 8 years of questionable operation before this was finally corrected. But did he really win? You can just imagine the rumors about this guy.

So, have you chosen the right and proper size pump for your system? Let's review a short list of some questions which you should have asked yourself and/or your pump supplier.

14- Chillers have a manufacturer mandated minimum flow rate. No part of an applied system shall reduce flow through a chiller, especially totally stopping flow. More information on this potential issued may be found in chapter 6, a no flow condition.

5.6 Important Questions for Choosing & Purchasing a Pump

1- Do I know my system's total GPM requirements?
2- Do I know my system's total calculated PD?
3- Have I calculated a proper Ft Hd value for item 2?
4- Do I want a base mounted or in-line style pump?
5- Is my designed system an Open or Closed Loop System?
6- Will NPSH be a factor for my pump's operation?
7- Can I use a standard shelf stocked pump?
8- Will I need a special order pump?
9- Will I need a special motor for my pump?
10- What voltage[15] do I want my pump to operate on?
11- What type of antifreeze will my system be using?
12- What percentage of antifreeze will I be using?
13- Will I need a special seal kit in my pump?

As you can see, there are a lot of questions which need to be asked and answered. Many will be your responsibility and many will have to be answered by a good pump supplier. Any person who has spent any amount of time in the hydronics industry (hot water heating or chilled water cooling) knows and understands the great value of a good pump supplier.

The Secret to Successful Water Pumping Experiences

1- Source out a Good and Knowledgeable Pump Supplier.
2- Choose the Best Pump Style for the Application (Open/Closed Loop System).
3- Install and Apply the Pump Properly (per manufacturer guidelines).
4- Read Manufacturer Guidelines ***"Prior"*** to installing Pump.
5- Assume Nothing, or Lose !

15- All pumps are best installed and applied near the source of the water, the equipment. The equipment will have specific voltage requirements and it is always best, not to mention the easiest, to purchase a pump which operates on the same voltage as the equipment does.

Chapter 6- System Designing & Engineering

Over the past 35 + years of being involved with hydronic heating and cooling systems, it never ceases to amaze me, how many times I have seen installed systems which have been butchered by service/repair individuals. Now I realize that it is not always a technician's fault. Customers have a great history for demanding makeshift[1] repairs, rather than spending the money to get the job done right. Engineers and designers have a way of adding in some personal self expression to their designed systems, which highlights their knowledge, individualism and independence. There is no way in the world, why I would ever want to take this self expression away from anyone either. But, I still cannot understand why a simple installation and design issue, has to become a maintenance and service nightmare. I firmly believe that every system should be designed and laid out in its simplest form first. Then add in any controls and/or devices which are system mandated by the equipment's manufacturer and the load zone's requirements, to provide the minimum needs for good and proper operation. Once this is accomplished, the bells and whistles may be added if necessary. But, a customer should be consulted as to the maintenance, up-keep requirements and potential cost factors.

OOPS ...

One of the neatest designs[2] I have seen over the years, was a three story apartment building which had several 5 ton chillers installed on the building's roof. Each chiller supplied chilled water to several apartments. In an effort to keep the control system (large interlocking control network) as simple as possible, a second water pump was added to keep the water circuit in constant circulation. The water temperature was controlled with an in-chiller control and the blower in the apartment's fan coils were just cycled on/off by a line voltage thermostat. Simple? Yes. But, here's the kicker. The building had a 6 foot attic space over the entire building, with a massive network of 2 x 4 struts. The constant circulating pumps were installed in the attic space, as designed, because water pumps never leak "?" One thing was found out very fast by the building owner, red antifreeze stains in drywall ceilings are not an easy fix.

OOPS ...

1- How many times have you seen controls which are by-pass, wired open or closed, or automatic devices which were changed to a much simpler manual device. All too often I suspect. Why not simple in the first place?

2- NOT !

6.1 Where Do We Start

Every good designed system starts with a proper load calculation of the home or building for which the system will be applied. If your company cannot perform this necessity, or totally accurate, sub-contract it out. ***"Preparation is Everything".*** Having a proper load calculation (5 ton, 7 ton, 10 ton, etc.), you must now choose an appropriate chiller for the system. This may be one chiller or it may be a combination of smaller chillers (manifolded chillers). Once a chiller (s) has been chosen, get all the information literature you can for the chiller and Read It. ***"Preparation is Everything".*** Now you must determine the air distribution requirements for the home or building. Will you use just one (1) blower system (air handler), or will you choose to use two (2) or smaller systems (fan coils). Always keep in mind, that the most efficient, effective and potential cost saving method is ***"Multiples",*** two or more fan coils. Once you have chosen a specific manufacturer's product, get all the information literature you can for the product and Read It. ***"Preparation is Everything".*** Now you must have or create a layout drawing of the home or building to; 1- locate a proper installation spot for the chiller (s). 2- locate a proper installation place for the air handler or fan coils. 3- layout the exact path which the piping system must be run, to deliver water from the chiller (s), to the air handler or fan coils, and then back to the chiller (s). Now you will be ready to start sizing your piping system and to add in all the required piping system items.

6.2 Assessing the Information We Now Have

If you followed the above stated preparation guidelines, here is the system information you should now possess;

1- The total cooling load requirements of the home or building.
2- The total size requirement for the purchased chiller (s).
3- The chiller system's GPM requirements, Ft Hd requirements, Electrical requirements, Gas requirements (gas-fired chiller), piping connection sizes, whether or not the chiller comes with a pump, chiller installation and operational clearance requirements and a lot more.
4- The number and size of the air handler or fan coils, plus; the GPM requirements of each, the Ft Hd of each, the CFM of each, the piping connection sizes of each and a lot more.
5- All this information is important for designing and sizing a proper piping system.

6.3 Beginning the System's Design Process

Chapter 7 will discuss many specific installation requirements for electric and gas-fired chillers, but many of these requirements create system design issues too. Namely one important beginning requirement, where will the chiller (s) be located outside the home or building? A proper designed and sized piping system mandates several correct and proper equipment locations (the chiller (s) and the air handler or fan coils) (see 7.4 chiller locations). Using a good layout drawing of the home or building, the chiller system must be drawn in and at its proper (final) installation location. Then, the air handler or fan coils must be drawn in at their proper locations. Now comes the fun. Lines must be added to the layout drawing to indicate the path that the piping must be run from the chiller system to all applied air distribution systems. Then a 100 % accurate measurement must be made, accounting for every foot of piping required, every fitting in the piping system (90 ells, 45 ells, tees, reducers, etc.), every valve in the piping system (manual and automatic) and anything else through which water must flow which will create a flow restriction in the designed piping system. Hopefully, the end result will be a properly sized piping system which can deliver a proper GPM flow rate to all applied load zones. And, keeping in mind that, some manufacturer mandated operational functions could play a major role in system designing and in system pipe sizing. The most important of which is, does the chiller come with a water pump in the chiller, or will you be responsible for sizing and purchasing a separate water pump.

6.4 Where's the Water Pump ?

Many chiller manufacturers provide a water pump right inside the chiller. They will also provide you with this pump's operating specifications (in the literature you read). They will list the pump's GPM flow rate (per chiller size requirement) and the Ft Hd capacity of the pump. "IF" the chiller's PD has been deducted from the pump's total capacity (Ft Hd), the Ft Hd rating should now be listed as "available" Ft Hd. Meaning this is what you have to work with for your system designing. "IF" it is not listed as "available ft hd", there should be a PD listing for the chiller itself, and you must deduct it from the pump's total Ft Hd, to obtain an available Ft Hd value. Also, chillers with a water pump inside the chiller, are normally installed and applied as a single stand alone unit. Multiple chiller installations, will normally require an external water pump, which you have to size for the designed system (internal pumps will be removed, or order a chiller without a pump if possible).

Most chiller manufacturers who do provide a water pump in their chillers, will normally provide you with a quick and easy method for sizing a piping system (you did notice this when you read the literature, right). Later in this chapter, I will thoroughly discuss system pipe sizing for separately purchased water pumps and for the sizing of a pump. Once you have read this information, it may be applied to in-chiller water pumps too. Before we discuss some application design variables for chiller systems, there are a few more very important system operational requirements which must be discussed and understood. Every chiller I know of has a specific and mandated requirement for its chilled water flow rate. Manufacturers specify a mandated minimum GPM requirement and, this flow rate must be set correct and it must be constantly flowing through the chiller any time the chiller is operating. This mandated function is basically controlled by the design and application of the air distribution systems.

6.5 What's a By-Pass Valve ?

The end use of all the chilled water produced in a chiller, is to deliver it to an applied air distribution system (one or more fan coils). A chilled water piping system may be applied to a fan coil (or air handler) in several ways; 1- A Wild Coil. 2- A By-Pass Coil. 3- A Proportional By-Pass Coil. Figure 6.1 shows these three applications.

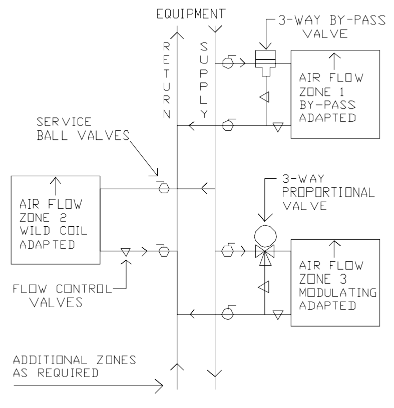


FIG 6.1 Load Zone Design Variations

1- a wild coil means that water is flowing through the coil all the time. This is normally used only for single air handler applications. Even if the blower is running all the time (constant air circulation), cooling will only be accomplished when the thermostat signals the chiller to operate. Some buildings (high rise apartments) by design and fan coil use (stack-on fan coils), are applied as wild coils due to limited thermostat options which typically just cycle a blower on/off to maintain room temperature.

2- a by-pass coil means that a 3-way by-pass valve has been added to the coil, to either direct flow through the coil, or to by-pass the coil totally. This allows for the maintaining of a totally correct and constant GPM flow rate which the chiller requires. Never a 2-way valve.

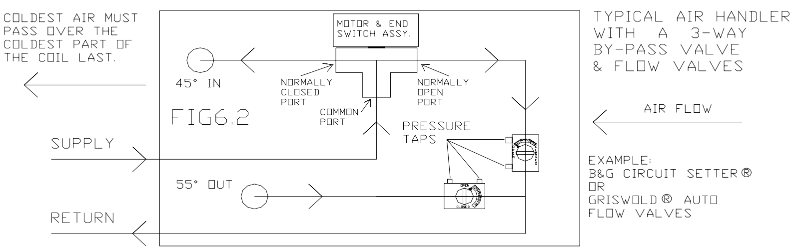
Three-way valves will add an extra PD factor for the piping system too. Its Cv value. Also, 3-way valves will require an extra flow control valve. Un-like the wild coil which only has one flow circuit to regulate (∇), a by-pass valve system will have two circuits to regulate due to the different PD of each circuit. The coil's flow rate has one PD factor and the 3-way valve's by-pass loop has another PD factor. The flow rate of each circuit must be identical.

3- a proportional by-pass coil is installed just like a by-pass coil, except that the operator head on the 3-way valve will be different. Instead of directing 100 % flow through the coil or by-passing the coil, this valve will now change flow paths in percentages. X amount through the coil and X amount by-passing the coil. This is typically used for controlling a specific air discharge temperature for dehumidifying and make-up air systems.

Any applied system could use any one of these methods, be it all one method or in any combination. Also note in figure 6.1, that the chilled water supply piping (coldest water) is entering the coil at the discharge air side of the coil. Coldest air must cross the coldest part of the coil for proper dehumidification, which also demands a proper chilled water temperature (45° F) and a proper water flow rate through the coil.

6.6 Flow Rate Controlling Methods

Water flow rates through a chiller and through cooling coils must be set properly if a system is going to perform properly and as designed. Figure 6.2 shows a couple of flow rate controlling methods (devices).



Water flow rate settings are typically performed by a pressure drop method. Gauges must read water inlet pressure, verses water out pressure and the difference is the PD of the flowing circuit. Manufacturers will provide you with the proper PD value of their chillers or fan coils; you just have to set a proper flow rate at start-up. You could install pressure gauges at each pressure reading point, or you could install Pete's Plugs® at each point and use a gauge adapter to obtain a reading. But, there is a better method.

There are special flow regulating valves on the market which may be manually set by a pressure reading right across the valve (pressure taps on flow valve) (e.g. B&G Circuit Setter®)[3]. There are also some automatic flow control devices available which will automatically control a specific flow rate (operating pressure at valve and GPM flow rate is required when order these valves) (e.g. Griswold® Auto-Flow Valves)[4].

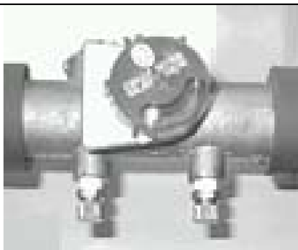
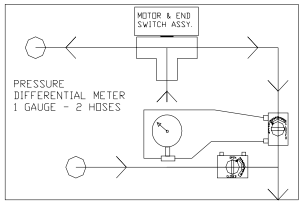


FIG 6.3 Special Flow Control Device



←Requires PD Meter

FIG 6.4 Pete's Plug® and Gauge Adapter

Figure 6.3 shows a close up of a special flow control device, highlighting the pressure taps right on the valve itself. A pressure differential meter must be purchased for connecting to the taps and obtaining a reading. Each manufacturer of these valves may have special adapters, but of three different manufacturer's valves which I have used, all adapters have worked on my meter. The manufacturer also provides a calculator wheel for referencing pressure readings and setting a correct flow rate.

Figure 6.4 shows a Pete's Plug®[5] and its pressure reading adapter which requires a pressure gauge. If physical pressure gauges are installed, or Pete's Plugs are used, a simple ball valve may be used for setting the flow rate of any given flow path (circuit). For any designed system, "IF" the piping system was sized properly, and the water pump is sized properly, there will always be a higher than required flow rate through all the applied equipment (chiller and fan coil). The flow control valve must be closed down to obtain a correct flow rate.

More information may be found in chapter 7 which will discuss flow rate settings at equipment start-up.

3- A product of the Bell & Gossett® Company, a division of ITT® Fluid Technology Corporation.
4- A product of Griswold Controls - Irvine, California.
5- Pete's Plug® is a registered Trade Mark of; The Peterson Equipment Co., Inc.

There is one other method of controlling water flow rates, which hydronic heating individuals have used for years with great success. This method refers to the installed piping system and it is called reverse return piping (RRP). The logic of this piping application is; All things being “Equal”, all load zones will receive equal flow. The first “Equal”, being equal lengths and sizes of piping. Figure 6.5 shows the basic logic of RRP.

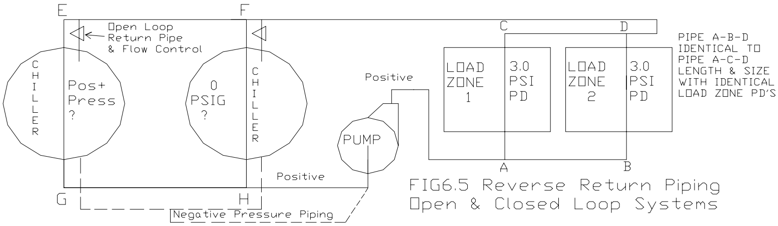


FIG6.5 Reverse Return Piping
Open & Closed Loop Systems

There is one major requirement for any piping circuit if RRP is going to be used and, if it will be expected to work. That is a 100% POSitive pressure circuit. This drawing highlights two systems; 1- A Closed Loop System and, 2- An Open Loop System (namely open in the chiller). Several piping installation and sizing requirements are also required if RRP is going to function properly; **1-** The first load zone (1) supplied by the supply water line (A), will be the last zone for the return water line (C). **2-** The last load zone (2, or 3, or 4) supplied by (B), will be the first to be connected to the return line (D). **3-** All piping from the initial supply splitting point (A), to the last return connection point (D), must be equal in size and length.

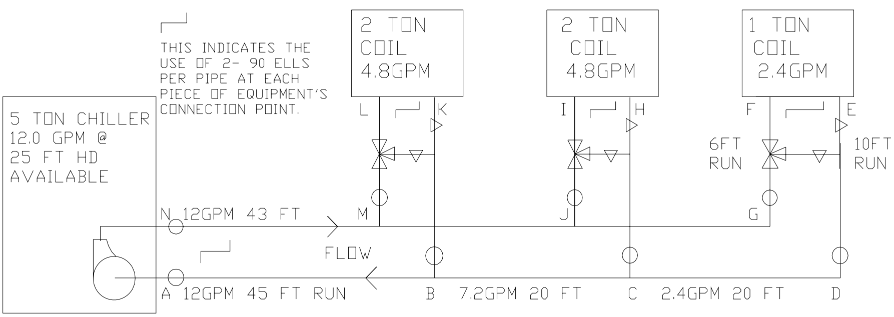
The pressure drop through pipe A-C-D, must be identical to pipe A-B-D. 4- All applied load zones must also have an equal pressure drop. 5- With all things being “Equal”, there will be an identical flow rate of water through all applied zones. This same logic applies to the chillers too. “IF”, they are closed loop positive pressure units and “IF”, they have equal PD values. But, what happens if the chillers are an open loop system. The returning water into the chillers will have open piping (a physical separation of the piping loop). Each chiller’s return line will have to have a flow control device to regulate a proper and equal flow into each chiller. Also, because a water pump will have to suck water out of the chiller (NEGative pressure piping), the pump’s suction piping must be designed as an equal distribution piping system (see dotted line). This means that there is an equal PD factor from the pump to all connected chillers, and the pump will suck water from all chillers equally.

Unfortunately, chilled water cooling systems cannot be applied using RRP in many instances. Due to their unique versatility and flexibility of being applied to many various sizes and styles of fan coils, equal PD values will be impossible to obtain. This means that many designed systems will have to use flow control devices at each and every fan coil.

6.7 Are We Ready to Design a System ?

Most manufacturers provide a lot of piping system design and installation literature for single chiller, single fan coil (air handler) applications. Many manufacturers, who provide water pumps in their chillers, also provide simple pipe sizing guidelines based on the supplied pump’s Ft Hd capabilities. But, more often, systems will be applied as multiple load zone and many will be multiple chillers too. This means you must learn and understand how to size a piping system and how to size a water pump. The logic of the sizing process is not hard to follow. This logic applies to any designed system, from a one on one system, to larger multiple systems. The main difference is that as a system gets larger and having more multiple factors, the sizing calculation process just takes a little longer to perform. Not harder, just more figures to add up. The system I have chosen to use for this sizing and design calculation is a single 5 ton chiller, being adapted to three load zones (2 - 2 ton loads and a 1 ton load).

6.8 Sizing Our First System



PD Calculation: Single Chiller – Multiple Load Zones JIT 200

Figure 6.6

MULTIPLE LOAD ZONE EXAMPLES:

This calculation will be for a single chiller having three (3) zones and it incorporates several new calculation factors; reduced pipe size requirements, fittings with new flow factor variables, three different flow rates and the farthest zone factor. Figure 6.6 highlights this system's design. We will calculate this system as an Open Loop System and a Closed Loop System. This will be done side by side to highlight the differences. Even though all installed piping items are not shown, they were discussed in the chapter 4 (4.15) and they will be calculated as if they were there.

1: LISTING ALL KNOWN VALUES:

A. Chiller Capacity = 5 Tons @ a Rated Flow of 12.0 GPM

B. Internal Chilled Water Pump's Rating = 25.0 Available External Ft Hd for pipe sizing purposes.

C. Three Load Zones (air handlers); 2 - 2 Ton Zones rated at 4.8 GPM each = 5.70 Ft Hd and 1 - 1 Ton Zone rated at 2.4 GPM = 4.40 Ft Hd (ft hd values per manufacturer's literature).

2: CHOOSING AN APPROPRIATE PIPE SIZE:

This designed system has 4 different flow rate requirements;

A. 12.0 GPM for the chiller and part of the initial main piping loop.

B. 7.2 GPM for the main piping loop between the first load zone and the second load zone (when the first load zone is supplied 4.8 gpm, this value is subtracted from the 12 gpm total).

C. 4.8 GPM for the first 2 load zones.

D. 2.4 GPM for the last part of the main piping loop and for the last load zone.

It is not necessary to use one pipe size for this system, and doing so would just increase the system's installed cost. We need to address each piping circuit which has its own specified flow rate and select an appropriate pipe size for the given flow rate. We must now refer to the friction chart (see A 6.1)[6] to choose an appropriate pipe size and we will refer to the copper piping information in the chart.

6- Appendix section at the end of this chapter.

Also, because we will be calculating an Open Loop and Closed Loop system side by side, we will only perform a calculation for one (1) appropriate pipe size. If your calculation was being performed for one system type only, Open or Closed, it would be highly advisable to perform a calculation for two pipe sizes. The minimum pipe size (per friction chart) and the next larger pipe size. This is especially important if you have to size a water pump too. A one size larger piping system could be more cost effective than a larger and more expensive special order pump. Many system variables will be added into and be pointed out during this calculation process. Whether the system is an Open Loop or Closed Loop, will not affect choosing an appropriate pipe size.

	SIZE	Ft Hd/100'
A. 12 GPM[7] - chiller's main loop piping (pipes A-B & M-N)	1 1/4"	3.38
B. 7.2 GPM - main loop piping (pipes B-C & J-M)	1"	4.50*
C. 4.8 GPM - piping to the 2 - 2 ton zones (M-L, B-K, J-I & C-H)	1"	2.70*
D. 2.4 GPM - piping loop for 1 ton zone (C-D-E & F-G-J)	3/4"	4.92*

(*) When a given flow rate is not listed, always use the closest listed flow rate which is the next highest listed entry. The PD values may be a little higher than a system will actually see, but if you were to down size a value, your calculation could provide a good end result, but the odds are against you that your pump would be able to do the job. If you must error, make sure it is in your favor. Doing it right the second time around costs money.

3: CALCULATING THE TOTAL FEET OF STRAIGHT PIPE:

(same for both systems)

There are two new factors to be considered here. First, are the three different pipe sizes, which mean three different Ft Hd values. Second, is the basic hydronic operational logic called "The Farthest Zone". As seen in the design drawing, the 1 ton zone is the farthest zone away from the chiller. This means that it will have the longest piping run to deliver its required gpm flow rate. "IF" the Total Piping System is sized right, and "IF" a proper PD calculation is made for all the piping and all the piping installed items, to guarantee a proper flow rate to and through the farthest zone, then every zone in-between the chiller and the farthest zone will also have a proper flow rate.

7- 12 gpm systems typically relate to a 1" piping system, but not typically for supplied pumps with Ft Hd ratings of 30 Ft Hd or less. This is an experience thing, and that is why a 1 1/4" main pipe size was chosen as the starting size.

The farthest zone logic is some times referred to as the Highest PD Zone. Any applied load zone, by design could potentially have a higher PD than the zone which is farthest from the chiller. The zone with the ***"highest calculated PD value"*** must be used for total calculation purposes. In this example, the farthest zone is the highest PD and therefore, the 2 - 2 ton zones may be eliminated from the calculation. However, the main line piping tees which are used to supply these zones must be calculated, because water flow must go through them to reach and flow through the farthest zone.

A. Pipe A-B = 45 feet & pipe M-N = 43 feet, which = a total of;	88 Feet of 1 1/4" Pipe
B. Pipe B-C = 20 feet & pipe J-M = 20 feet, which = a total of;	40 Feet of 1" Pipe
C. Pipe C-D-E = 30 feet & pipe F-G-J = 26 feet, which = a total of;	56 Feet of 3/4" Pipe

4: CALCULATING EQUIVALENT LENGTHS FOR SYSTEM PIPING ITEMS: (see A 6.2)[8]

Now we must start our calculation separation for an Open Loop System and a Closed Loop System. Also, since we have three different pipe sizes, we must do three different conversions.

1 - For the 1 1/4" Piping Items;	**Open Loop**	**Closed Loop**
A. Unions; not considered for calculation.		
B. 4 - 1 1/4" 90 ells @ 4.0 feet each =	16 feet	16 feet
C. 2 Pete's Plugs® (pressure/temp reading) = 2 tees - side connection (Std. Thru) @ 1.2 feet each =	2.4 feet	2.4 feet
D. 2 - 1 1/4" ball valves @ 0.8 feet each =	1.6 feet	1.6 feet
E. Flow Control Valve (none - flow is set at zones)		
F. 1 - Boiler Drain = side outlet tee @ 1.2 feet each =	N/A*	1.2 feet
G. 1 - Fill Assembly (ball valve + 2 boiler drains) 0.8 + 1.2 + 1.2 =	N/A	3.2 feet
H. 1 Relief Valve & 1 Expansion Tank = 2 tees @ 1.2 each =	N/A	2.4 feet
I. 1 - 1 1/4" x 1" x 1" supply tee = sudden contraction @ 1.8 feet each	1.8 feet	1.8 feet
J. 1 - 1 1/4" x 1" x 1" return tee = sudden enlargement @ 3.0 feet each	3.0 feet	3.0 feet
Total Equivalent Length:	**24.8 Feet**	**31.6 Feet**

(*) N/A = Not Applicable for specified system.

8- The Fitting Conversion Chart. Converts piping installed items to an equivalent length of straight pipe.

Finalizing the 1 1/4" Piping Calculation:	**Open Loop**	**Closed Loop**
Total Equivalent Lengths =	24.8 Feet	31.6 Feet
Plus Total Straight Pipe =	88.0 Feet	88.0 Feet
Total of Both = (round up all fractional totals)	112.8 Feet	119.6 Feet

Total Ft Hd = 3.8[9] X (1.13)* & (1.20)* = (4.29) & (4.56)

Always round off figures and ***Always Round** Up*	**5.0 Ft Hd**	**5.0 Ft Hd**

* Ft Hd is a per 100 ft value. 113 feet = 1.13 per 100

2 - For the 1" Piping Items;	**Open Loop**	**Closed Loop**
A. 1 - 1" x 3/4" x 1" supply tee =		
sudden contraction @ 1.2 feet each	1.2 feet	1.2 feet
B. 1 - 1" x 3/4" x 1" return tee =		
sudden enlargement @ 2.0 feet each	2.0 feet	2.0 feet
Total Equivalent Length:	**3.2 Feet**	**3.2 Feet**
Plus Total Straight Pipe =	40 Feet	40 Feet
Total of Both =	43.2 Feet	43.2 Feet
Total Ft Hd = 4.5 x .44 = 1.98 rounded up to =	**2.0 Ft Hd**	**2.0 Ft Hd**

3 - For the 3/4" Piping Items;	**Open Loop**	**Closed Loop**
A. 6 - 3/4" 90 ells @ 2.5 feet each =	15 feet	15 feet
(2 per pipe at coil, and 1 each at D & G)		
B. 3 - 3/4" ball valves @ 0.5 feet each =	1.5 feet	1.5 feet
(1 considered as flow control by E)		
C. 1 - 3/4" tee (by-pass line) std. thru @ 0.8 feet each =	0.8 feet	0.8 feet
D. 2 - 3/4" tees (air vent & boiler drain) @ 0.8 feet each =	N/A	1.6 feet
(Std. Thru tee. Closed loop items not shown)		
E. 1 - 3/4" x ½" supply coupler at coil =		
sudden contraction @ 1.0 feet	1.0 feet	1.0 feet
F. 1 - 3/4" x ½" return coupler =		
sudden enlargement @ 1.5 feet each	1.5 feet	1.5 feet
Total Equivalent Length:	**19.8 Feet**	**21.4 Feet**

9- PD value for specific pipe sizes obtained from piping friction chart.

Finalizing the 3/4" Piping Calculation:	**Open Loop**	**Closed Loop**
Total Equivalent Lengths =	19.8 Feet	21.4 Feet
Plus Total Straight Pipe =	56 Feet	56 Feet
Total of Both =	75.8 Feet	77.4 Feet
Total Ft Hd =		
4.92 x (.76) & (.78) = (3.73) & (3.83) rounded up	**4.0 Ft Hd**	**4.0 Ft Hd**

5: System Strainer Calculation:	**Open Loop**	**Closed Loop**
A. 1 - 1 1/4" Y Strainer (PD by manufacturer)	N/A	**3.0 Ft Hd**

6: PD OF THE THREE WAY VALVE:

This system has three 3-way valves, but we only need to consider the valve on the farthest zone. Assuming a manufacturer's Cv rating for a 3/4" valve @ Cv 3.5. The designed flow rate for this zone is 2.4 GPM, which is less than 3.5. This means if Cv3.5 = 1 PSI, 2.4 will be less than 1 PSI. But we should consider it as at least being 1 PSI. Remember the formula; 1 PSI = 2.31 Ft Hd.

A. 1 - 3/4" 3-way valve = **2.31 Ft Hd** **2.31 Ft Hd**

7: FINALIZING THE SYSTEM'S FT HD CALCULATION:
Now, all that is basically left, is to list all of the Ft Hd values (known & calculated), add them all up and see what the resulting value is.

A. CHILLER; not required, subtracted from pump's total Ft Hd.	Open Loop	Closed Loop
B. LOAD ZONE; this is the farthest zone (the 1 ton zone)	4.40 Ft Hd	4.40 Ft Hd
C. 1 1/4" PIPING & PIPING ITEMS; calculated in items 3 & 4	5.00 Ft Hd	5.00 Ft Hd
D. 1 "PIPING & PIPING ITEMS; calculated in items 3 & 4	2.00 Ft Hd	2.00 Ft Hd
E. 3/4" PIPING & PIPING ITEMS; calculated in items 3 & 4	4.00 Ft Hd	4.00 Ft Hd
F. 1 1/4" STRAINER	N/A	3.00 Ft Hd
G. 3-WAY VALVE	2.31 Ft Hd	2.31 Ft Hd
Total For All Entries:	**17.71 Ft Hd**	**20.71 Ft Hd**
Plus Antifreeze Correction Factor @ 30 % = 1.12 times each = (See chart in appendix section A 6.3)[10]	**19.83 Ft Hd**	**23.19Ft Hd**
Water Pump's Total Available Ft Hd =	**25.0 Ft Hd**	**25.0 Ft Hd**

10- When you have an existing water pump (manufacturer supplied), you have the responsibility to figure in the antifreeze weight factor (viscosity), to ensure that your calculation takes this PD value into account too.

Since both calculations resulted in a value which was ***less than*** the available Ft Hd value, your pipe sizing choices were appropriate and the pump will do the job. If either one, or both calculations proved to be higher than the pump's available Ft Hd, you would have to decide how to correct this issue. Here are some options; 1- All or part of the pipe sizes would have to be increased to reduce the total PD value (e.g. change 3/4" pipe to 1" pipe). 2- A small booster pump could be added to the field installed piping system. 3- The pump supplied in the chiller could be removed and an external pump, properly sized for the system's total calculated PD, could be purchased and is field applied.

SIZING AN EXTERNAL, SEPARATE PURCHASED PUMP:
If you did have to purchase an external pump, or maybe you even chose to do it that way any how, the above calculations have already given you 90% of that pump's requirements. The only thing left to add into the calculation, is the chiller's PD value and a little safety slush factor. Yes, it's better to be safe than sorry.
A. K. A. Doing things right in the first place.

PUMP SIZING:	**Open Loop**	**Closed Loop**
A. Total System Ft Hd Calculations =	19.83 Ft Hd	23.19 Ft Hd
B. Chiller's PD Factor[11] =	5.00 Ft Hd	12.0 Ft Hd
B. Plus a Slush Safety Factor =	5.00 Ft Hd	5.00 Ft Hd
Total for Both =	**29.83 Ft Hd**	**40.19 Ft Hd**
Rounded Up to the next highest 5.00 rating increment =	**30.0 Ft Hd**	**45.0 Ft Hd**

Water Pump for the Open Loop System = 12.0 GPM @ 30.0 Ft Hd
Water Pump for the Closed Loop System = 12.0 GPM @ 45.0 Ft Hd

I won't guarantee you that I may not have missed some small item, but I do know that this calculation is totally accurate enough to perform properly. The installed system is performing great. Also, the added slush factor in the pump sizing will certainly cover small errors, that's why it's there. Remember, too much Ft Hd can be regulated down, but to little means trouble and added expenses. In the appendix section at the end of this chapter, you can also find a PD Calculation Form. This form basically outlines the sizing values which you must enter to perform a PD calculation. You may find it useful.

11- The PD entries for the Open and Closed Loop Chillers are from a manufacturer's specification sheet for the chillers. Both chillers are gas-fired. Open Loop courtesy of Servel. Closed Loop courtesy of Cooling Technologies.

Calculating any designed system's PD requirements are no harder than the example we have just done. It could take longer to perform due to a larger designed system (more chillers and/or more load zones), and it could take longer due to calculating two different pipe sizes at the same time. Remember, calculating two different pipe sizes will help you to determine whether it is best to; 1- increase all or some of the pipe sizes. 2- add a small booster pump, or 3- size and purchase a separate pump. The two pipe sizes can also be very important for purchasing a separate pump. A smaller pipe size will require a larger pump than the next larger pipe size would. Finally, having to reference many tables and charts for performing a calculation, it would sure be a lot easier and faster to reference two pipe sizes at the same time.

The last part of this chapter will provide information on various application styles, and how various water pumping methods may best be incorporated into an application. Should any of the following applications which I will be illustrating and discussing, create any special PD factors which have not been already discussed, I will point them out for each application being discussed. This will most likely be for multiple chiller applications, rather than multiple load zones.

6.9 Application Variations (PUTTING PIPING AND PUMPING TO WORK)

6.9.1 Reverse Return Piping: Figure 6.7 shows a typical layout drawing for a system being applied as a RRP piping circuit for the load zones.

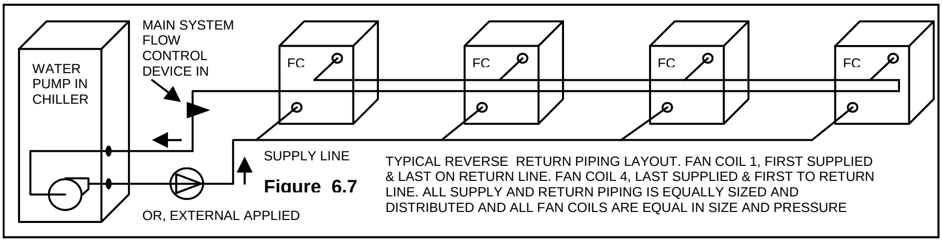


Figure 6.7

As noted earlier for RRP, if all things are equal for the load zone's piping distribution circuits and all load zones have equal PD values, all zones will see equal water flow. But, a main line flow control device will still be required to set a proper system flow rate. If the piping system is sized properly, the system pump will provide a higher than required GPM.

Every chiller manufacturer has a mandated minimum flow rate which is required to flow through the chiller when it is operating. They also have a maximum acceptable flow rate. Even though all load zones are receiving equal flow, the total flow of all loads may not be acceptable for the chiller. The main line FCV must be shut down some to set a proper and acceptable rate.

RRP is also an option for multiple chiller applications (closed loop systems only) and this is shown in figure 6.8.

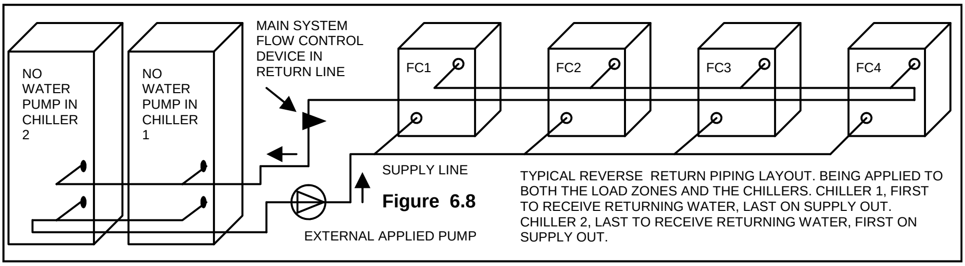


Figure 6.8

Note that there are no water pumps in the chillers now, but a main system flow control valve is still required to set a proper flow rate per equipment specifications and system design. Figure 6.9 shows another option to the RRP which was shown in figure 6.7.

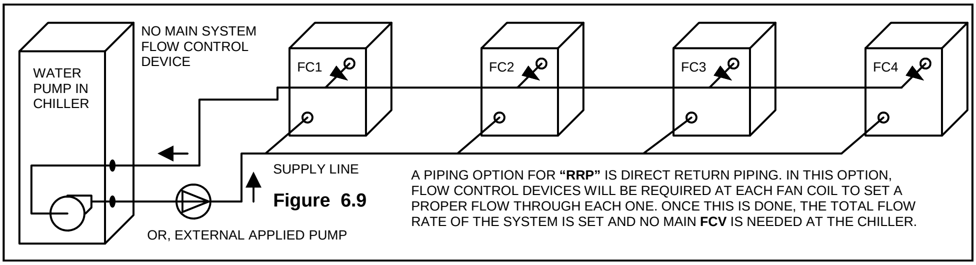


Figure 6.9

You always have the option of using a direct return piping system too. If this option is used the logic of having all equals at the load zones has now flown out the window. For direct return systems, each load zone will require its own flow control valve to set a proper flow rate. Remember, the total set flow rate of all zones must satisfy the chiller manufacturer's flow requirements for the chiller. There is always some minor flexibility for a load zone's flow rate, but chillers are not forgiving and their flow rate must be correct. With total flow being set at the load zones, the main FCV will not be required.

Figure 6.10 shows another option for RRP, which is now addressing the chillers.

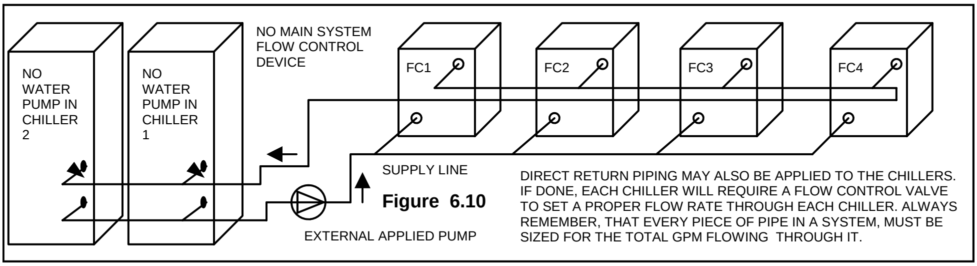


Figure 6.10

Direct return piping (DRP) can also be applied to chillers, but this too will now require a flow control valve at each chiller. Once a proper flow rate has been set for each chiller the system's total flow rate is set, and no main system FCV is required. If the load zones are piped as an RRP system, the flow settings are now done. "IF" the load zones will also be piped as a direct return system, than they too will require their own FCV as noted in figure 6.9. As long as all the rules of piping are followed exactly, RRP and direct return logic can be mixed, but only for one area (e.g. chillers = DRP, load zones = RRP) (chillers = RRP, load zones = DRP) (Or, same design for chillers and load zones).

6.9.2 New PD Calculation Factors

RRP piping will add a new factor for performing a pressure drop calculation. The total main loop piping system is now much longer than a direct return piping system. The total length of the main piping loop must be part of the PD calculation. The side supply/return lines to only the farthest fan coil needs to be added and the PD of one fan coil (RRP assumes that all fan coil PD's are equal). RRP mandates equals. Second is the use of two chillers. The chillers are piped in parallel and only the farthest chiller (extreme ends of system. Farthest chiller from farthest zone) needs to be calculated along with the extra piping to the farthest chiller. This too assumes that both chillers have equal PD values. For direct return systems using two chillers, and should one chiller have a higher PD than another, the chiller with the highest PD value must be used along with the longest piping circuit. ***Note:*** Chillers piped in parallel only use one (1) chiller PD value. Chillers piped in series, must have the PD values of both chillers added together. Series adding logic applies to load zones too, if applied as such.

6.9.3 Booster Pumping, a Neat Alternative

Booster pumping can be an in-expensive and neat alternative to removing a manufacturer's supplied in-chiller pump. Why purchase a larger and definitely more expensive pump to replace the in-chiller pump, when a small booster pump can handle the in-chiller pump's deficiency, not to mention that you will now have an extra pump lying around (removing in-chiller pump).
Figure 6.11 highlights the use and application of a booster pump.

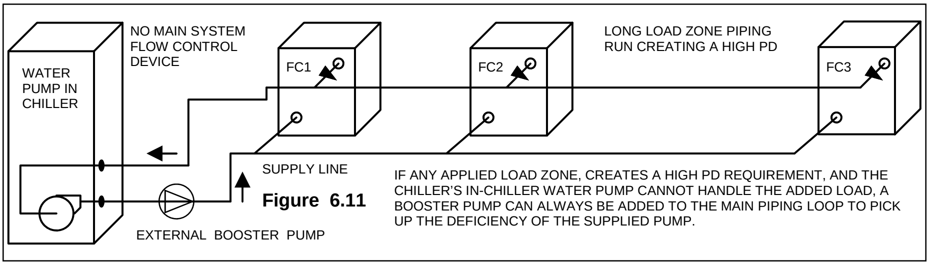


Figure 6.11

Hopefully you have a good and proper PD calculation for the designed piping system (e.g. 40 Ft Hd). The manufacturer has provided you with the in-chiller pump's available Ft Hd (e.g. 25 Ft Hd). The booster pump only has to make up the difference (e.g. 40 - 25 = 15 Ft Hd). While a 15 Ft Hd pump (same GPM rating as chiller's pump) may now match the total calculated PD, it is always best to have a little extra. The booster pump should be rated at; xx GPM @ 20 Ft Hd. Remember, extra can always be throttled down by a flow control valve, but to little means a bigger pump. Figure 6.12 shows an alternative pumping logic for the booster pumping requirement shown above.

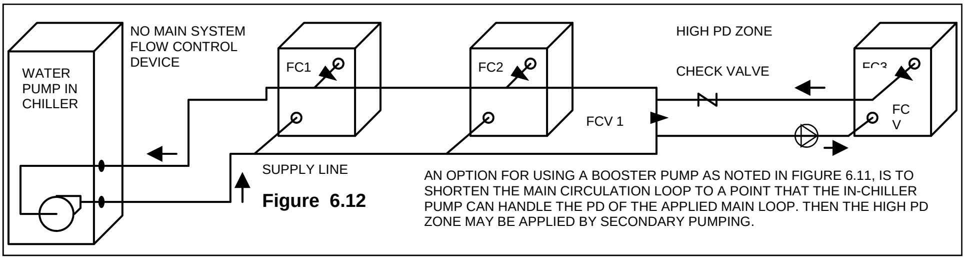


Figure 6.12

Instead of running the main piping loop all the way to the high PD load zone, size and design the main loop around the closer fan coils (1 & 2). Be sure this new loop's calculated PD can in fact be handled by the in-chiller pump. Then the high PD zone may be applied by secondary pumping.

A flow control valve (FCV 1) will be required in the main loop to set a flow rate equal to the GPM requirements of fan coil 3. Without this FCV in the end return loop, you would not be able to set a good and proper flow rate through the chiller. More information on secondary pumping will be provided later in this chapter.

6.9.4 Booster Pumping / Constant Circulator

Chiller systems are noted for their adaptability to multi-load zone systems. The question now becomes, how to interlock the chiller's operation with each load zone. Many chiller systems and chiller/boiler combination systems have been designed to provide a constant circulating water loop and the load zones only require blower cycling by a thermostat. Many fan coil manufacturers also provide thermostats with their fan coils and a change-over sensor for signaling the stat whether it should be operating in the heating mode or the cooling mode (sensor monitors water piping temperature). Many times, multi-zone systems can create a high PD factor too, and this can require a booster pump. The booster pump may also be adapted to act as the constant circulator. This operational logic is highlighted in figure 6.13.

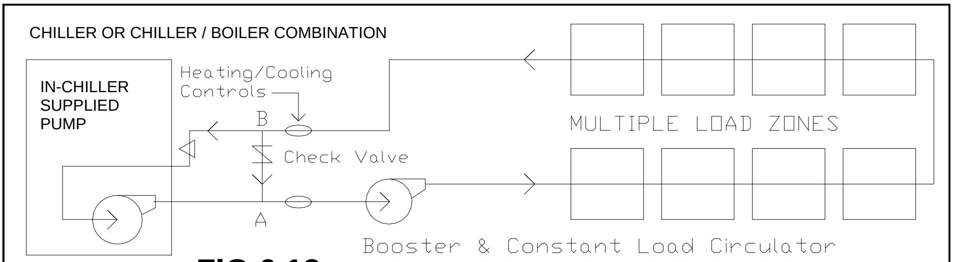


FIG 6.13

The booster/circulator is wire to operate all the time. When the in-chiller pump is operating, water pressure at point A is higher than point B. All water flows through the chiller and then through the load zones. When the main loop's water temperature is at design temperature (remote bulb controller operated), the chiller shuts off, but the booster/circulator continues to operate. Now, water pressure at point A becomes lower than point B, the by-pass line's check valve opens and the water system is constantly circulated through the load zones and across the seasonal controller's remote bulbs. This has been a highly applied design for multiple apartments, motel/hotel rooms and multiple offices.

6.9.5 Constant Circulator Only

Some multiple load zone systems may not require a booster pump, but they still require a constant circulating water circuit. Some chiller manufacturers do not want water flowing through the chiller when it is not operating and cooling the water. For this need, a system may be designed around a constant circulator only. This pumping logic is highlighted in figure 6.14.

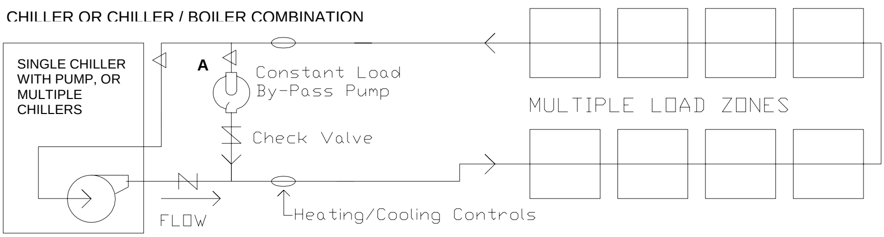


FIG 6.14 Constant Load Demand

A = A FLOW CONTROL VALVE JUST FOR THE BY-PASS LOOP. FLOW RATE OF BY-PASS SHOULD NEVER EXCEED MAIN SYSTEM RATE.

The constant circulating pump is basically sized for the calculated PD of the total system, minus the chiller's PD value. A bypass loop is added between the returning water line and the supply line and the pump is installed in this bypass line. When the main system's water pump is operating (in-chiller or field adapted), its control circuit will energize a control relay (NC contacts of a SPDT relay) for the by-pass pump, breaking the B-P pump's operating circuit, turning the B-P pump off. When the main system pump shuts off, the B-P pump's control relay will be de-energized and the B-P pump's operation will start again. ***Note:*** "If" a chiller manufacturer is 100 % agreeable that water can flow through their chiller all the time, even if it is not operating to cool the water circuit, then the main system pump may be wired and controlled to be the constant circulator too, in lieu of the B-P pump.

6.9.6 Multiple Chillers - Multiple Loads

Many applied multiple load systems will require larger chiller systems (10 tons and up). Many chiller manufacturers do not produce a single large chiller, but their small chillers can be manifolded to produce larger systems. Some manufacturers even produce these larger manifolded systems themselves. Larger tonnage, manifolded chiller systems may be applied in several ways. The following figures highlight some of these application variables.

Figure 6.15 highlights a manufacturer’s factory built 15 ton manifolded chiller system. This system is being applied to four (4) dedicated load zones (zones which will typically be using a true full system capacity).

Please note the equal distribution piping system under the factory packaged chiller system. These are Open Loop Chillers and a special suction piping system was designed to ensure that the field added water pump (sized for system’s calculated PD and purchased separately) would in fact draw water equally from all chillers (all suction piping operating in a negative pressure). ***Note;*** Pump located close to chillers with very few items in the suction piping. Good NPSH applied.

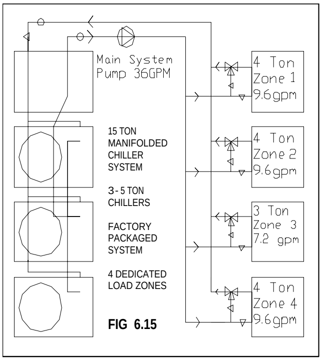


FIG 6.15

Figure 6.16 shows a very close and similarly designed system, as was shown in figure 6.15. But there are some major differences and a new pumping logic being applied. The three (3) 5 ton chillers are now Closed Loop Chillers which have been field manifolded on the job site. They are piped as a direct return system, having flow control valves at each chiller. This chiller manufacturer does allow constant water flow through the chillers and one single primary system pump has been applied for the main piping loop.

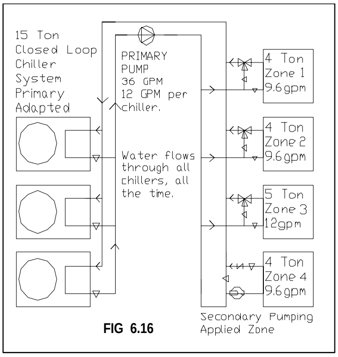


FIG 6.16

A major change for this system is load zone 4. This zone is a part time load which will only be cooled if the load zone area is being occupied (special use area). This load zone is being secondary pumping applied, because of its limited use. Why circulate water through a zone which is seldom used. Circulation itself can add in a little load factor. Also, if you add up all the loads of each zone, you will get 17 tons of potential load zone demand being cooled by a 15 ton system.

The neat aspect of a chilled water cooling system is that it has many application and operational variables which no other system can offer; 1- One chiller system can be easily adapted to many load zones. 2- Load zone operational demands may be tailored to any main system. 3- Applied pumping variables enhance system designing. 4- Larger total loads may be adapted to smaller chiller capacity systems (occasionally used load zones). 5- The redundancy of large multi-load zones enhances chiller down sizing (not every zone will be calling at the same time). A percentage will always be off, while others are calling. 6- Staging of a multi-chiller system increases efficiency and operational savings. Figure 6.17 highlights a unique pumping variable for chiller staging which aids in operational savings and efficiency loss (secondary pumping, using in-chiller supplied pumps).

Every multiple load zone system will have a wide variable in its total load demand for any given day of the cooling season. Total cooling demand will normally occur, only on the hottest of days. As the outdoor temperature falls, and as personal cooling comfort temperatures change, load demand on the chiller system will be reduced. Staging chillers on and off as load demand rises and falls is an important efficiency factor.

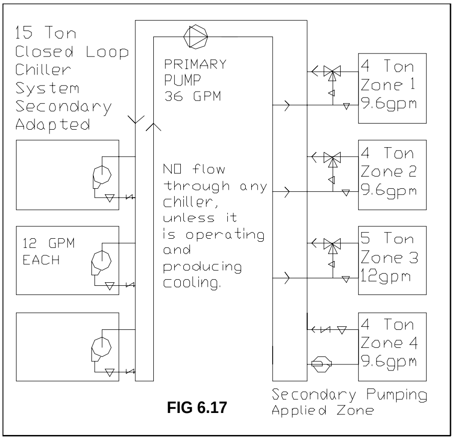


FIG 6.17

Also, if water flow through a chiller can be stopped when cooling is not required, this too will increase efficiency and savings. When a chiller sets idle for a long time, and having water flowing through it all the time, the chiller itself may become a minor load on the system. Last, some manufacturers do not want water flowing through the chiller all the time. This is where a Primary/Secondary Pumping system can really shine. Multiple Chillers, Multiple Load Zones, Primary/Secondary Pumping, Load Zone Diversity, Dedicated Loads verses Part Time Loads, ALL add up to one totally unique and applied system which only a Chilled Water Cooling System can offer for your customer’s air conditioning comfort. Sounds like that great flexible and versatile hot water heating system you just installed, doesn’t it?

Win or Loose, You Decide ?

A dealer I know was working with an engineering firm on a large home which was going to require 25 tons of dedicated cooling equipment. Three 5 ton systems were required for the general cooling requirements of the home, and the other two 5 ton systems were to be used for the quite large combination living room/great room when the home owner was entertaining guests (big parties). The dealer ask the engineer why he wouldn't consider a chiller system, a 15 ton staged chiller system. When the home owner was having their parties, normal cooling water could be diverted to two 5 ton air handlers applied just for this party area, and when the party was over, it's back to normal cooling again. As much sense as this made, the engineer totally balked at the idea due to a previous bad experience with a chilled water system. After the job was finished and all 25 tons of dedicated cooling equipment was installed (5 single and independent 5 ton systems), this same dealer ran into the engineer again one day. The engineer said to him, "You remember that large home you tried to talk me into using a chilled water system for?", "Well, in retrospect, I really think your idea would have been the best way to go!" The dealer smiled to himself as he quietly went on his way. You could be a winner too, if you would smartly get involved with chilled water cooling systems.

6.9.7 Chiller Capacity verses Load Demand

Another neat aspect of a chilled water cooling system and multiple load zones, is that in many instances a smaller cooling system may be applied to a larger potential load. As noted above, the home really only required a 15 ton chiller system, but there was a potential need for 10 extra tons of cooling (special purpose cooling). The flexibility and adaptability of a chilled water piping system, can really provide total installed cost savings, when knowledge and know-how are designed into a system. Then, when you factor in a versatile Primary/Secondary Pumping System, there's no limit to the design and application flexibility of a hydronic applied system.

The next two figures; Figure 6.18 and 6.19 show a very basic drawing of some general system designs where the chiller's capacity is less than the designed system's load demand. They also point out how primary/secondary pumping may be applied to enhance the effectiveness and the efficiency of the system.

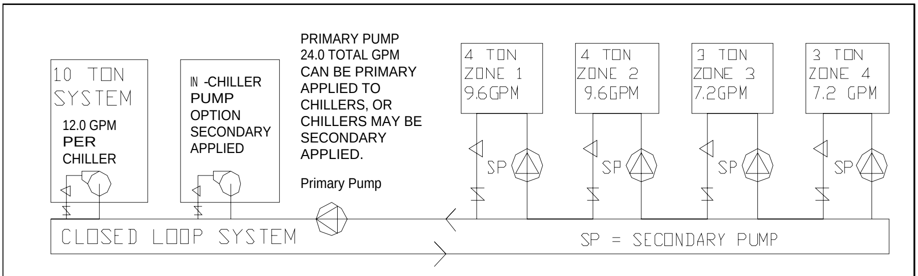


FIG 6.18

Figure 6.18 shows a 10 ton chiller system being applied to a 14 ton load. For a multiple load zone system, the odds are that at least one load zone area will be off when the other three are demanding load. This diversity factor will also increase as the number of load zones is increased. There are several methods which may be used and applied for water pumping this designed system; 1- first, there is no way that this system could be properly applied by a single pump. One part of the system (chillers or load zones) must be applied by secondary pumping. Each one has a different total flow rate requirement. 2- the primary pump could have been the only main system pump, directly circulating the main loop and through the chillers too. 3- the chillers could also have been adapted by secondary pumping, removing the chillers as a potential load themselves when they are idle. 4- the chillers would have to be applied by secondary pumping if the manufacturer will not allow constant flow through the chillers. 5- the load zones must be applied by secondary pumping if the main loop's primary pump also circulates the water through the chillers. 6- if the chillers are secondary pumped, the main loop's total GPM could be increased to match the load zone's total GPM requirement and the load zones could now be directly circulated by the main pump. 7- if option 6 was applied, this would require a larger size main pump and a larger size main piping system. Also, each load zone will now require a 3-way by-pass piping application. Every designed system has many pumping and application potentials. Some offer easy alternatives and some offer added expenses (option 6 & 7).

Chilled water cooling systems, for small stand alone multiple manifolded chillers, are typically applied from 10 to 50 ton systems (2 to 10 chillers). Figure 6.18 featured a 10 ton chiller system, but figure 6.19 features a larger potential applied system.

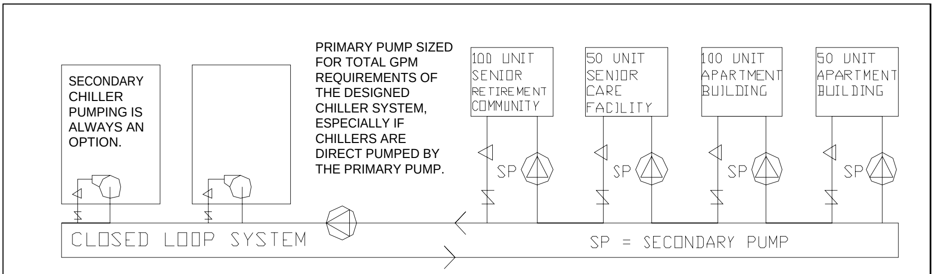


FIG 6.19

Many multiple load zone applied systems, have very low cooling loads per zone, due to the load zones sharing common interior walls in a building. Also, building hallways are typically handled by their own system due to make-up air requirements for these building styles. This means that the majority of the load zones will only have one exterior wall exposure. Chilled water cooling systems are very popular for these applications just due to the low, per room load demand. This can typically be less than ½ ton per applied zone. A 100 unit apartment building can normally be handled by a 50 ton chiller system. Then, if desired, a 20 to 25 % load diversity factor can be added in, and the end result could be a 40 ton chiller system. Another factor which I have seen many times and no one ever calculated this into the design criteria, is that many systems are applied for senior citizens living facilities. Seniors are freezing at 70 degrees and they are comfortable at 80 degrees. Quite a load demand difference here. If a building is going to be dedicated to senior housing, chiller capacity may be down sized considerably. I know of many buildings which have been up-dated (new chiller replacements required), and many have seen as much as a 30 to 40 % reduction in total cooling capacity.

As you should have noticed by now, a chilled water applied cooling system can be one of the most versatile and advantageous systems, through the design flexibility of a hydronic applied system. There is really no end for the designing of these unique systems, save your knowledge and understanding of applying water pumping methods. Primary/Secondary Pumping, by far, offers a designer the most flexibility and a potential for giving a customer that specific and tailored system which offers true and total comfort, high efficiency and the highest potential for operational savings. Primary/Secondary pumping does create some pipe and pump sizing issues which are not common to single pump systems, and this must be mentioned.

6.9.8 Primary/Secondary Pump & Pipe Sizing

Where ever primary/secondary pumping (P/SP) logic is used and applied, it simply means that each water circuit which has its own dedicated pump, must have a PD calculation performed per pumping circuit. Sizing a piping circuit for P/S systems, is no harder than a single pump system. The PD calculation logic is the same, you just have more circuits to perform a calculation for. You just need to make sure, that every piece of pipe and every piping circuit installed item, per pumping loop, are included in a circuit's PD calculation. Whether it's a primary pump, a secondary applied pump, or a manufacturer's supplied pump, there are several factors to be considered; 1- P/SP offers the highest design potential for keeping all piping loop sizes to the bare minimum. 2- making good use of a manufacturer's in-chiller pump, will reduce the primary pump's size. 3- the piping tees which connect to a secondary side circuit, are calculated for the circuit in which fluid will be flowing straight through the straight run of the tee. 4- as the number of secondary applied circuits increase, the primary pump's size will decrease (Ft Hd requirement). 5- pipe sizing for any secondary pumping circuit, is basically only dependent upon the total GPM requirements of a given circuit. 6- if a primary pump's application includes the chiller's circuit (s), the PD of both must be calculated for pump sizing purposes. 7- if a primary pump's application includes any or all of the load zone's circuits, all such applied circuits must be part of the primary pump's sizing calculation and the primary loop's pipe sizing. 8- if a primary pump is only applied for the main circulation loop, the pump will be sized for the designed flow rate of that loop.

Small pipe sizes, small pump sizes, no chiller load loss during idle operation, no load loss for load zone if not operating, diversity of chiller operation, diversity of multiple loads, maximizing on efficiency and operational costs, all add up to a unique chilled water cooling system. Then, when you factor in the versatility and flexibility of a Primary/Secondary applied system, there is no end to what one may accomplish. Of course you already know this, because you have been giving this same kind of efficiency to your customers for years, with those uniquely adaptable hot water heating systems you've been designing and installing. Just to round out your knowledge of water pumping variables, I have a few more pumping styles to show you and to discuss. Who knows, these too may come in handy some day.

6.9.9 Water Flow Rate Variables

Small tonnage, stand alone chillers are not available in as many size variables as Freon systems are. There may be times when you have a total load zone demand which is less than an available chiller system's capacity (e.g. 4.5 ton load and a 5 ton chiller). Or, you could have a total load zone demand which is slightly greater than a chiller's capacity (e.g. 5 ton chiller and a 7 ton load). Figure 6.20 highlights one of these potential applications.

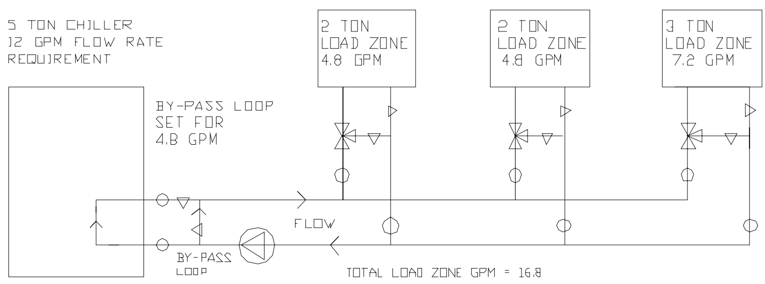


FIG 6.20 **Chiller capacity less than total load zone demand**

The important item which must always be noted and remembered for chillers, is that their water flow rate requirements ***must always*** be correct and proper for any application.

The 5 ton chiller in figure 6.20, has a 7 ton applied multiple load zone system. As designed and applied, each load zone must have a correct flow rate through the zone and all of them add up to a total of 16.8 GPM. This flow rate is too high for the chiller which requires a 12 GPM flow rate. This design is best applied by using a single field applied water pump and having a by-pass flow loop added to the piping system. The by-pass loop will be flow controlled for a 4.8 GPM flow rate and when added to the chiller's 12 GPM flow rate, the total system will have its proper 16.8 GPM flow rate. The water pump is sized for 16.8 GPM, plus the PD of the chiller, the piping system and the load zone with the highest calculated PD. ***Note:*** *"IF" the load zone was one single load, the above logic will not work for good cooling. A 10 ton chiller system (or 8 ton if available) would be required, because a single load could demand full load capacity* (multiple load zones = diversity in load demand).

Figure 6.21 highlights an application where the chiller's capacity is greater than the total load demand of all applied zones.

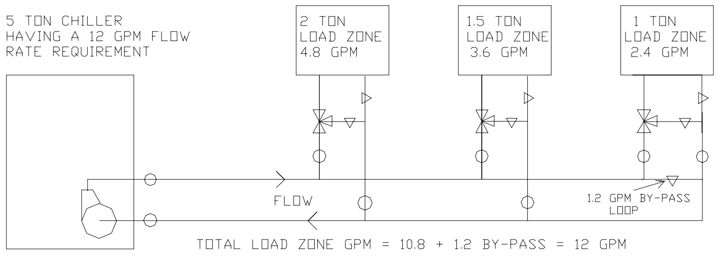


FIG 6.21 **Chiller capacity greater than total load zone demand**

Some load zones can be flow rate sensitive if they are to perform properly. Many designed and applied loads demand a specific water flow rate, and even the entire system may require this too.

There are basically two options here; one is easy and one requires a by-pass loop. 1- "IF" the other load zone's GPM requirements are not critical, the flow rate of each zone may be increased a little to pick up the 1.2 GPM shortage. 2- "IF" all load zones' GPM requirements are critical, a by-pass loop will have to be added to account for the chiller's mandated 12 GPM requirement. This same logic could be applied to a single load zone which has a smaller flow rate requirement than the applied chiller. ***Note:*** *Chillers function a little different than Freon systems, in that the chiller is cooling a circulating water system. Smaller loads can cause chiller short cycling and for this reason, some chiller manufacturers even require a minimum fluid capacity for a system (field added storage tank). This storage tank logic is a good application idea for any system being applied as above.*

There is one last water flow rate variable to discuss and that is called a "No Flow Condition". This application variable is not typically seen for comfort cooling systems, but it is highly used for process cooling applications. Just in case you do get seriously interested in chilled water cooling systems, you may come across this application potential some day, and it would be ashamed to have to turn the job down. How many times have you passed a dry cleaning establishment (there are a lot of them)? Did you know that dry cleaning machines have a cooling requirement? Many, many companies have production equipment which also has cooling requirements. So, if you're interested, here's a little info on these systems.

Figure 6.22 shows an application design drawing for an applied cooling load which has a low to no flow operating condition. This means that the cooling load may require a full flow rate at one point in time, but due to the operational requirements of the applied load, that rate may be reduced considerably and it may even stop totally. This creates several critical system issues; 1- the chiller's flow rate must be set correct and nothing in a system should cause a change in this mandated flow rate. 2- the load zone having a flow rate variable condition, must be applied by a secondary pumping circuit (the primary loop's flow rate [chiller] will not be affected by the application of a secondary loop). 3- a water pump must be properly sized for the secondary loop. 4- due to the potential of a no flow condition, some means of preventing a no flow condition through the secondary pump must be provided (pumps cannot run dead headed, with no flow. This will damage the pump).

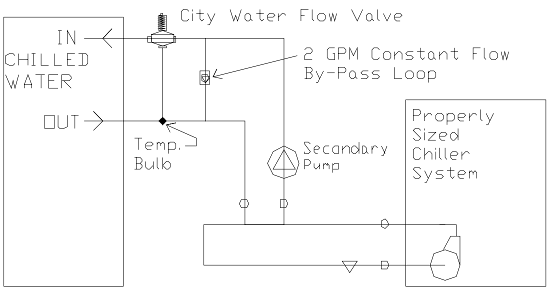


FIG 6.22 Low to No Flow Condition

Depending upon system size, this is an ideal application for having an in-chiller pump and making it the primary pump. The secondary loop for the cooling load, will have its own pump and some where near the load, a by-pass loop will be installed.

This by-pass will have a fixed 2 GPM flow control to maintain a minimum flow rate for the secondary pump. Even if the flow through the load were to stop totally, the pump would still be circulating some water to protect the pump. Many process cooling loads have city water valves right on the equipment. This controls water flow through the load based on operational load conditions and the leaving water's temperature. So, the secondary loop will be designed and applied just like a city water supply. In order to do this, the equipment manufacturer's specifications must be consulted for the process cooling load. Many process cooling loads do not typically supply a chiller tonnage requirement, a GPM requirement, or a PD value for the equipment. They normally provide an operational GPH usage (gallons per hour of city water usage). This is typically the maximum amount of water which will be used up for any given full hour of operation.

The rest of the information is obtained from a typical city water supply (the pressure [Ft Hd] and temperature). Typically, a city water supply will be delivering water under a pressure which is in the area of 30 to 40 PSIG (30 times 2.31 Ft Hd = 69.30 or 70 Ft Hd). The typical temperature of city water is in the area of 45 to 55 degrees. Chiller systems are normally designed for a 45 degree delivered water temperature. Process cooling loads (equipment requiring chilled water as a heat rejection medium) may provide a total heat rejection value, and some provide a GPH value if they have a manufacturer supplied city water valve on the equipment. A heat rejection value can easily be divided by 12,000 btuh per ton of cooling for system sizing, or the GPH value may be converted into a GPM value. If a process load specified a GPH value of 600 (being 600 gallons of discharge waste water per hour of operation), you will divide 600 by 60 minutes to get a typical GPM usage value (600 ÷ 60 = 10 GPM). We know that cooling is based on a GPM factor too, 2.4 GPM per ton of cooling (10 GPM ÷ 2.4 GPM = 4.16 tons, or a 5 ton chiller system). You now know that a 5 ton chiller will be required. You now know what the water pump's size should be (10 GPM @ 70 Ft Hd). The only item left is the by-pass loop. Because this loop will always have water flowing through it, it must be added to the water pump's sizing requirements (10 GPM + 2 GPM = 12 GPM).
SO the pump really needs to be; 12 GPM @ 70 Ft Hd.

There may be other requirements and/or adjustment factors which can only be obtained from a manufacturer's literature for the process load.

The chiller system will be controlled to operate and to maintain a constant flowing water circuit (primary loop) with a controlled temperature range of 45 to 55 degrees. The secondary pumping loop will be controlled to operate constantly when ever the process load is operating. As the process load demands cooling, chilled water will flow through the load and its flow rate through the load will be controlled by the city water valve. The secondary pump will always provide a proper operating pressure for the cooling water and its operation will not be affected by any change in water flow through the load. Also, the secondary loop's operation cannot affect the operation of the primary loop which is keeping the chilled water cool based on total load demand. If, for any reason (typical usage and operation of process load), the secondary loop's water flow stops totally through the process load, the by-pass loop providing a constant 2 GPM flow, will prevent the water pump from becoming damage due to a dead headed operation (a no flow condition through pump).

6.9.10 Process Cooling Variables

All process cooling loads, are not as easy and simple to apply a chilled water cooling system to, as the city water method just discussed. Some process loads require the cooling of another fluid. ***Note: "NO" chiller, should have any fluid, other than a good quality water/antifreeze mixture flowing through it. "Any" other type of fluid, requiring cooling, must be cooled through the use of a heat exchanger.*** Figure 6.23 highlights several options for process cooling applications.

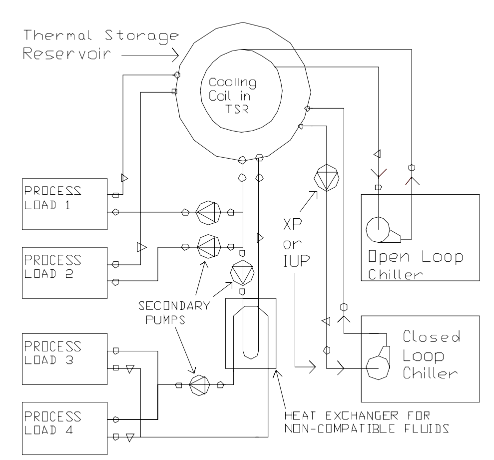


FIG 6.23 Process Load Variables

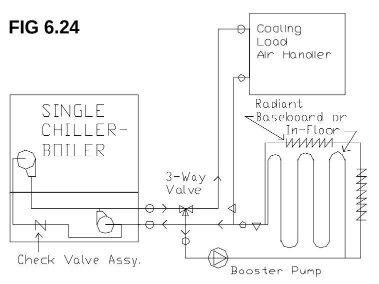
This drawing highlights several application ideas; 1- Many process loads are not necessarily large tonnage requirements and one site may have several process loads. 2- Any site may have a mixture of load requirements (either direct use of chilled water, or an in-direct heat exchanger adapted). 3- Due to the typical On/Off operation of process loads, they are many times better applied by a thermal storage tank, than just a primary loop.

4- Open loop chillers, by design, cannot be connected to a second open loop item (storage tank). For this reason, an open loop chiller should be adapted to a serpentine coil which is located in the storage tank. 5- "IF" all process loads are a non-compatible fluid load, the serpentine coil application, can in itself, be the applied heat exchanger device. 6- "IF" there are just one or two non-compatible loads, one or two independent heat exchangers may be applied for their needs. 7- Secondary pumping loops can be applied to single loads, or multiple loads as required. 8- Closed loop chillers may be applied to a storage tank using either an in-chiller pump (IUP), or an external field applied pump (XP). As you can plainly see, a chilled water cooling system offers great flexibility of design and application.

6.9.11 Chilled Water Cooling & Hot Water Heating

The beauty of a Hot Water Heating System (be it radiant baseboard or radiant in-floor), when applied with a Chilled Water Cooling System, is that you now have a third system too. A forced-air heating system. Some cooling systems (chillers which are part of a combination chiller/boiler unit) make controlling of the forced-air heating addition a little easier to control. But, independent systems (separate chiller and separate boiler) can also be connected through the adaptation of some 3-way valves. The following drawings will show a simple and basic layout of several systems which have been installed and have been operating to the customers delight.

FIG 6.24



This home (Fig 6.24) had a manufacturer's combination unit installed as a single forced-air cooling/heating system. Several years later, a dealer added baseboard heating to half of the home's basement area which was remodeled. A year or two later, a sun-porch addition was added to the back of the home and in-floor radiant heating was installed in the slab floor. Just a simple answer for an existing chilled/hot water system.

This home (Fig 6.25) had baseboard heating and no cooling. A dealer installed a combination chiller/boiler unit and applied it to an air handler in the attic space for cooling. The hot water side was applied to a primary loop and the existing secondary baseboard loops just drew out of the primary loop. A manual by-pass control allowed hot water operation to circulate through the air handler, if the home owner wanted a quick and fast warm up.

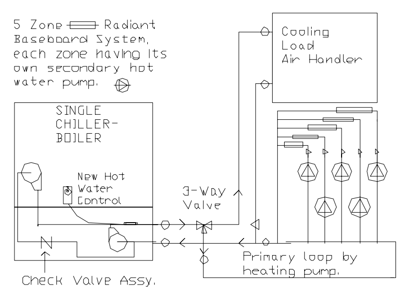


FIG 6.25

While these drawings do not offer all the answers for total controlling of a system, they do offer application ideas. You know your heating requirements, I am providing you with many cooling ideas, and between the both of us, we should come up with many neat systems.

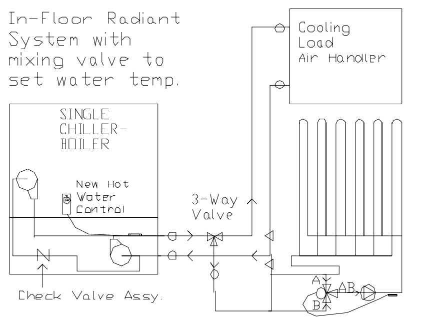


FIG 6.26

Figure 6.26 shows a home where radiant in-floor was installed for the entire first floor of the home which was a slab design. A control was added to the combination chiller/boiler to reduce hot water delivered temperature (factory set for 160°, control set for minimum of 140°). The hot water loop was primary applied (in unit pump), but the in-floor was secondary pumping applied.

The in-floor loop also had a mixing valve applied to reduce the heating water's temperature even more. Again, this system had a manual by-pass control so the home owner could have a forced-air heating option when desired.

Figure 6.27 shows a system having an independent chiller and boiler. It highlights the addition of a hot water by-pass loop so the forced-air cooling system can be used for heating too. If and when desired.

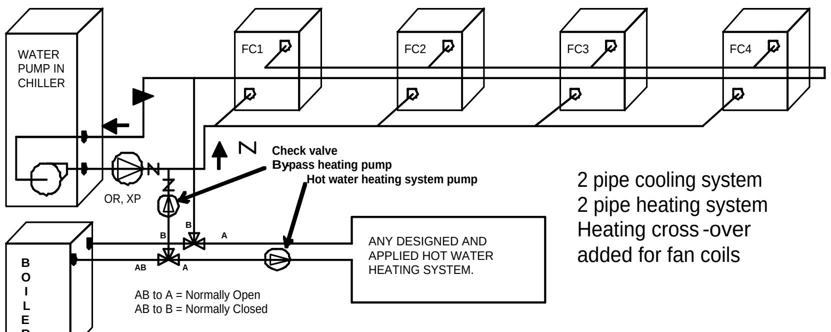


FIG 6.27

The 3-way valves are normally open to the main heating system which will operate the majority of the time. A manual control can signal the 3-way valves to open to the by-pass loop and an end switch in the 3-way valve's operator can signal the by-pass pump to operate when the valves open. A check valve prevents water flow into the chiller and it will flow through all applied fan coils. The return by-pass loop will direct water flow back through the boiler, because of the lower pressure in this piping (by-pass pump's suction operation).

The last drawing, figure 6.28 follows much of the same logic as noted in figure 6.27, but it highlights the application of applying independent hot water heating coils in the fan coil assemblies.

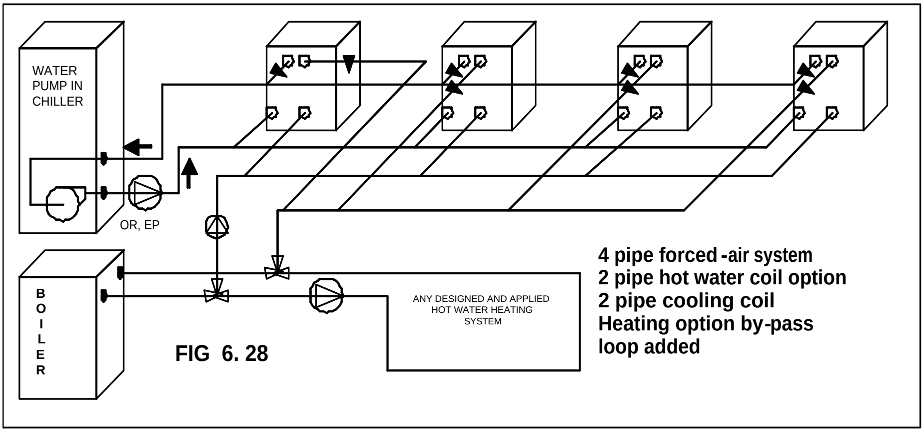


FIG 6. 28

The last chapter of this book, installation of systems, will discuss some controlling features a little more in-depth. In finishing this chapter, I just want to give you a couple of short stories. One, is the old Genie in a lamp story, and the other highlights a good design gone wrong.

A man was walking the beaches of California and tripped over something in the sand. As he cleaned the sand away, retrieving the object, he realized he had found an old, old lamp. While rubbing the sand off the lamp, a Genie appeared and told him that he would grant him one wish. The Genie also noted to be sure it was a good one too. The man looked at the Genie and said, “I would like a super highway from here to Hawaii”. The Genie sputtered and said, “Goodness gracious man, that’s impossible, even for a Genie. Isn’t there anything else you would like”? The man thought for a minute again and said, “Tell me everything you know about Hot Water Heating and Chilled Water Cooling Designed Systems”. The Genie hesitated for a minute, scratched his head and then, turning to the man the Genie said, “Would like that highway to be a 2 lane or 4 lane highway”?

Yes, the potentials are endless. They are only limited to one’s imagination.
Hydronics, the more you know, the more you’ll grow.

Several years ago, a good customer of mine asked me if I would go to another building his company managed to check on a re-occurring boiler problem. I reminded him that I was not a boiler expert, but I would be glad to have a look at it and do what I could. The building was approximately 9-10 years old. It seemed that almost every year, one of the two heating boilers had to have the hot water heat exchanger replaced. Also, almost yearly, one or both boilers would have a severe flame roll-out problem and most of the control wiring would get burnt up really bad. Service/repair individuals kept repairing the boilers and getting them operational again, but the problem continued to happen, over and over. My customer thought, that not only should the boilers be repaired, but the issue causing the problem should be corrected too. I certainly agreed with him.

The first thing I noticed was a note on the wall in black magic marker. ***Turn on second pump*** when outdoor temperature drops below 30 degrees (dé-jà vu). The building prints showed a 6" 3-way valve in the piping system which was suppose to control water flow for the building. The building's total flow rate, being too great for the boilers, was supposed to have a percentage of the flow always by-passing the boilers. Bingo! No 3-way valve. Yes, there were 3- 6" flanges, insulated and sealed off, but no expensive valve. ***The boilers received total building flow when the second pump was turned on.*** High velocity = erosion = frequent heat exchanger replacements.

Flame roll-out being typically a cleanliness or venting issue, signaled me to 1- check the boiler's internal flue assembly, and 2- check the boiler's venting (flue stack). The boilers were clean and the building print showed a 36" by 30 foot flue stack (2 heating boilers and 1 domestic boiler). The flue stack on the outdoor roof was only 8 feet high, and it was located close to a wall which was a penthouse for the elevator equipment. Down drafts over this penthouse roof were infringing upon the flue stack's ability to properly discharge vented gases all the time. Well, I even surprised myself, by being able to find their problem issues. I couldn't fix them myself, but I pointed them to a good company who could. Now, I know that I am not smarter than everyone else out there. But the question still remained in my mind, "Why did it take so long to finally correct this issue, and why me"?

Good heating and cooling systems are being designed every day. Yes, I do realize that some designers do make mistakes too. But, my field experience has proven that more issues are created during the installation of the system, than they were on the drawing board. Any one who says that a good designed system, is always going to be bid on and installed, exactly and identically as designed “?” Well, I have some property I would like to sell them too.

Chapter 7, is going to discuss a whole lot of criteria for installing chilled water cooling systems, and for the adaptation of some hot water heating too. This chapter will most likely have the most personal comments and opinions too. In fact, I even believe I will start this chapter with another neat story.

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A-6.1 PIPING FRICTION CHART 1:

A piping friction chart is used to choose an appropriate pipe size for designing a piping system. The chart provides many different pipe sizes, an appropriate GPM value for a pipe size, and a PD value in Ft Hd **per 100 feet** of a given pipe size. As a pipe size increases, its allowable GPM value increases in relation to a proper velocity factor. A high velocity factor, over 6 fps [feet per second] will cause noise in the piping and potential erosion. Some charts list different values for different piping materials due to the internal smoothness factors. Also, some charts list PD values in PSI and these values must be converted to Ft Hd values.

FLUID FLOW RATE GPM	TYPE L COPPER NOMINAL SIZE	TYPE L COPPER – PD PER 100 FEET	SCH 40 PVC NOMINAL SIZE	SCH 40 PVC – PD PER 100 FEET
GPM	INCHES	FT HD	INCHES	FT HD
1	½	2.40	½	0.5
2	½	8.04	½	2.43
4	¾	4.92	½	5.57
6	1	2.70	¾	3.01
8	1	4.50	1	1.58
10	1	6.70	1	2.63
12	1 ¼	3.38	1	3.77
14	1 ¼	4.48	1 ¼	1.50
16	1 ¼	5.65	1 ¼	1.7
18	1 ¼	7.02	1 ¼	2.0
20	1 ¼	8.43	1 ¼	2.45
22	1 ½	4.52	1 ¼	2.85
24	1 ½	5.30	1 ¼	3.35
26	1 ½	6.10	1 ¼	4.0
28	1 ½	6.97	1 ½	2.0
30	1 ½	7.58	1 ½	2.43
32	1 ½	8.92	1 ½	2.70
34	2	2.30	1 ½	3.06
36	2	2.55	1 ½	3.4
38	2	2.80	1 ½	3.7
40	2	3.36	1 ½	4.13
50	2	5.01	2	1.83
60	2	6.95	2	2.57
70	2	9.16	2	3.41
80	2 ½	4.12	2	4.37
90	2 ½	5.09	2 ½	2.29
100	2 ½	6.14	2 ½	2.78

Courtesy of Cooling Technologies, Inc. - Toledo, Ohio

A-6.1.2 PIPING FRICTION CHART 2:

FLOW	**PRESSURE LOSS DUE TO FRICTION - PSI PER 100 FEET OF PIPE (TYPE L COPPER)**						
GPM	3/8" Pipe	½" Pipe	5/8" Pipe	¾" Pipe	1" Pipe	1 ¼" Pipe	1 ½" Pipe
1	3.38	1.10	.422	.193	.045		
2	*11.5*	3.70	1.42	.652	.183	.068	
3	*23.2*	*7.53*	2.90	1.33	.374	.137	.060
4	*38.5*	*12.5*	4.81	2.20	.619	.228	.100
5		*18.4*	*7.11*	3.25	.915	.337	.147
6		*25.4*	*9.79*	4.48	1.26	.464	.203
7			*12.8*	*5.87*	1.65	.608	.266
8			*16.2*	*7.42*	2.09	.768	.336
9	2" Pipe	2½" Pipe	*19.9*	*9.13*	2.57	.944	.413
10	.133	.048		*11.0*	3.09	1.14	.497
12	.184	.066		*15.1*	4.25	1.56	.685
15	.272	.097		*22.4*	*6.29*	2.31	1.01
20	.450	.161	3" Pipe		*10.4*	3.83	1.68
25	.666	.238	.102		*15.4*	*5.67*	2.48
30	.917	.327	.140		*21.2*	*7.81*	3.42
35	1.20	.429	.184			*10.2*	4.48
40	1.52	.542	.233			*12.9*	*5.66*
50	2.25	.802	.344			*19.1*	*8.37*
60	3.09	1.10	.474				*11.5*
70	4.05	1.45	.621				*15.1*
80	5.12	1.83	.785				*19.1*
90	*6.30*	2.25	.965				
100	*7.58*	2.71	1.16				
125	*11.2*	4.00	1.72				
150	*15.4*	*5.51*	2.37				

This chart does not factor in a velocity factor. All figure entries which are in *Italics,* denotes values which may exceed 6 FPS (feet per second) and may cause a noise/erosion problem. Chart Courtesy of Arkla Industries, Inc.

A-6.1.3 PIPING FRICTION CHART 3: FRICTION LOSS (PER 100 FT) SCH 40 PVC PIPE

Velocity* = Speed of Water Flowing through a Pipe (Typically 6 FPS or less).

	3/4" PIPE			1" PIPE			1 1/4" PIPE			1 1/2" PIPE		
gpm	Vel	PSI	FtHd	Vel	PSI	FtHd	Vel	PSI	FtHd	Vel	PSI	FtHd
1	0.67	0.14	0.32									
2	1.34	0.51	1.17	0.81	0.04	0.09	0.46	0.04	0.09			
5	3.36	2.81	6.49	2.03	0.21	0.48	1.15	0.21	0.48	0.84	0.10	0.23
7	4.70	5.24	12.1	2.84	0.38	0.87	1.60	0.38	0.87	1.17	0.18	0.41
10	*6.71*	10.1	23.3	4.05	0.74	1.70	2.29	0.74	1.70	1.67	0.34	0.78
15	*10.1*	21.5	49.6	*6.08*	1.57	3.62	3.44	1.57	3.62	2.51	0.73	1.68
20				*8.11*	2.68	6.19	4.58	2.68	6.19	3.34	1.24	2.86
25				*10.1*	4.05	9.35	5.73	4.05	9.35	4.18	1.87	4.32
30				*12.2*	5.68	13.1	*6.88*	5.68	13.1	5.01	2.63	6.07
35							*8.02*	7.55	17.4	5.85	3.50	8.08
40							*9.17*	9.67	22.3	*6.68*	4.48	10.3
45							*10.3*	12.0	27.7	*7.52*	5.57	12.8
50							*11.5*	14.6	33.7	*8.35*	6.77	15.6
60										*10.0*	9.49	21.9

	2" PIPE			2 1/2" PIPE			3" PIPE			4" PIPE		
gpm	Vel	PSI	FtHd	Vel	PSI	FtHd	Vel	PSI	FtHd	Vel	PSI	FtH D
10	1.00	0.10	0.23									
15	1.50	0.21	0.48	1.05	0.09	0.20						
20	2.00	0.36	0.83	1.40	0.15	0.34						
25	2.50	0.54	1.24	1.75	0.23	0.53						
30	3.00	0.75	1.73	2.10	0.32	0.73						
35	3.50	1.00	2.31	2.45	0.42	0.97	1.58	0.15	0.34			
40	4.00	1.29	2.97	2.80	0.54	1.24	1.81	0.19	0.43			
45	4.50	1.60	3.69	3.15	0.67	1.54	2.03	0.23	0.53			
50	5.00	1.94	4.48	3.50	0.82	1.89	2.26	0.28	0.64			
60	*6.00*	2.73	6.30	4.21	1.15	2.65	2.71	0.39	0.90	1.56	0.10	0.23
70	*7.00*	3.63	8.38	4.91	1.53	3.53	3.16	0.52	1.20	1.82	0.14	0.32
80	*8.00*	4.64	10.7	5.61	1.96	4.52	3.61	0.67	1.54	2.08	0.18	0.41
90	*9.00*	5.78	13.3	*6.31*	2.43	5.61	4.06	0.83	1.91	2.34	0.22	0.50
100	*10.0*	7.02	16.2	*7.01*	2.96	6.83	4.51	1.01	2.33	2.60	0.27	0.62
125				*8.76*	4.47	10.3	5.64	1.53	3.53	3.25	0.40	0.92
150							*6.77*	2.15	4.96	3.91	0.56	1.29
175							*7.90*	2.86	6.60	4.56	0.75	1.73
200							*9.03*	3.66	8.45	5.21	0.96	2.21
250							*11.3*	5.53	12.7	*6.51*	1.45	3.34
300										*7.81*	2.03	4.68
350										*9.11*	2.70	6.23
400										*10.4*	3.46	7.99

(*) This Chart shows many entries for reference purposes only. Each Velocity column (Vel) has several entries which exceed 6 FPS (in *Italics*) and this factor may create water flow noise in piping and/or erosion.

Chart Courtesy of; **Lasco**® *Fittings, Inc.*

A-6.1.3-2 PIPING FRICTION CHART 3: CONTINUED

Friction Losses are Per 100 Feet of a given pipe size.

5" PIPE				6" PIPE			8" PIPE		
gpm	Vel*	PSI	FtHd	Vel	PSI	FtHd	Vel	PSI	FtHd
125	2.07	0.13	0.30						
150	2.48	0.19	0.43	1.71	0.08	0.18			
175	2.90	0.25	0.57	2.00	0.10	0.23			
200	3.31	0.32	0.73	2.28	0.13	0.30			
250	4.14	0.48	1.10	2.85	0.19	0.43	1.64	0.05	0.11
300	4.96	0.67	1.54	3.42	0.27	0.62	1.97	0.07	0.16
350	5.79	0.90	2.07	3.99	0.36	0.83	2.30	0.09	0.20
400	*6.62*	1.15	2.65	4.56	0.46	1.06	2.63	0.12	0.27
450	*7.45*	1.43	3.30	5.13	0.58	1.33	2.95	0.15	0.34
500	*8.27*	1.74	4.01	5.70	0.70	1.61	3.28	0.18	0.41
600	*9.93*	2.43	5.61	*6.84*	0.98	2.26	3.94	0.26	0.60
700	*11.6*	3.24	7.48	*7.98*	1.31	3.02	4.60	0.34	0.78

(*) This Chart shows many entries for reference purposes only. Each Velocity column (Vel) has several entries which exceed 6 FPS (in *Italics*) and this factor may create water flow noise in piping and/or erosion.
Chart Courtesy of; **Lasco**® *Fittings, Inc.*

A-6.2 CONVERSION CHART: a.k.a. Equivalent Length of Pipe Chart:

RESISTANCE OF VALVES AND FITTINGS IN EQUIVALENT FEET OF STRAIGHT PIPE
(*) ALL VALVES FIGURED AS FULLY OPEN, BALL VALVES =
APPROXIMATELY 50 % LESS THAN A GATE VALVE FULL OPEN

EQUIVALENT FEET CHART		NOMINAL PIPE SIZE IN INCHES						
Symbols	Valve/Fitting	3/4"	1"	1 ¼"	1 ½"	2"	2 ½"	3"
	90° Elbow	2.5	3.0	4.0	5.0	7.0	8.0	10.0
	45° Elbow	1.5	1.8	2.4	3.0	4.0	5.0	6.0
	180° Elbow	3.2	4.1	5.6	6.3	8.2	10	12
	Long Radius	1.4	1.7	2.3	2.6	3.3	4.1	5.0
	Miter Elbow	4.0	5.0	7.0	8.0	10.0	12.0	15.0
	Miter 45 Ell	.9	1.0	1.5	1.8	2.3	2.8	3.2
	Sudden Increase	1.5	2.0	3.0	3.6	4.8	6.1	8.0
	Sudden Decrease	1.0	1.2	1.8	2.2	3.0	3.8	4.9
	Plug Cock	1.3	1.6	2.1	2.5	3.2	3.8	4.8
	Gate Valve*	.5	.6	.8	1.0	1.3	1.6	2.0
	Ball Valve*	.25	.3	.4	.5	.65	.8	1.0
	Globe Valve*	20.0	25.0	35.0	45.0	55.0	65.0	80.0
	Check Valve	8.0	10.0	14.0	16.1	20.0	25.0	30.0
	Tee Thru	.8	.9	1.2	1.5	2.0	2.5	3.0
	Tee Side Out	4.0	5.0	6.0	7.0	10.0	12.0	15.0
	Tee ½ Reduced	2.0	2.6	3.4	4.0	5.0	6.0	7.5
	Tee ¼ Reduced	1.9	2.3	3.1	3.7	4.7	5.6	7.0

Once an appropriate pipe size has been chosen for designing the piping system, a total piping layout must be made including all piping required items (tees, 90 ells, 45 ells, valves, unions, couplers, reducers, etc.). First, the total length of all straight pipe is calculated. Then, ALL required piping items must be converted to an equal length of straight pipe using the above chart. These two values are then added together to obtain the grand total length of straight pipe. Then, referring to an appropriate friction chart, find the friction loss value for that pipe size and multiply that friction loss value by the length of pipe value to obtain the friction loss value for the designed system. This may be for one entire system having the same pipe size, or it may be for a separate circuit of a system having the same pipe size. All separate circuits must then be added for a total system value (normally in Ft Hd).

The data in the above chart, may be applied to a liquid or a gas.

Chart Courtesy of: Cooling Technologies, Inc. - Toledo, Ohio.

A-6.3 Antifreeze Correction Table: AND MORE

When antifreeze is added to the water system, and based upon the percentage added, two (2) important operating characteristics are created; 1- the viscosity of the fluid is increased which may require a larger horsepower pump motor, and 2- the total capacity of the chiller is reduced. The following charts may be used to reference these operating factors. These charts are based on ethylene glycol and may be used to size a water pump, or to verify a system's PD calculation which may be affected by an increased fluid viscosity factor.

Antifreeze Correction Chart		**Antifreeze Capacity Loss Chart**		
Antifreeze %	PD Sizing Multiplier	Outdoor Temp F Freezing Point	E. Glycol % By Volume	Capacity Loss By %
0 %	1.00	**25° F**	**10 %**	Negligible
10 %	1.03	**15° F**	**20 %**	**4 %**
20 %	1.06	**5° F**	**30 %**	**7 %**
30 %	1.12	**0°**	**33 %**	**9 %**
40 %	1.19	**- 5° F**	**35 %**	**10 %**
		- 10° F	**40 %**	**12 %**
Courtesy of;	Cooling Technologies	**- 20° F**	**45 %**	**16 %**

When calculating a designed system's PD, based on a manufacturer's supplied water pump and when choosing an appropriate pipe size based on the manufacturer's available external Ft Hd, do not forget to factor in the antifreeze correction multiplier. Your calculated PD may be ok for pure water, but not for the added antifreeze. This could mean a larger pipe size, a booster pump, or purchasing a separate external pump.

Fluid Volume Charts:

When antifreeze addition is required, the total fluid volume of a system must be calculated to determine the correct antifreeze volume (based on % desired).

Major System Components				**Water Piping (Gal. / Lineal Foot)**		
Equipment	Equip. Size	Approx. Volume Gal		Nominal Pipe Size Inches ID	Type L Copper	Other Piping
Chiller O/C*	5 Ton	5.0 / 2.0		1/2"	.0121	.0159
Water Coil	1 Ton	0.5		3/4"	.0251	.0279
Water Coil	2 Ton	0.8		1"	.0429	.0453
Water Coil	3 Ton	1.0		1 1/2"	.0924	.1066
Water Coil	4 Ton	1.5		2"	.1647	.1757
Water Coil	5 Ton	2.0		2 1/2"	.2479	.2507
Water Coil	7.5 Ton	3.0		3"	.3539	.3841
Water Coil	10 Ton	4.0				

(*) O = Open Chiller, C = Closed Loop Chiller. Courtesy of; Arkla & Cooling Technologies.
All figures are approximate, based on typical A-Coils. Always consult equipment manufacturer.

A-6.4 Other Useful Charts: CAPACITY CHARTS, COOLING & HEATING

Typical Cooling Coil Capacity Chart: 5 Ton A-Coil @ 2000 CFM.

Ent Wtr Temp° F	GPM	PD FtHd	Total MBH	
42	9.6	4.0	63.0	Note that as the entering water temperature drops, the total capacity increases for equal GPM values. Typical design conditions are; 45° F water @ 95° F ambient. Typical 5 Ton Chiller @ **12.0 GPM**
42	12.0	6.1	68.0	
42	14.4	8.7	72.0	
45	9.6	4.0	57.0	
45	**12.0**	**6.1**	**61.5**	
45	14.4	8.7	65.0	

Hot Water Heating: 2 Row Coil verses a 4 Row Coil

Chilled water cooling systems are applied by using a 4 row water coil. Most chilled water systems do not normally use an added 3 row heating only coil. The cooling coil is used for heating too. All water coils deliver heating and cooling based on an entering water temperature. 4 row coils, by design, do not require the same entering hot water temperature as do 2 row coils, to perform properly. The entering hot water temperature for a 4 row coil may be reduced considerably and can still provide proper heating. By referring to a manufacturer's capacity charts, it is possible to determine an appropriate entering hot water temperature for any applied 4 row or 2 row coil. By keeping the temperature as low as possible, and ensuring that proper heating is accomplished, extra savings will be seen for the system's total operating cost. The next two charts, show a comparison between a 4 row and 2 row coil when being applied for heating. Be sure to compare identical temperature and gpm entries per chart.

Typical Heating Capacity Chart: 5 Ton, 4 Row Coil @ 2000 CFM				**Typical Heating Capacity Chart:** 2 Row Heating Only Coil @ 2000 CFM			
Ent Wtr Temp ° F	GPM	PD FtHd	Total MBH	Ent Wtr Temp ° F	GPM	PD FtHd	Total MBH
120	9.6	3.33	85.0	120	6.0	0.43	54.0
120	12.0	5.21	88.0	120	12.0	1.81	62.0
120	14.4	7.50	90.0	120	18.0	4.48	65.0
150	9.6	33.3	129.0	150	6.0	0.43	81.0
150	**12.0**	**5.21**	**133.0**	150	12.0	1.81	91.0
150	14.4	7.50	135.0	150	18.0	4.48	97.0
180	9.6	3.33	172.0	180	6.0	0.43	109.0
180	12.0	5.21	177.0	**180**	**12.0**	**1.81**	**123.0**
180	14.4	7.50	180.0	180	18.0	4.48	130.0

All Charts are Courtesy of; Magic Aire®.

Please note that a 2 row heating only coil having 180 degree entering water, will deliver 123,000 btuh of heating capacity. But, a 4 row coil can deliver the same heating capacity having an entering water temperature of 150 degrees (**bold entries**). The water temperature could most likely be reduced a little more (145 degrees). Tailoring entering water temp and delivered capacity equals savings. What else but a 100 % true hydronic system could offer so much?

A-6.5 ANTIFREEZE TYPES & THEIR USE:

<u>Very Important to Remember, "All Antifreezes ARE NOT Created Equal !"</u>

There are 3 major factors which one must consider when choosing an antifreeze to be used with any chilled water and/or hot water system; 1 - Antifreeze Type (Ethylene Glycol based, or Propylene Glycol based), 2 - Inhibitors (A Good Inhibited product designed as a good heat transfer fluid for HVAC systems), 3 - Purity (Beware of the water you choose, it may be in your best interest to purchase a pre-mixed antifreeze product).

ANTIFREEZE PRODUCTS:

Over the years I have seen many systems with many types of antifreeze products being used, and many of these systems have been a mess. I had one large job which really needed a good cleaning and it needed new antifreeze. Not knowing a whole lot about antifreeze, I had to do a lot of home work on the subject and I finally made what I thought was a good choice. Fortunately, it was not only a good choice, it was a great choice. That same system, 15 years later, is still clean as new and most of the equipment still has the initial antifreeze in it which I put in. My choice was **DOWTHERM** * SR-1, manufactured by the Dow Chemical Company. Now I am not saying that there are no other appropriate antifreezes on the market, I have just learned over the years, never to argue with success. **DOWTHERM** is a good inhibited ethylene glycol based antifreeze, specifically developed as an HVAC heat transfer fluid. Dow Chemical also produces a propylene glycol based antifreeze called **DOWFROST**.* This product is also a good inhibited heat transfer fluid and it is typically used for environmentally sensitive applications (restaurants, hospitals and underground piping systems). Both of these products are available from Dow in pre-mixed percentages which use good clean distilled water. Many of the systems which had to be cleaned and replenished with new antifreeze, had been using automotive type antifreeze. While these antifreezes may be great for cars, they do not stand up well with the chiller systems, especially the Open Loop systems. Many systems required yearly additions of antifreeze to keep the freeze factor correct and some even allowed (created) a slime residue in the chiller's chiller tank. It is very highly advised to stay away from automotive antifreeze products.

FREEZE PROTECTION:

Every chiller system will require a minimum of 20% antifreeze by volume for general operational protection of the chiller and its evaporator cooling section. In geographical areas where the ambient temperatures can fall below freezing (32 degrees F) even more antifreeze will have to be added to protect the idle system from rupturing due to freezing. Antifreeze protection (% by volume) is basically established for one of two reasons; One for "Freeze Protection", or Two for "Burst Protection". **Freeze Protection**: This means that the fluid will always stay in a liquid form so that a water pump can easily circulate the fluid. This is a mandatory requirement for chiller-heater applications. **Burst Protection:** This means that the fluid may develop ice crystals, typically a water pump will not be able to circulate it, but it will not freeze solid enough to rupture any piping or component. This may typically be used for chiller only systems.

Because the addition of antifreeze causes a cooling capacity loss, it is never a good idea to use any larger percentage than a system really requires. Heating systems (chiller-heaters must be installed outdoors) must be freeze protected where applicable, but cooling only systems may be either freeze protected or burst protected. Protecting a cooling only system for burst protection makes the most sense due to the minimal capacity loss factor. The next page has a Freeze / Burst Protection Chart which the Dow Chemical Company has developed for their products; **DOWTHERM** SR-1 and **DOWFROST**. This chart outlines the volume percentages required for producing a proper fluid concentration for a given operational ambient temperature. No matter whose antifreeze product you choose to use, be sure it is specifically developed for HVAC Heat Transfer System. Be sure it is a Good Inhibited Product. Be sure to use a good quality water (alternately, Distilled Water or De-ionized Water) and purchase the antifreeze as a pre-mixed fluid if available. Good antifreeze products do pay for themselves by providing a good clean operating system which can last for years.

***   Trademark of The Dow Chemical Company**

A-6.5.2 DOW CHEMICAL PROTECTION CHART:

Concentrations of DOWTHERM SR-1 and DOWFROST fluids required to provide freeze protection and burst protection at various temperatures. “Used with permission of The Dow Chemical Company”

PROTECTION	PERCENT VOLUME OF GLYCOL CONCENTRATION REQUIRED			
CHART	FOR FREEZE PROTECTION		FOR BURST PROTECTION	
Temperature ° F	**Dowtherm** Ethylene Glycol	**Dowfrost** Propylene Glycol	**Dowtherm** Ethylene Glycol	**Dowfrost** Propylene Glycol
20	16.8 % †	18 %	11.5 % †	12 %
10	26.2 %	29 %	17.8 % †	20 %
0	34.6 %	36 %	23.1 % †	24 %
- 10	40.9 %	42 %	27.3 %	28 %
-20	46.1 %	46%	31.4 %	30 %
- 30	50.3 %	50 %	31.4 %	33 %
- 40	54.5 %	54 %	31.4 %	35 %
- 50	58.7 %	57 %	31.4 %	35 %
- 60	62.9 %	60 %	31.4 %	35 %

NOTE: These figures are examples only and may not be appropriate to your situation. Generally, for an extended margin of protection, you should select a temperature that is at least 5° F lower than the expected lowest ambient temperature. Inhibitor levels should be adjusted for solutions of less than 25-30% glycol. Contact Dow for information on specific cases or further assistance.
ATTENTION: These are typical numbers only and are not to be regarded as specifications. As use conditions are not within its control, Dow does not guarantee results from use of the information or products herein; and gives no warranty, express or implied.
† Inhibitor levels in glycol solutions less than 25-30% may not provide adequate corrosion protection. Solutions of glycol less than 25% may be at risk for bacterial contamination.
Courtesy of; The Dow Chemical Company - Midland, Michigan.

The Protection Chart shows the protection from freeze damage provided by various concentrations of **DOWTHERM** and **DOWFROST** glycol inhibited fluids. To determine the concentration required, select the lowest expected ambient temperature and decide whether the HVAC system requires **“Freeze Protection to keep the fluid Pumpable”, or *“Burst Protection to simply prevent damage from fluid expansion”.***

As a further measure of protection against dilution error, or unexpected cold temperatures, select a temperature that is at least 5° F colder than the lowest expected ambient temperature. If, for example, the lowest expected temperature is -15° F, select the line in the chart for -20° F. The chart shows that at this temperature, a solution of 46.1% **DOWTHERM** SR-1 is required for freeze protection. A concentration of 31.4% **DOWTHERM** SR-1 would be sufficient to provide burst protection at this temperature. If **DOWFROST** were being used, a 46% concentration would be required for freeze protection and 30% for burst protection. Care should be taken to avoid the use of excess glycol in order to minimize the impact on system efficiency.

Special Note:
Please note in part of the chart that propylene glycol requires a larger percentage by concentration than ethylene glycol does to provide an equivalent protection (freeze or burst). Propylene glycol has a little higher viscosity factor than ethylene glycol does and its use may require a higher horse power pump than ethylene glycol. The antifreeze correction chart (A 10.8) was for ethylene glycol and not for propylene glycol. When using either product (should you choose to follow my success), it may be best to contact Dow Chemical and request their Manual on these products. This manual covers all factors for using the products, including PD and calculation factors. Dow even has computer software for their products. If you use the Dow products and have any questions regarding the products inhibitors (break down in protection), a sample can be sent to Dow for a free analysis. Many times, a system may only require an inhibitor additive and not necessarily more fluid.

No Matter What Antifreeze Product You Choose, <u>BE A SMART CONSUMER</u> . Make sure that you have purchased a product which will serve you and your customer **B E S T !**

A-6.6 SYSTEM PD & PUMP SIZING CALCULATION FORM:

This form is intended to be an aid in completing a system's PD calculations. Depending upon a system's size and/or design, all information and data entry requirements may or may not be pertinent for every calculation. Also, for larger systems with multiple fluid pumps or a large intricate piping system, some data entry pages may have to be duplicated.

STEP 1: Listing Known Information & Data:

Project Name: ______________________________ Date: _______________.

Address: ___________________________ City: _______________ State: _______ Zip:__________.

System Capacity: (tons): _______ Chiller System: (number of or Model): __________

Chiller(s) System's GPM Rating: _______ Load Zone(s) Total GPM: (if different): __________

% Antifreeze: _______ PD of Chiller(s): __________

Internal Pump (Y/N): _______ Ft Hd Available: __________

External Pump (Y/N): _______ Single Pump System: __________

Multiple Pump System: _______ Primary/Secondary Pump System: __________

Total # Load Zones: _______ Primary / Secondary Zones: _____/_____

Zone 1: Tons _________ GPM Rating ________ PD Rating ________ PSI or _________ Ft Hd

Zone 2: Tons _________ GPM Rating ________ PD Rating ________ PSI or _________ Ft Hd

Zone 3: Tons _________ GPM Rating ________ PD Rating ________ PSI or _________ Ft Hd

Zone 4: Tons _________ GPM Rating ________ PD Rating ________ PSI or _________ Ft Hd

Zone 5: Tons _________ GPM Rating ________ PD Rating ________ PSI or _________ Ft Hd

Farthest Zone: _________ (duplicate page for more zones) **Ft Hd = PSI x 2.31**

STEP 2: Choose Pipe Material & Size(s): select appropriate pipe size from the Friction Chart

Piping Material: Schedule 40 PVC __________ Copper ____________.

Pipe 1: Size _______ Inches. PD Rating ______ Ft Hd per 100 feet

Pipe 2: Size _______ Inches. PD Rating ______ Ft Hd per 100 feet

Pipe 3: Size _______ Inches. PD Rating ______ Ft Hd per 100 feet

Pipe 4: Size _______ Inches. PD Rating ______ Ft Hd per 100 feet

Pipe 5: Size _______ Inches. PD Rating ______ Ft Hd per 100 feet

STEP 3: Calculating Total Feet of Straight Pipe:

Pipe 1: Total Length _______ Ft (A) PD ________ (B) (A ÷ 100) x B = Total Ft Hd____________.

Pipe 2: Total Length _______ Ft (A) PD ________ (B) (A ÷ 100) x B = Total Ft Hd____________.

Pipe 3: Total Length _______ Ft (A) PD ________ (B) (A ÷ 100) x B = Total Ft Hd____________.

Pipe 4: Total Length _______ Ft (A) PD ________ (B) (A ÷ 100) x B = Total Ft Hd____________.

Pipe 5: Total Length _______ Ft (A) PD ________ (B) (A ÷ 100) x B = Total Ft Hd____________.

Grand Total Straight Pipe Ft Hd (Pipe1 + Pipe2 + Pipe3 + Pipe4 + Pipe5):

____________.

A-6.6.2 SYSTEM PD & PUMP SIZING CALCULATION FORM:

STEP 4: Equivalent Lengths of Piping System Items:
Use the system schematic and the Equivalent Length Conversion Chart to calculate an equivalent length of pipe and Ft Hd value for the system fittings and items. All pipe size reductions (sudden contraction, chiller's supply pipe to zone & coil inlet connection) and pipe size increases (sudden enlargement, zone's return pipe to chiller & coil outlet connection).

EPL = Equivalent Pipe Length.

Pipe 1: Size ______ Inches. PD value for this pipe size __________ Ft Hd / 100 Ft

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

Total EPL for all Pipe 1 Items: __________

Total PD (Ft Hd) for all Pipe 1 Items: Total EPL ________ ÷ 100 x Pipe1 PD ________ = __________Ft Hd

Pipe 2: Size ______ Inches. PD value for this pipe size __________ Ft Hd / 100 Ft

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

Total EPL for all Pipe 2 Items: __________

Total PD (Ft Hd) for all Pipe 2 Items: Total EPL ________ ÷ 100 x Pipe1 PD ________ = __________Ft Hd

Pipe 3: Size ______ Inches. PD value for this pipe size __________ Ft Hd / 100 Ft

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

A. Item Type __________ B. Quantity _______ C. EPL ________ Ft B x C = Total EPL _______.

Total EPL for all Pipe 3 Items: __________

Total PD (Ft Hd) for all Pipe 3 Items: Total EPL ________ ÷ 100 x Pipe1 PD ________ = __________Ft Hd

Note: Depending upon the designed system's size (different pipe sizes, quantity of items, etc.) this page may need to be duplicated or modified for one's particular needs. ***The important factor is, do not miss any items. Double check all.***

A-6.6.3 SYSTEM PD & PUMP SIZING CALCULATION FORM:

STEP 5: PD of 3-Way Valves:

The Cv rating of most valves are available from the manufacturer. Use 3-Way Valve from farthest zone.

3-Way Valve: Size __________ Inches Cv Rating _________ PD (psi) = $(GPM \div Cv)^2$ = ______________

PSI x 2.31 = ______________Total Ft Hd

STEP 6: Finalizing the System's Total Ft Hd Calculations:

Add up all the system PD's. Compare to the available head from a factory installed water pump, OR use the PD to size a to be purchased water pump.

1. Enter the PD value for the chiller(s) (if internal pump used, enter zero):		Ft Hd ______.__________
2. Enter the PD value of the farthest zone (Step 1):		Ft Hd ______.__________
3. Enter the PD value of the system's pipe: (Step 3 Grand Total):		Ft Hd ______.__________
4. Enter the PD value of the piping items (Step 4 - each pipe size):	Pipe 1	Ft Hd ______.__________
	Pipe 2	Ft Hd ______.
	Pipe 3	Ft Hd ______.__________
	Pipe 4	Ft Hd ______.__________
	Pipe 5	Ft Hd ______.__________
5. Enter the PD value of the 3-way valve (Step 5 - farthest zone):		Ft Hd ______.__________
6. Add up all PD entries for a Sub Total PD: .		Ft Hd ______.__________
7. Multiply By Antifreeze Correction Factor		**x** ______.__________
8. System PD Grand Total:		Ft Hd ______.__________
9. Round up to the nearest whole figure (special note):		Ft Hd ______.__________
10. Enter a PD safety value of 5.0 Ft Hd. (this is for separate pump sizing purposes):		+ ____5____
Grand Total System PD:		**Ft Hd ______.__________**

For Factory Installed Water Pump:

(1) If the Grand Total PD is less than the Available Head for the pump, system design is acceptable.
(2) If the Grand total PD is more than the Available Head for the pump, try a larger pipe size.
(3) If a larger pipe size is not feasible, either purchase a separate external pump, or use a booster pump.

For Purchasing a New External Water Pump:

(1) Use the Grand Total PD and the system flow rate (GPM) to size and order a pump. If the cost or horsepower is not acceptable, try using a larger pipe size to reduce the PD, or consider two pumps in either series or parallel.

Special Note: Always round calculated values up to the nearest whole number (no decimals) to stay conservative.

Chapter 7- "Installation" the Way it Should Be

In 1989, my business partner worked many long hard hours with an engineering company who was designing a 50 ton chiller system and a 25 ton chiller system for a new training center building. In 1990, my business partner passed away having a bad bout with leukemia for which he lost the battle. Now this job was 100 % my baby. The job was sold and installed in 1990 and I had to be there for the start-up of the equipment and to aid the installing contractor. No, this is not an installer issue. But, it is a common installation issue.

During the start-up of the equipment, I noticed that the water flow rate through the equipment was changing. I commented to the installing contractor that something was screwed up in the water flow regulation of the system. We couldn't finish the start-up that day and had to come back the next day. A special company had been hired to set and regulate all the water circuits (proper flow rate per applied circuit) and to set the proper air flow of all applied air handlers and/or fan coils. When this man walked up to me and I introduced myself to him, he said, "Oh, you're the one who said the water flow rates are all screwed up". Yes, he did have an attitude. I said to him, "No, I'm the one who said that something was screwed up in the water flow regulation of the system. My equipment is seeing changes in its mandated flow rate when the system is operating". I explained the equipment's mandated requirements and he immediately said, "I know exactly what is wrong". It seems that all the designed 3-way by-pass valves had some how been changed to 2-way valves and when any given load zone was satisfied, the water flow rate through the equipment was reduced by that zone's flow rate.

The whole issue started when the general contractor and the building owner were seeing cost over-runs during the construction of the building. Corners had to be cut, and as is typical done, it was more important to have aesthetics, decorative trees and flowers, than it was to have a proper heating and cooling system. A 4 pipe designed system had been changed to a 2 pipe system. 2-way, Open-Closed valves were allowed in lieu of the required 3-way valves, and the list went on. I had to write a letter to the installing contractor notifying them, that if this water flow issue was not corrected, it would cause operational problems for the equipment and it was good cause for the manufacturer to void all warranties on the equipment. I should have been talking to a wall; I may have gotten more accomplished. Yes, problems occurred. The engineer was mad. The building owner was mad. Everyone was mad, but absolutely nothing was done to correct the issue.

Three years later, a new contractor was hire to fix all the problems. Change a 2 pipe system back to the originally designed 4 pipe system. Replace all the 2-way valves with 3-way valves, and on and on. But, it was too late for the equipment. It was already suffering with operational problems. Yes, the building owner pointed the fickle finger of fate at the manufacturer and blamed the equipment. Even after they read my letter again, which they said they had not seen before, the whole situation was not good. The big problem is, that this installation gone wrong story is not an isolated issue. This issue happens all too often.

During the writing and production of another book I wrote, I had the opportunity to talk to many manufacturers, seeking their permission to include information about their products and/or their name in my book. Many of them related this same scenario to me, telling me other horror stories about installations gone wrong. It seems that no matter how hard a manufacturer tries to produce a good quality product, some smart and learned individual will surely install it wrong, apply it wrong, or find some way to screw things up.

OOP's, there goes brand name reputation! Why is it, that the true culprit seldom gets the blame? Manufacturers have spent hours, upon hours, developing good and appropriate literature and manuals for the proper installation and application of their products. Now, they still have one big problem left.
"How to get people to read the instructions" ?

I must apologize for this some what long-winded introduction to this chapter. But, I have spent almost 25 years in the service/repair field before I entered the sales, engineering and design side of things. The stories I could tell are numerous, but the important item is, I truly believe I have a handle on this thing called proper installation. Now, I don't mean on everything, but chilled water cooling systems have been my life and the majority of them use hot water for heating too. I am some what limited in my knowledge of in-floor radiant systems, but my truly enjoyable membership in the Radiant Panel Association is changing this too.

A well rounded installation person, should know and understand many aspects of system designing and various equipment types. Or, they will just be following a design layout drawing and/or orders from a superior. The issue here is, are these factors right in themselves? Service/repair technicians have the same problem. Service/repair issues may not be an equipment problem; it could be a design or product/part choice problem.

7.1 Beginning an Installation

One word can basically define the beginning point for every installation;
<u>"READ"</u> **!**
Yes, get your hands on every piece of installation literature you can for all the equipment, air handlers, specialty valves and any other system items and read the installation requirements for all of them. Just because you have installed one company's chiller, air handler, 3-way valve, special flow control device, or any thing else, ***it does not mean that all chillers, air handlers, 3-way valves, etc, are the same or are identical.*** A boiler is not just a boiler, and a chiller is not just a chiller. Nuff Said !

7.2 Code Requirements

Every installation is going to be involved with many code requirements; Plumbing Codes, HVAC Codes, Electrical Codes and Gas Codes (gas-fired chillers). Every manufacturer typically tries their best in their installation literature, to provide as much information as they can, relating to typical code requirements as possible. But, as we all know, codes still vary from one city to another and from one inspector to another. This is getting much better in recent years, but it is still ***your responsibility to either know, or to find out what codes will govern your installation.*** Manufacturers provide information which their products mandate for proper operation. While these mandates may not necessarily violate any code, they could raise a question for an inspector. Having a manufacturer's installation manual to show and discuss with an inspector, is always a good idea.

7.3 Installation Prerequisites

There are many factors which must be considered for any chilled water cooling system, ***<u>before</u>*** it is ever installed. Yes, no different than any good hot water system too. System designers and engineers can not be expected to know every aspect of every chiller product on the market. Neither can an installer and/or service technician. But, it is always anticipated that they do. The poor service technician can really catch the majority of problem issues, because he/she is expected to keep a system in good repair and operation. But, a lot of these issues could have been avoided in the first place, simply by following some good prerequisites.

No matter how good a particular product may be for an application and installation, ***it will not operate properly if the installation (application) has not been designed and engineered properly in the first place*** . This is why system designing and engineering should always precede an installation and informational literature on installing. Then, having knowledge 1 in the first place, read installation literature in the second place and follow it. It is not un-common for an installer and/or service technician to run across a conflict between a system's designs verses a manufacturer's installation requirements. This is where a good installer and/ or technician can really shine. No engineer wants a designed system to be a failure and/or a black mark against their name. Contact the system's designer and discuss this conflict (Tip; never tell an engineer their wrong. Simply discuss the issue). If an installer just follows a design layout, knowing that something is wrong, he/she now becomes the problem. The end goal for everyone involved with a system's design and installation, should be, 100 % customer satisfaction. This of course equals a properly designed and installed system.

Special Note: *Many manufacturers, in their warranty polices, many times make a special note that, "IF" their product has not been installed per manufacturer recommendations, the manufacturer may reserve the right to constitute the installation as a mis-application of the product, and the product's warranty may be voided.*

I don't know about you, but I sure wouldn't want to be the designer and/or installer of a system for which this may have occurred.

7.4 Installation Location of Chiller

Small tonnage comfort cooling chillers come it two basic types; 1- Electric Operated Chillers, and 2- Gas-Fired Chillers. Gas-Fired Chillers are further defined as Air-Cooled Chillers, while Electric Chillers can be either Air-Cooled or Water Cooled (typically process cooling applications). Water cooled chillers require an outdoor cooling tower[1] as a heat rejection medium, while Air-Cooled Chillers, by definition, are strictly designed for outdoor installation. This book does not cover water cooled equipment, only Air-Cooled products.

1- Cooling tower applications will require a water pump and a designed and PD calculated piping system. Water tower pumping and piping are considered an Open Loop System. By following Open Loop piping logic, a cooling tower manufacturer's literature and a water cooled chiller manufacturer's literature, this application should be a breeze too.

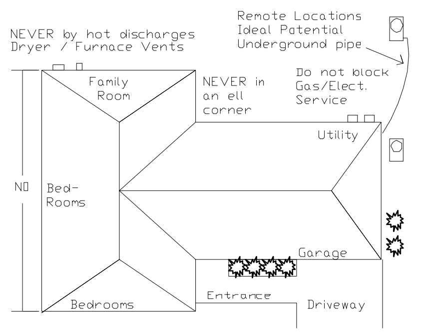

FIG 7.1 Typical Installation Locations

Figure 7.1 highlights several good choices for an installation location of a chiller, and several bad choices. Several factors enter into a choice for a proper location; 1- Is it an Electric Chiller? 2- Is it a Gas-Fired Chiller (3 times as much heat rejection). 3- Does the chiller reject heat (condenser air flow) upwards or sideways? 4- Is there only one chiller, or is there two or more? All these questions must be answered.

Bedroom window areas[2] should always be avoided due to the equipment's operational noise. Hot exhaust discharges must always be avoided to prevent heated air entering a chiller's air cooled coil section. Utility services must be open and accessible. Ell corners[3] should be avoided due to the limited ability of heated air dissipation.

Note: any chiller operating in an ell corner, will create an increased percentage of discharged heat re-circulation.

For any given ambient of the day, an ell corner will be hotter than the ambient of the day. Chillers which have their heat rejection discharged sideways, should never discharge from one chiller right into another chiller setting along side of it. Side discharges are always best installed by having air flowing directly away from a building. Keep chillers a good distance away from a building for good heat rejection. Another neat aspect of chillers, which Freon systems cannot provide, is the remote location potential. Chilled water piping can easily be run under-ground from a chiller into a home or building. This may require increased pumping capabilities, but it sure could be a plus for many installations.

The last location issue is a real pain. Where a chiller should be located, verses where the customer wants it to be located.

2- Many cities and communities have code restrictions for side yard locations and for windows of the home. Gas-Fired, Air-Cooled Chillers, by code, may not be installed by a window. The minimum side clearance to a window has to be three feet. Always be sure to check local codes.

3- "IF" a gas-fired chiller is installed in an ell corner, it is destine to fail. Gas-fired chillers have three heat rejection operations; 1- is a gas-fired burner's combustion heat rejection. 2- is a condenser coil's heat rejection of the refrigerant. 3- is the absorber coil's heat rejection. By operation and design, the absorption process is critical to these chillers's performance. A gas-fired chiller must never be installed in an ell corner.

Chillers, by their nature and design, are much larger than traditional Freon units. This creates two issues for the customer; 1- where to locate this large ugly unit, and 2- what to place (build) around the chiller to hide it. Yes, where a chiller "should" be located and where a customer "thinks" it should be located can be a major battle. The bad side of this is, that too many installers have let the customer win the battle. Then, when chiller operating problems occur (and they will, sooner or later), now listen to what a customer has to say and who they are saying to. Yes, there are a lot of stories here too. "IF" this situation occurs, write up a Mis-Application Disclaimer Sheet and have the customer sign it, you sign it and have a third party sign it. Then make copies for all. This may even change the customer's mind as to where to locate the chiller. But, it will protect you and the manufacturer down the road.

What do Trees, Shrubs and Fences all have in common? They can all prevent a chiller from operating properly, if they are too close to a chiller. Customers love to hide air conditioning equipment, and I can certainly appreciate this. But, when doing so infringes on the equipment's ability to function properly, it now becomes a big issue. Yes, the customer will still blame the equipment when it breaks down and/or serious repair issues arise. A good installer must educate his customer regarding the equipment's operational requirements.

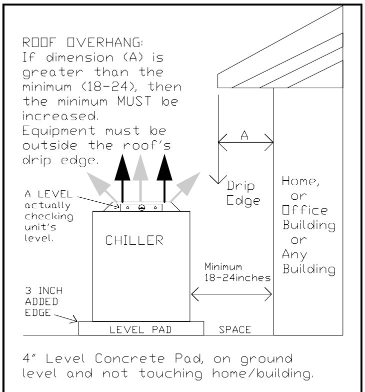

FIG 7.2 Clearances & Obstructions

Figure 7.2 highlights some more location issues and some clearance issues. The drawing shows a vertical air discharge chiller. Roof overhangs could infringe on heated air dissipation and can cause re-circulation. Stay outside the roof's drip edge. Chillers need room to breath and a good chiller to building clearance is 18 to 24 inches. Remember, more is better, less is trouble. Gas-Fired chillers must set level (shouldn't everything for good looks and saying another job well done?) Many manufacturers even ask that you use a level on top of the chiller to check the level.

Chillers weigh a lot more than a traditional Freon unit and they normally require a better/stronger supporting base (e.g. concrete pad). Be sure to check the chiller's weight factor and choose an appropriate base pad that will hold up and last. Many of these requirements are manufacturer mandated and that's why you should always consult installation literature.

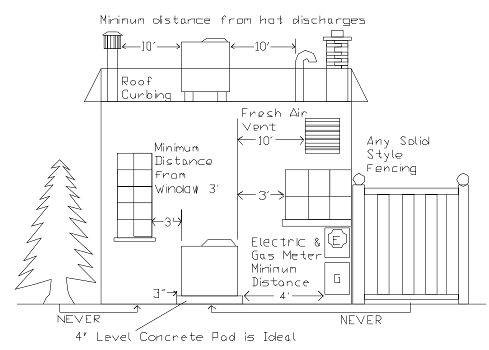

FIG 7.3 More Location Concerns

Few homes have a flat roof, but many small commercial businesses do, and this can be an ideal equipment location (very few trees and shrubs grow on roofs). Figure 7.3 highlights some more location concerns and a couple of code issues (more for gas-fired chillers). There's even a common sense[4] issue for heated discharges, keep chillers away from them.

Roofs can also create a unique operational issue just due to the prevailing winds. When wind currents travel over (across) a high peak or high flat roof, a lower pressure will be seen downstream (other side) of the peak. This will cause wind currents to "Fall" as they cross over the peak and if any operating equipment is too close to a peak or wall, this down current will infringe upon a chiller's ability to reject its operational heat properly. Figure 7.4 highlights some of these issues.

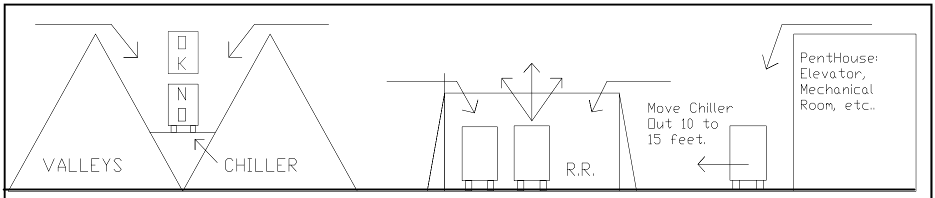

FIG 7.4 Dominant Wind Current – Valleys, Recessed Roofs & Penthouses

Every chiller manufacturer provides installation literature defining what a proper installation location is for their equipment. Success = following the instructions[5]. Roof top installations typically require special roof curbing, or a steel rail assembly may be provided for the equipment. As always, equipment weight is a concern, operational noise and/or vibration is a concern and the base frame design of the chiller can be a concern (some gas-fired chillers have u-channel rails under a base pan with sharp edges down).

4- Common sense for chiller installations, is the non-emotional and totally objective ability to know what is right, to know what is wrong, and then, to find the mental and physical capability to do that which is right.

5- READING, "Preparation is Everything !" **"PIE"**

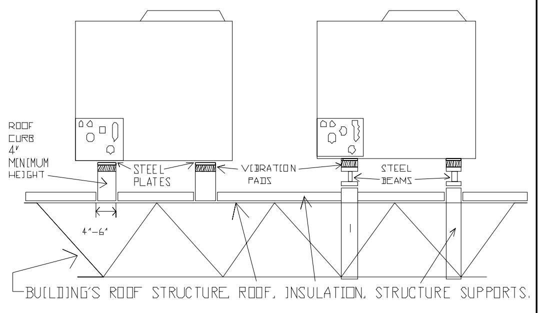

FIG 7.5 Roof Top Supporting

Figure 7.5 highlights some installation concerns for roof curb and steel rail structures. As with all chiller installations, the piping will soon be connected. Very important, chiller leveling starts with a level supporting mechanism (concrete pad, roof curb, etc.), then check a chillers level with a level (shim as needed, maximum 1/4" total) and then, start piping.

7.5 Chilled Water Piping

Special Note: More often than not, the main piping loop will be a larger pipe size than the connection point at a chiller and/or air handler (fan coil). The main piping loop <u>must never have any appreciable length of piping down sized</u>. When a main piping loop is larger than a connection point, use one reducing coupler and keep it as close to the connection point as possible. This rule applies to equipment, air handlers, fan coils, "And" water pumps which typically have smaller connections than the main piping.

Traditionally in past years, steel piping was commonly used for chilled water systems and I unfortunately worked on a lot of them. It was very common to have to clean strainer screens due to internal piping debris. That is, If I could access the strainer[6] to get to the screen. The initial logic was, that only the original filling water carries sediment and once it settles out, the system will be ok. Some one forgot about leaks and fresh water additions. Then came Open Loop chiller systems (water oxidation continually). Open loop chiller manufacturers, in their installation literature, emphatically stated, "No Ferrous Metal Piping". Then, PVC piping became the chilled water standard. Copper was always an option, but at a little added cost. Also, if any chilled water piping shared any part of its circuitry with hot water, that piping would definitely have to be copper piping. Some electric chiller manufacturers recommend the use of composite tubing for their systems. This is always a good option if a correct tubing size is available. Under-ground piping can be copper tubing, composite tubing and even poly tubing (minimum 100 PSI rating).

6- Be sure to purchase a strainer (if used) which has easy access to the screen for cleaning purposes.

Note: Be careful of any tubing which uses insert connections which penetrate inside the tubing. This will create a high PD potential. Always minimize poly barbed fittings and be sure to calculate a proper PD so the applied water pump works.

Basically, there are two good choices for a piping type for chilled water systems; PVC pipe and Copper pipe. Composite tubing and poly tubing, though useable, offer a high potential for a high PD piping system. This can be very critical when using a manufacturer's supplied water pump (limited Ft Hd). Also, I do not have, nor do I know of a PD chart which converts tubing insert fittings into an equivalent feet value or provides a Ft Hd value (PSI value). Some chiller manufacturers, who do recommend tubing, may provide some of this information for you (hopefully).

Note: Copper piping and PVC piping are available in different pipe wall thickness values. Each one is available with a very thin wall, called drainage/waste pipe. This should never be used. Copper has an assigned letter value which indicates a good (M), better (L) and best (K) wall thickness. PVC is rated by a schedule factor indicating a good (sch 40) and best (sch 80) wall thickness. The better the piping is, and the larger a pipe size is, will reduce the number of supports required to hold it up and/or to secure the piping.

7.6 Piping Insulation

All chilled water piping, including valves, fittings and all supporting mechanisms[7], must be insulated with a good quality insulation[8] to prevent condensation. All seams and wrappings must be sealed really good to ensure that no air can enter and come in contact with the piping. It is always a good practice to insulate all condensate drain piping for all air handlers (fan coils) too.

7- All piping styles will require some type and style of a supporting method. Some are connected directly to the piping which will require insulation OVER the support. Some are connected over the insulation and great care must be given to protect the integrity of the insulation.

8- There are many insulation types on the market. Be sure to choose one which is designed for chilled water applications and be sure to follow a manufacturer's use and application instructions. No insulation should be less than 1/2" in wall thickness.

7.7 Piping Connections

Every installed piping system will have many different styles and requirements for making a pipe connection; 1- Screwed connections which could be copper to copper, copper to PVC, copper to steel (manufacturer fitting on chiller), PVC to PVC, PVC to steel and maybe some brass fittings and/or flanges used with water pumps. 2- Sweat connections which could be copper to copper, or copper to brass/bronze. 3- Glued connections for PVC piping. 4- Special tubing connections. Every installed piping system will have some type of an antifreeze product being used in the circulating water system. ALL of these factors will create another ***very important factor***, choosing a good and proper pipe sealant, glue and/or soldering method. The goal of course is a leak proof connected system and to stay that way for a long time.

All pipe sealants are not created equal and one must be chosen which can be appropriately used with antifreeze products. PVC threaded connections, especially to metals, can be tricky too due to the different expansion factor of metal verses PVC. Pipe sealant used in conjunction with a good Teflon tape, can be a good option for this need. Copper to copper sweat connections may be a 50/50 or 95/5 soldered connection or a silflos soldered connection. Copper to brass/bronze sweat connections must be a silver-soldered connection.

> ***Special Note: Every piping system must be leak checked which is typically done by an air pressure test, or by filling a system with water. NEVER add antifreeze to a system which has not been leak checked. Antifreeze leaves a residue on/in the piping, and this will make solder repairs a virtual nightmare. Also, never perform a final filling of the system, until the entire piping system has been flushed out good too.***

PVC connections will require using a glue to make socket to socket connections. PVC glue is not just any PVC glue. Always use glue which the PVC manufacturer recommends and always follow a PVC manufacturer's gluing recommendations. Some times, this may also require the use of a cleaning fluid. No matter what type of a connection you make, one word can define your anticipated success rate; "Cleanliness".
Remember, "Preparation is Everything" (**PIE**).

Always, follow manufacturer recommendations and if problems occur, it's their problem, not yours. And, be sure to follow the National Piping Code too.

7.8 Vibration Isolators

Some equipment (chillers and/or air handlers) may require the use of vibration isolators in the piping system, due to their installation location and/or to reduce the potential of mechanical noise transmission. When and if required, be sure to choose an appropriate product for a chilled water piping system. Also, be sure to consult a manufacturer's literature for a potential PD value for these isolators. It could affect your designed system's PD.

7.9 Piping Supports

Every installed piping system will require some supporting methods which can vary due to the item requiring support (piping, water pump, strainer, air separator, etc.).

<u>Note: No supporting type should ever be installed or applied in any manner which could be detrimental to the piping and/or the piping's insulation</u>.

Always refer to the National Piping Code for all supporting requirements. They do vary by piping type and piping size[9]. Some piping may require hanging supports, base hold down supports, raised leg supports, or some other support type based on a special need. Be sure to always use the best method for each requirement.

7.10 Load Zones

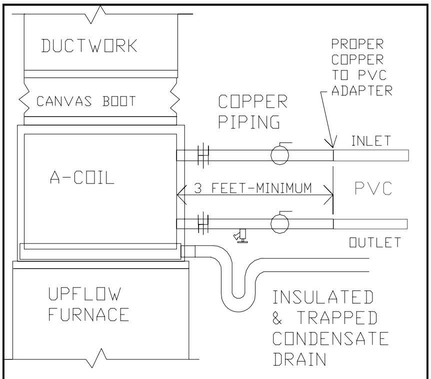

FIG 7.6 Typical Furnace Application

Just in case you ever do install a chiller system which has an a-coil (s) installed in a furnace (s), there is a special precaution which must be taken when PVC piping is being used for the main piping loop. Fluid in the a-coil will become heated during heating season operation. This could cause the PVC to soften and even break. To prevent this potential, always install 3 to 4 feet or more of copper piping right at the a-coil and then connect the PVC.

Note: Chilled water A-coil manufacturers state that, an a-coil applied in a counter-flow furnace, may see condensate blow off and they advise the use of a secondary drain pan in the duct work just below the a-coil.

9- The NPC lists piping support requirements based on; 1- a pipe type (copper, PVC, etc.). 2- piping hardness (copper harder than PVC). 3- a pipe's size (large size requires less supports). 4- pipe flexibility and much more.

7.11 Piping & Blower Systems

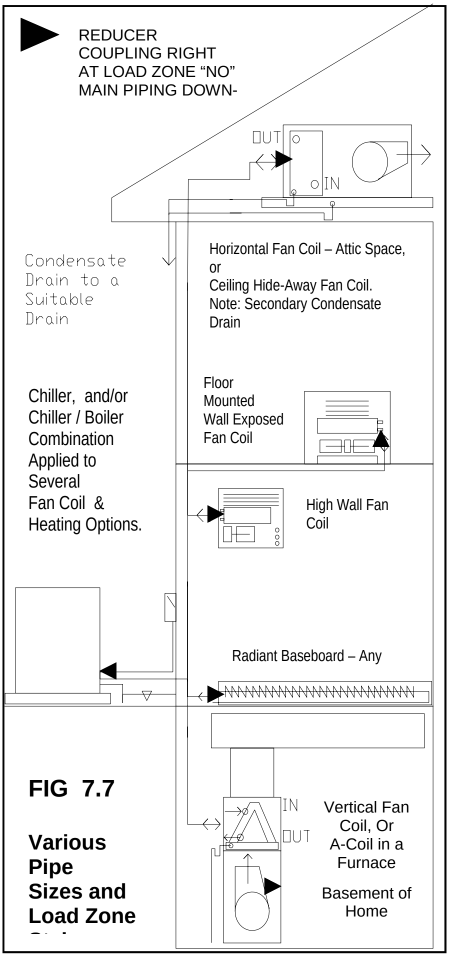

FIG 7.7

Various Pipe Sizes and Load Zone

Any installed piping system could have several different pipe sizes and several load zones which may also vary by size and/or manufacturer. The pipe size for each portion of a total system, must be sized properly for the GPM requirements of each circuit. The main piping loop may only be down sized after one zone has been fed (side outlet tee) and the continuing piping must be sized properly for the continuing GPM requirements. The connection at the chiller must be identical to the main loop piping, or a reducing coupler must be used right at the chiller. The reducing coupler must use a very short piece of connecting pipe (e.g. short nipple). As each properly sized water circuit is fed to an individual zone, that proper pipe size must be run to and be connected to each load zone. "IF" a load zone's connection point is smaller than the piping circuit, than another reducer coupling must be used right at the load zone. Again, using a very short piece of pipe.

Special Piping & Load Zone Considerations:

Any load zone installed above a finished ceiling must have a secondary condensate drain pan. Condensate drain piping and connections must be absolutely leak proof above finished areas. Condensate piping must be insulated really well above finished areas. All piping must be insulated really well above finished areas. Many times, piping may be hidden in wall voids with little to no accessibility. If and when piping is installed and applied in this manner, it is always best to; 1- use a better and/or thicker walled insulation. 2- insuring an air tight insulating factor is a must. 3- choosing a proper supporting method which will last is also imperative. 4- make sure total system operation is checked and double check before closing up walls. **"PIE" !**

Figure 7.8 highlights some typical piping connections for closed loop chillers, open loop chillers and a roof top applied chiller.

TYPICAL CLOSED LOOP - COPPER PIPE PRESSURE GAUGE, LOW PRESS ZONE PETE'S PLUGS, FLOW CONTROL VALVE IN-CHILLER PUMP & EXP TANK	TYPICAL OPEN LOOP - PVC THERMOMETER WELLS, FLOW CONTROL VALVE, 1" MIP X 1 1/4" REDUCERS AT CHILLER	TYPICAL ROOF TOP CHILLER ON ROOF CURBING, CONSTANT CIRCULATOR APPLIED, IN-CHILLER WATER PUMP

7.12 Special Pipe Sizing Information

Some chiller manufacturers, who supply water pumps in their chillers or chiller/boiler combination units, also provide some easy to use pipe sizing charts. The following chart is for a gas-fired chiller.

Chiller Pipe Sizing Chart:

		Chiller Size & Flow Rate		
Type of Piping	Nominal Pipe Size	3 Ton 7.2 gpm	4 Ton 9.6 gpm	5 Ton 12.0 gpm
Copper	3/4"	115ft	****	****
Copper	1"	432ft	262ft	154ft
Copper	1 1/4"	1167ft	706ft	412ft
PVC	3/4"	162ft	98ft	****
PVC	1"	532ft	313ft	182ft
PVC	1 1/4"	1998ft	1159ft	668ft

**** Exceeds velocity limits of 6 FPS.

The logic is to add up the total length of straight piping to get one value. Then, add up the number of installed items in the piping circuit (90's, tees, 45's, valves, wells, etc.) and multiple the number of these items (e.g. 15 items) by 3 (3 feet per item).

15 times 3 = 45, or 45 straight feet of pipe. This is a manufacturer's answer to a conversion chart. Now, add the actual straight feet of pipe (e.g. 125 feet) to the 45 feet for a grand total of; 170 feet. Now, based on the chiller's size (e.g. a 5 ton chiller) look in the column under a 5 ton chiller and find a pipe length entry value which is equal to or larger than your calculated value of 170 ft. You will see in this chart that there are two potential choices; 1 1/4 Copper pipe (154ft is less than 170), or 1" PVC pipe (182ft is greater than 170). There is a slight chance that this may be an over-kill, but it definitely works. The manufacturer has taken into account the PD value of "One" standard water coil in their chart. This chart is only good for a single chiller and a single water coil.

Chiller / Boiler Combination Units with a manufacturer supplied water pump.

		Unit Size & Flow Rate		
Type of Piping	Nom. Pipe Size	3 Ton 7.2gpm	4 Ton 9.6gpm	5 Ton 12gpm
Copper	3/4"	0 to 82'	****	****
Copper	1"	83-300'	0 to 90'	0 to 60'
Copper	1 1/4"		91-225'	61-200'
Copper	1 1/2"			201-500

This chart uses the same logic as was used for the chiller. Only copper pipe may be used (hot water) and the useable figures are reduced due to the added piping in the manufacturer's unit (more piping = larger PD = less available pump Ft Hd). Never use a smaller pipe size, even if your total length is close (e.g. 5 T @ 62' = 1 1/4" pipe).

A Multiplication Factor: Some manufacturers (and others) may tell you that a good rule of thumb is to just multiply the total straight feet of pipe by 1.50 (50 % for piping items) and then calculate your PD from the friction chart. Then take that PD value, add in your slush factor and your all set. While this may work now and then, you really need to ask yourself, if you're willing to take that chance?

7.13 Gas Piping

Most small tonnage gas-fired chillers have a 1/2" or 3/4" gas pipe connection on the chillers. But, most gas supply lines will be 1" or larger. That's because, just like water piping, gas piping has a PD factor too. Gas supplies have a piping supply pressure and the chiller has a specific gas volume usage factor (btuh). All piping must be sized to deliver this usage volume, and pipe sizing is based on some specific variables (gas supply pressure, typically 0.5 psi or less and the distance the chiller is from the main supply source, gas meter). If you do not know and/or understand gas pipe sizing, always consult a professional and the National Fuel Gas Code.

All installed gas piping must be pressure tested to ensure that there are no leaks. This pressure testing could exceed 0.5 psi and if it does, it will certainly damage gas valves which are supplied in the chiller and boilers too. The equipment should always be isolated from the main gas piping when pressure testing exceeds 0.5 psi (typically a manual gas valve in the piping system and near the equipment). Most gas-fired chillers can also be operated by propane gas. If this need ever arises, be sure to consult a propane professional, because propane gas has some pipe sizing and supply issues all to it self.

7.14 Electrical Wiring

Let's get the almighty disclaimer out of the way first. ALL electrical wiring must conform to the latest edition of the National Electrical Code (**NEC**). Most manufacturers provide you with the electrical specifications and operating requirements of their products, but they provide very little regarding code requirements. It is your responsibility to either know the electrical codes, or to find out what is required. Disclaimer done.

There are several issues for electrical wiring; 1- gas-fired chillers typically have little electrical needs, a 15 to 20 amp maximum service. 2- electric operated chillers will have a much larger electrical service requirement, three to four times more than a gas-fired chiller. 3- each chiller type will have control wiring as well as a main electrical service. Control wiring choices for a wire's size is critical too. In our new age of electronics and solid stage ignition systems, many manufacturers are mandating a specific size for the control wiring (minimum acceptable size).

7.14.1 Service Disconnect

Almost every manufacturer's literature I have seen, indicates the necessity of having a fused disconnect for the equipment (chiller, boiler or combination). Most, if not all codes require one too. Most codes limit the distance a disconnect may be from the equipment. Many installers even mount disconnects right on equipment and this is a service person's nightmare[10]. When wiring is being run and supplied to a piece of equipment from a main fuse or breaker panel, its size will be based on the total operating amps of the equipment and the distance the equipment is from the main panel (**NEC**). IF, two or more pieces of equipment are being installed (maybe even a water pump or two), one supply, properly sized for the total amps of all applied equipment can typically be run, and then be split near the equipment for individual services and disconnects to each item. Even though it is typically a code requirement today, many manufacturers, especially gas-fired chiller manufacturers, will remind you that a common ground wire will also be required for the rectification process of the solid state ignition systems. Many manufacturers even provide electrical connection information and ideas in their literature (that is if you have read the literature).

10- Disconnects have a way of always being conveniently located right on a panel you have to access to service the equipment. Boy, have I use some good words for these guys in my servicing days.

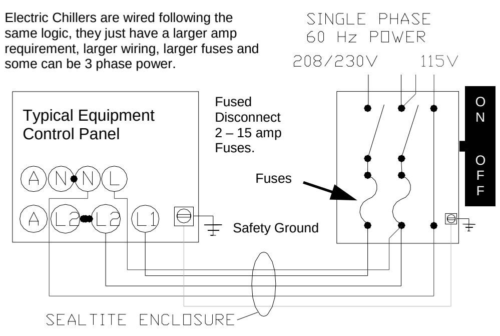

FIG 7.9 Typical Disconnect & Wiring

Figure 7.9 highlights a typical disconnect being connected to a piece of equipment. Gas-fired chillers can operate on 115 volts and 208/230 volts being a single phase service. Electric chillers having a higher amp load, typically operate on 208/230 volts which may be a single or three phase service. 115 volt panels are typically marked L (main power line) and N (the neutral line).

7.14.2 Wire & Disconnect Sizing

208/230 volt panels, having two (2) hot legs, are typically marked L1 (one hot line) and L2 (the second hot line, often referred to as the common line). Common typically means it is not used in the controlling circuit. This leg is commonly wired to all high voltage operating devices. Leg L1 will typically be used for the controlling circuit, for any normally open controlling devices. Sizing of wiring and disconnects are very important for proper equipment operation. As the total operating amps increases (single or multiple equipment) so will the supply wire size (e.g. 15 amps = # 14 wire, 20 amps = # 12 wire, 30 amps = # 10 wire, 40 amps = # 8 wire, etc.). The size requirement of a disconnect will increase to. As a disconnect increases in size, so will the type of fuse which is used in a particular disconnect (30 amp disconnect uses 15 to 30 amp fuses, 60 amp disconnect uses 35 to 60 amp fuses and with a different fuse design so they can only be used in this size disconnect).

7.14.3 Control Wiring

CAUTION: Many good electricians still do not necessarily understand good control wiring. This statement is not being made to condemn electricians. It is being stated because many control systems today, require special attention for their operational logic and application. Thermostat wiring ***is not necessarily the same as Control Wiring.*** Chiller systems can require an extensive control system due to the highly applicable variable of multiple zones. Also, chillers typically have a control transformer in them and this transformer is limited in its capacity to handle an extensive (long and/or multi-circuited) controlling system.

Many variables can enter into a chiller's controlling system; 1- By their nature, chillers typically have more controlling devices in them which creates a higher amp draw for the 24 volt control circuit. 2- Many manufacturers even set limits for a control circuit's wire size (e.g. minimum 24 volt wire size of 18 gauge). 3- Every installed and applied load zone will require a thermostat to operate the load zone's blower relay. 4- Every load zone will typically require a 3-way zone valve and this must be controlled by the load zone's thermostat. 5- Every load zone, when requiring cooling (or heating) must have a method of signaling the chiller (or boiler). 6- IF, there are multiple chillers (boilers), some means of staging must be provided for total effectiveness and efficiency of the system. 7- IF, there are any long runs of control wiring, the wires size may need to be increased (e.g. 50, 75 or 100 foot plus runs). 8- Having two or more load zones, typically means having a separate and independent control transformer for the zones. 9- Multiple chillers and multiple zones, equals multiple transformers and isolation relays must be used to isolate all applied transformers.

The following figures will highlight several controlling options for chilled water cooling systems.

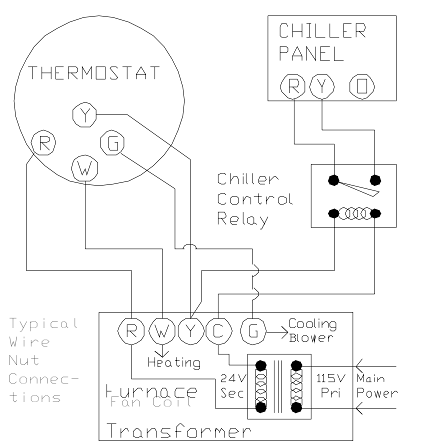

Fig 7.10 Isolation Relay

Figure 7.10 highlights a simple one on one system. Starting with a basic system and building from here, should make it easier to understand and follow the logic of larger applied systems. Typical control transformers, as provided in many chillers, are rated at 24 volts having a current rating of 40 VA (volt amps). This means that we can develop the following formula; (40 VA ÷ 24 V = 1.66 A). A 40 VA transformer can handle a 1.6 amp load, maximum. It is not a good idea to demand more than 75% of this total capability either (1.6 x .75 = 1.24).

So the maximum amp load for this transformer should really not exceed a 1.2 amp draw. Most chillers will use from 0.6 to 0.8 amps just to operate the chiller, so there is not a lot of power left for external use. Long wiring runs, the thermostat and a blower relay can really use up the excess amps fast. Very few systems will be a one on one system and it is easy to see why a second and independent control transformer will be needed.

To help keep the amp load resistance factor to a minimum, many manufacturers today are recommending a minimum wire size for any controlling circuit (18 gauge wire). Knowing that a two transformer system will most likely be used, it now becomes necessary to isolate these two power sources. This is done by adding a chiller control relay (isolation relay - Fig 7.10). To minimize the amp draw on the chiller's control circuit, use the thermostat's transformer to operate the relay and use the relay's contacts to operate the chiller's circuit. Also, knowing that we will most likely have a multi-zone system, means that we will have 3-way zone valves. This means that we now have an easier way to interlock a chiller's operation.

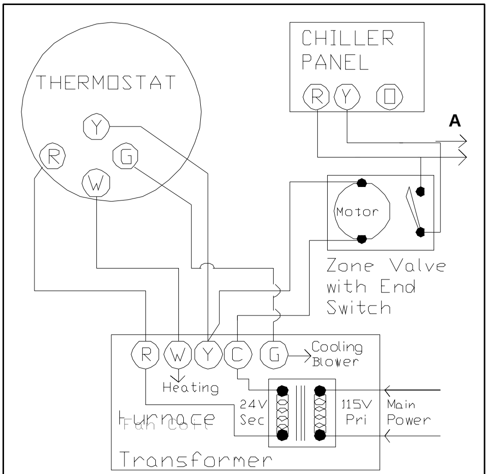

FIG 7.11 Zone Valve & End Switch

Figure 7.11 highlights the application and use of a 3-way valve. 3-way valves can be purchased with an end switch in them (set of normally open contacts). When a zone valve is powered to open, and at the end of its opening (motor operated arm), the end switch's trigger is pushed to close its contacts. The thermostat will energize the blower relay and the 3-way zone valve (one transformer) and the end switch contacts will signal the chiller to operate (second transformer). The end switch now isolates the two power sources.

The chiller's R to Y circuit may be parallel wired to all applied end switches (A). This is a common circuit and any one or all end switches will be closing the same circuit. "IF" a particular system had multiple chillers, the chillers would be operated by an applied staging control. Instead of the end switches signaling the chiller, they would now signal the staging control and the staging control would in-turn signal the chillers. If heating is going to be used with a cooling fan coil system, there is typically no means of controlling a blower's operation for heating. A typical heating system circuit, R to W, normally only signals the heating device itself to operate. There has to be another device added to the fan coil, to control the blower operation for heating (normally incorporated into a standard furnace system). There is a very easy answer for this need. A fan delay switch.

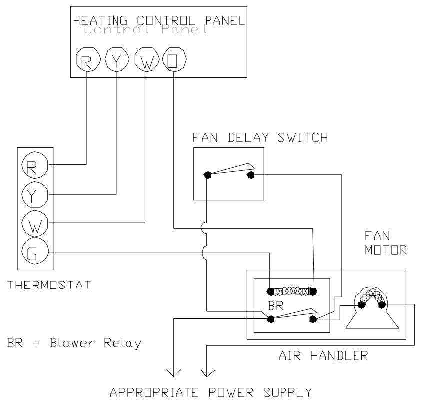

FIG 7.12 Fan Delay Relay

Figure 7.12 highlights the application and use of a fan delay relay. This is simply a pressure actuated switch which is parallel wired to the blower motor's control circuit. Figure 7.13 shows one such device which has been used for many years with gas-fired chiller systems. The blower relay in the fan coil is operated by the thermostat to close the blower relay's contacts on a demand for cooling. The fan delay relay's contacts are parallel wired to the BR's contacts which allows either device to turn on the blower motor (common circuit).

This fan delay relay is a remote bulb device (3/8" diameter by 6" long). The remote bulb is strapped to the face of the water coil (down stream air side). When hot water is circulated through the coil, the bulb is heated and the switch is energized (130° F On). When heating is done and hot water ceases to flow through the coil, continued air flow cools the bulb and the switch is de-energized (100° F Off). The switch is amp rated at 5.0 amps max. A very easy and effective method for automatically controlling the blower's operation.

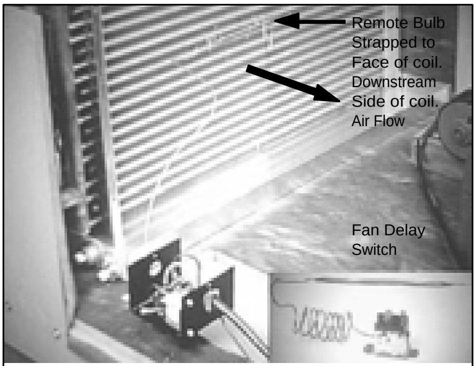

FIG 7.13 Remote Bulb Installation
Pictures Courtesy of Arkla Industries

Any remote bulb style switching device could be applied for this need, provided it meets similar specifications to that noted above. A couple of items do require special notes; 1- Many remote bulb controls have adjustable dials and the required operating temperature (e.g. 130° F), should be some where in the mid-range of the dial's total adjustability. 2- Many remote bulbs are shorter than 6 inches and this will take longer for them to heat up. Try to avoid short bulbs. 3- Be sure that you have the ability to set at least a 25 to 30 degree differential on the control. 4- Make sure the control has an appropriate amp rating for its contacts. Remote bulb controllers are very popular for hydronic systems. But, all too often they are installed and applied wrong and troubles can occur.

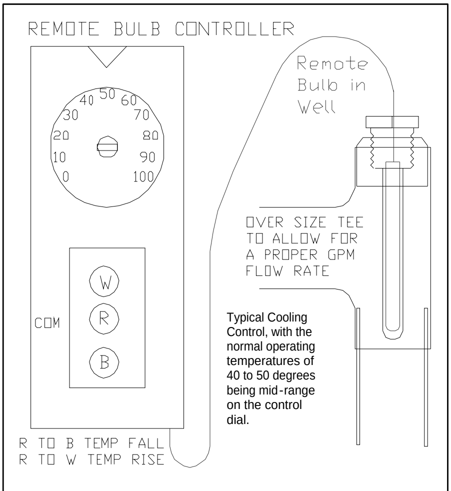

FIG 7.14 Installing a Remote Bulb

Figure 7.14 highlights the application requirements of a typical remote bulb. The remote bulb normally requires a bulb well which must be located in the piping's circulating water stream. The bulb can only perform properly, IF, the total bulb is submersed into the water stream. The bulb well is typically 1/2" O. D. to accept a 3/8" remote bulb (there are some larger remote bulbs too). When a bulb well is inserted into a piping circuit, the well itself will consume a good portion of the water's flowing area. IF, the pipe is not over-sized by one size, it could infringe upon the water's ability to flow properly (proper GPM).

This need is typically required for systems having a 1 1/2" pipe size or smaller. Every thing possible must be done to get the entire remote bulb totally submersed into the water stream. This means no side outlet tee adaptations.

7.14.4 Wiring Connections

One big issue which has really bothered me over the years, has been the method by which many people use to install and connect control wiring. Nothing is more frustrating than to have to trouble-shoot a system, only to find a poor wire connection due to laziness or what ever on the part of an installer. Figure 7.15 highlights some wiring connection issues.

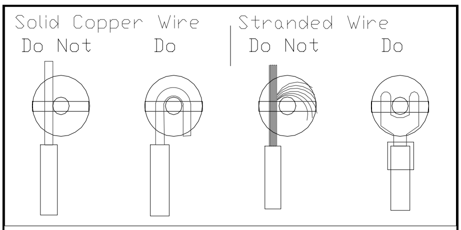

FIG 7.15 Proper Control Wiring Connections

Some other issues I have are; 1- wires nuts, when applied right, can be appropriate in a closed panel. But, exposed wiring, especially in equipment, should be connected by crimp on butt connectors and shrink wrapped when appropriate.

2- electrical tape is very handy and works great to add extra security over wire nut connections. But, when used by itself as the only securing means, I'd like to hang the jerk who does this. 3- use common sense. Choose proper wire types, proper sizes and when necessary, match a manufacturer's existing wiring for all repairs.

7.14.5 Staging Chillers & Multiple Zones

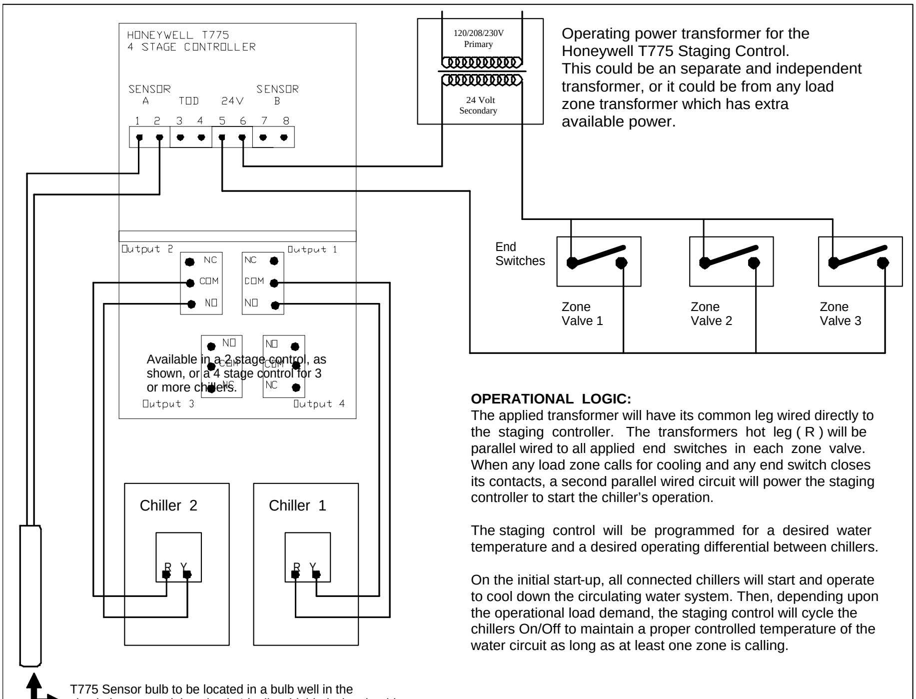

FIG 7.16 Staging Controls & Operational Logic

There are a few items to take note of regarding this Solid State Staging Controller[11];

1- It uses a remote bulb which must be installed in a bulb well (we know what that means).

2- Special shielded wire may be required for remote bulb connections (always consult manufacturer's literature). 3- It has many adaptive options which can be highly adaptable, even for heating systems too. 4- It has independent relay contacts which easily isolate a multi-transformer system. 5- It is available as a 2 stage or 4 stage device. 6- It can be operated by 110 volt and 220 volt power too.

11- This Solid State Staging Control is manufactured by the Honeywell Corporation. I have used many of their controls and have had great success in doing so. I would like to personally thank Honeywell International, Inc. for all their support.

Many, many pages could be written on controlling circuits, but that is another book all to itself. If and when the need occurs, and should you have any trouble in developing a good control system design, always consult a control specialist. When designing any control circuit for any system, always have every manufacturer's literature for every type of equipment which your system will be using (chiller, fan coils, 3-way valves, staging controls, etc.). The more information you have for everything, will only make your job easier and your control expert.

7.14.6 Controlling Water Pumps

There are numerous ways in which a water pump's operation may be controlled. Unfortunately, there is no typical method, save a manufacturer supplied pump right in the chiller. This too, is another reason for having a good control specialist to rely on. Water pumps will most likely be controlled through the normal 24 volt control system. As the number of items being controlled by a 24 volt circuit increases, so will the total amp draw of a given control circuit. Because you will be purchasing extra control transformers for added load zones, do not just settle for more 40 VA transformers. They are available in higher VA outputs. If you add up the amp draw of all devices for any given designed control circuit (you must consult a manufacturer's specifications per device), you can determine the VA requirement of a circuit (e.g. 65 VA) and you can now purchase an appropriate transformer (e.g. 100 VA). You may only need one larger transformer for one special circuit and all the others can be 40 VA (you should never use less than a 40 VA transformer per control circuit).

The important item to remember for all applied water pumps is, when should they be operating and when should they be off. Providing a control specialist with a good operating logic, will enable them to design a good and proper control system. Here are a few more items to consider; 1- An in-chiller pump will operate when the chiller's circuit tells it to. 2- If a booster pump has been added to an in-chiller pump, the chiller's circuit should tell the booster when to operate (e.g. use in-chiller pump's power circuit to energize booster). 3- A primary external pump can be controlled to operate all the time or it can be cycled On/Off through the designed system's main controlling device (be sure to consult a chiller manufacturer's literature regarding constant flow through their chillers). 4- If chiller's are to be secondary pumped, the chiller's circuit can control the secondary pump and the primary circuit is all to itself. 5- Any secondary applied pump must be controlled by the circuit it is feeding (load zone or chiller).

CAUTION: Many, many chillers have a post operational period (operational pump down and/or operational cool down) when the controlling R to Y circuit is opened. Most manufacturers mandate that water must be circulating through their chillers during this post operational period. This simply means one thing; ***Every water pump must have a time delayed shut off period when its controlling circuit opens, and this time delayed period must match or exceed the chiller's post operational period.*** Applications using in-chiller pumps will be covered by the manufacturer's designed chiller control package. All field applied pumps, must either interlock with a chiller's circuit, or a separate time delay relay must be added to a pump's control circuit. There is an appendix section at the end of this chapter. In this appendix, I will show some of the system design layouts which were shown in chapter 6, Designing and Engineering, and I will provide some controlling ideas for all applied water pumps.

7.15 Filling the System with Water & Antifreeze

With the system installed, piped, wired and controlled, it must now be made ready for the starting of the system. The first thing which must now be done, is the filling process of the water/antifreeze mixture.

> ***Special Note: During the wiring process of the system, many people like to operate electrical devices to ensure proper operation and proper rotation of these devices. NEVER, NEVER, OPERATE A WATER PUMP WITHOUT FLUID IN THE SYSTEM !***

Depending upon the chiller system type (Open or Closed, Gas or Electric), there may be some different requirements for the filling of the system. Always consult a manufacturer's literature. Also, before filling any system with a water/antifreeze mixture, you must be able to answer yes to these two questions; 1- Was the piping system leak checked good? 2- Was the piping system flushed and cleaned good ? If yes, proceed. If no, you know what to do.

In order to determine an appropriate amount of antifreeze for the system, you must; 1- Decide on an antifreeze percentage factor, and 2- You must calculate the total fluid volume for the entire system. These factors were outlined in chapter 6 - appendix. Most manufacturers mandate a minimum antifreeze percentage of 20% and many manufacturers also mandate purified water (distilled and/or de-ionized water). If you purchase your antifreeze as a pre-mixed percentage mixture, you will have both of these factors covered.

Most chiller systems today will be closed loop system. They will require some access point into the piping system for pumping the water/antifreeze mixture into the system. This was highlighted in Figure 7.8.

FIG 7.17 Filling Apparatus

Figure 7.17 shows a picture of a filling device which I have used for years to pump the fluid into a system. I just used a plastic holding tank and mounted it over a small pump. I can easily pour my mixture into the tank and I will connect a fill hose from the pump to a boiler drain in the piping system. With a main ball valve closed in the piping system, the fluid mixture I pump in can only flow in one direction into the system. I then open a second boiler drain on the other side of the ball valve to relieve air from the system. With a hose connected to this second drain, I hang it in my holding tank. At some point, fluid I am pumping in, will start coming out and I keep pumping until I have a steady stream.

The system now has enough water/antifreeze mixture to allow for normal water pump operation and for operating the system. Any air which may still be trapped in the system, will soon be removed by the air removing devices which are installed on the piping system. I will not remove the filling device yet, because when the chiller (s) are operated and as the water's temperature cools down, the pressure in the system will drop. It is very important to have a positive operating pressure (5 to 10 PSI) when the system is fully operational and the chilled water temperature is at least 50 degrees or lower. This is why a pressure gauge is needed at the suction side of the system's pump (or as close as possible).

As the system's water pump operates and as the air relief device (s) removes more air from the system, continue to add fluid maintaining a 10 psi system. When the chiller is ready to be operated, do so, and when the water's temperature reaches 50° F or lower, check the pressure gauge and add as needed. If you are still in doubt as to whether or not more air may still be removed, leave the filling device connected. There will surely be a little more work to do before you will leave and just before you leave for the day, you can make one more final system pressure check. If you really would like to save yourself some time and provide a little insurance factor for your customer, you could always install an auto-fill system.

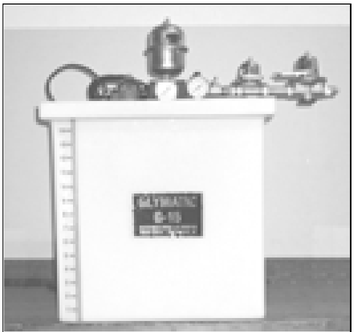

FIG 7.18 Auto-Fill System

There is finally, a small, in-expensive and really neat automatic filling system for water/antifreeze systems. It called the GLYMATIC® Glycol Make-Up Package and it is manufactured by the Wessels Company[12]. This neat little device can not only be a time saver for new installations, it's a great insurance package for systems which cannot have a city water make-up system. Once your main filling device has done the main filling (much faster than the auto-fill) the auto-fill system can easily handle all the rest.

7.16 Setting Water Flow Rates

Once the water system has been filled and the system's water pump (s) are able to operate, the flow rate settings may now be made. The method and or manner by which the flow rate (s) will be set, is totally dependent upon; 1- Whether it is an open or closed system. 2- The number of chillers being used. 3- The number of load zones for the designed system. 4- The flow control devices chosen for the system, and 5- If there are any special applied piping loops.

7.16.1 Open Loop Systems

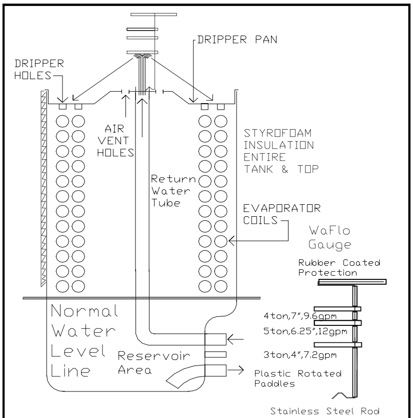

FIG 7.19 Open Chiller Flow Rates

Open loop chiller systems are a breed of their own and the manufacturer of these systems typically provides special requirements for flow rate settings. Figure 7.19 shows a cut-away drawing of a chiller assembly which has been around for over 30 years. A proper water flow rate is set by the height of a water column right inside the chiller (requires accessing the chiller's open tank assembly which is covered, but not pressurized). ***Be Sure*** to consult a manufacturer's literature if you come across an open loop system. This logic is for a single chiller, single coil application.

12- My sincere thanks to the Wessels Company. We have needed this system for a long time.

Very Important !
Most chiller manufacturers mandate a minimum acceptable flow rate through their chillers, when they are operating and cooling the water circuit. "And", during the post operational pump down period (cool down period) should this exist. Chillers can typically operate with a "Larger" flow rate (25%), BUT, NEVER less than the mandated rate.

7.16.2 Closed Loop Systems

Closed loop systems must have their flow rates set by a pressure drop method. This can be accomplished by three basic methods; 1- A PD reading through a chiller. 2- A PD reading across a special flow control device. 3- A PD reading across a water pump.

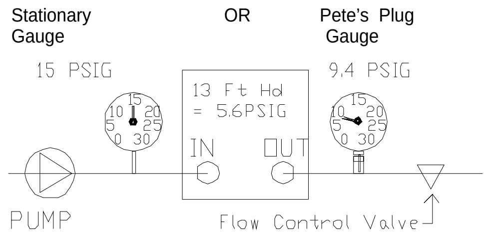

FIG 7.20 PD Reading Across a Chiller

Figure 7.20 highlights a PD reading being performed across a chiller. Using the manufacturer's PD rating for the chiller (13 Ft Hd), it must be converted to a PSI value (13 ÷ 2.31 = 5.6). This means the difference between Pressure IN and P - OUT, must be 5.6 or more (higher flow rates = higher PD's).

As shown, the P - In reads 15 psig. (15 - 5.6 = 9.4) The **.4** value will be hard to read on a typical pressure gauge. Therefore, the gauge needle **must** be closer to **9**, than it is to 10. 9 PSIG = a little higher PD (6.0) and it equals a little higher GPM. A 10 PSIG reading would = a 5 psig PD and a lower than mandated GPM. Last, the pressure in gauge reading is higher than the chiller's PD rating, and this means the pump is providing sufficient Ft Hd for the system. If the P - IN reading was equal to or lower than the chiller's PD rating, the pump is too small (either sized wrong, pipe sizing issues, or some other issue to be addressed).

This method only works for an external applied water pump. If you have a chiller with an in-chiller pump, you cannot take a PD reading across the chiller and the pump. You will have to use one of the other PD methods. The logic shown in figure 7.20 also works for fan coils (air handlers). Fan coil manufacturers do provide PD ratings for their water coils, based on a specific water flow rate through the coil. If P - In, minus P- Out, equals a manufacturer's PD rating, the flow rate is correct.

Special Note: When the system is initially started, the initial pressure PD reading must be "Higher" than required. This means that there is a higher GPM flow rate than required (proper pump sizing) and that's why flow control valves are installed. To be closed down to set a correct and proper GPM flow rate.

FIG 7.21 Pete's Plug® & Adapter

Remember, you always have the option of installing physical stationary pressure gauges, or you can install Pete's Plugs® and then use a pressure gauge with an adapter for taking pressure readings. I prefer the Pete's Plugs® because my experience has shown that stationary gauges due not last a long time, and there is always a question of calibration between gauges. BUT, for every closed loop system, there should be at least one physical gauge installed at the lowest pressure zone to monitor system pressure.

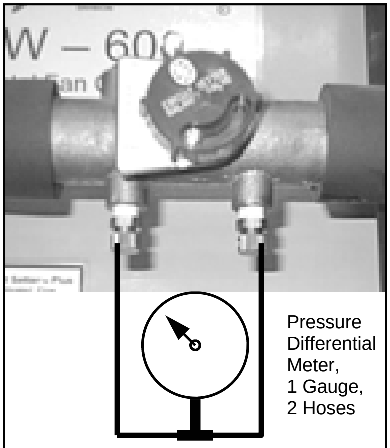

FIG 7.22 Special Flow Control Devices

Figure 7.22 highlights method two. Using a special flow control device which has pressure reading taps right on the device. While this method does require the purchasing of a pressure differential meter, it is by far the easiest and most universal method, and it can be used any where. This method is highly appropriate for multiple load zones, where every zone will require its own specific flow rate setting. Flow valve manufacturers provide and easy to use chart, for taking PD readings and for setting any specific flow rate.

NOTE: *Any given size flow control valve (e.g. 3/4", 1", 1 1/4", etc.) can only handle a specific range of flow (e.g. A 1 1/4" B&G Circuit Setter® = 13 GPM maximum in a fully open condition). GPM flow ratings for a given valve size can vary by manufacturer*[13] *. Be sure to consult all valve types and styles for proper usage and application.*

13- Many thanks goes out to Bell & Gossett and ITT Fluid Technology Corporation.

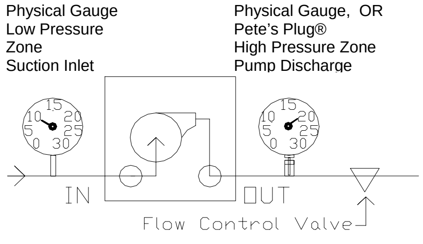

FIG 7.23 PD Across Operating

Figure 7.23 highlights a PD reading being made across an operational water pump (some pumps have pressure taps right on the pump). If, pressure taps do exist, they are typically plugged off. Remove plugs and add gauges and piping. The other option of course is, to have pressure gauges right in the piping system (the closer to the pump, the better and more accurate the reading will be).

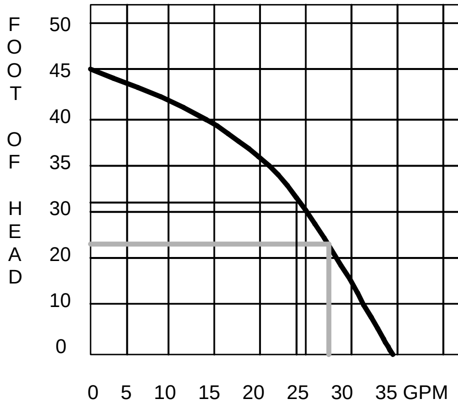

FIG 7.24 Typical Manufacturer Pump Curve

To perform this PD test and to set a proper flow rate, requires one to have a manufacturer's pump curve for the specific pump being used (manufacturers normally have a pump curve for every designed pump). Pressure IN = system static fill pressure being controlled by the filling process or an auto-fill system (e.g. 10 to 12 psig). Pressure OUT = the pump's capability + static. Pressure OUT minus Pressure IN = Pump's operational capacity.

Referring to figure 7.23, the differential between Pressure IN (10 psig suction inlet) and Pressure OUT (20 psig discharge outlet) is 10 psig (20 - 10 = 10). We must now convert this PSI reading into a Ft Hd value (1psi = 2.31 Ft Hd) (10 times 2.31 = 23.1 Ft Hd). Now, referring to figure 7.24, the manufacturer's pump curve, find the 23 Ft Hd on the left side of the chart. Draw a straight line (gray line) across to the manufacturer's operating curve (heavy dark line). Now, draw another line straight down to the GPM entry line. This pump is moving approximately 27 GPM. If your designed system has a GPM requirement of 27 GPM or less, this pump is fine. If your GPM flow rate is less, just close down the flow control until your pressure reading calculations match the GPM entry on the manufacturer's pumping curve for your designed GPM requirements (e.g. you want 24 GPM. This means the pressure reading calculations should provide an approximate 31 Ft Hd value).

7.16.3 Multiple Chiller / Load Zone Flow Settings

Any installed and applied system could have multiple chillers, multiple load zones and a combination of both. Every individual chiller and load zone must have a correct flow rate through it and it must be set properly at the time of starting the equipment. This means that the system's total flow rate will now be set at the chillers and/or load zones. The three basic potentials for this are; 1- Multiple chillers and one load zone. This will require flow control valves at the chillers and when each chiller's flow rate is set properly, the total system's flow rate is set. 2- Multiple load zones and one chiller. This will require a flow control valve at each load zone and when each load zone's flow rate is set properly, the total system's flow rate is set. 3- Multiple chillers and multiple load zones. This will require a flow control valve for all applied chillers and all applied load zones. Each item must have its particular flow rate requirement set properly for proper operation of each one. The above logic assumes that the total flow rate requirements of the chillers and the load zones are identical. Other flow controlling options were discussed in the design and engineering chapter.

7.16.4 Multiple Water Pumps & Special Needs

If any system is being applied by Primary/Secondary Pumping (multiple pumps), each pumping circuit will require its own flow control device. This is also mandatory for special pumping needs which are typically handled by secondary pumping (low to no flow circuits and/or special cooling loops which only operate when needed). No matter how many circuits require controlling of a given flow rate, one of the three flow controlling methods discussed in 7.16.2 will definitely work.

7.17 Low Ambient Operation

Many installed and applied chilled water cooling systems have the potential for operating in cold weather. Most manufacturers will note an acceptable outdoor temperature which their chillers can operate at (maximum and minimum). Many chillers can operate at lower ambient conditions, but only with some special items added (low ambient kits). Always consult a chiller manufacturer for this need, if you know that there is a potential for any chiller system to require low ambient operation. Many manufacturers will even set up the equipment for low ambient operation prior to shipment of the equipment. This is the easiest and best option. Order the equipment already pre-controlled for low ambient.

7.18 Basic Operational Start-Up Adjustments

Many manufacturers provide a list of basic adjustments and operational checks which need to be made at the time of start-up. This is not only for the chiller (s), it is also for the fan coils (air handlers). Because products can vary by manufacturer and style, it is always best to consult a manufacturer's literature for the specific adjustments for a given product (that is, if you can still find the manufacturer's literature). Here is a general list of some of these items which you may see for a given product type.

7.18.1 Electric Chillers

1- Check for a correct and accurate water flow rate through the chiller.
2- Check the operating amps for all high voltage operating devices.
3- Check all controls for operation and calibration.
4- Check condenser fan (s) operation and rotation.
5- Check system for any potential fluid leaks.
6- Check the refrigerant system for any potential leaks.
7- Check the refrigerant system for proper operating pressures.
8- Check all connected external controlling devices for proper operation.
9-Check the water circuit for a proper operating temperature.

7.18.2 Gas-Fired Chillers

1- Check for a correct and accurate water flow rate through the chiller.
2- Check the chiller to make sure it is setting perfectly level.
3- Check total chiller operating amps.
4- Check all controls for operation and calibration.
5- Check hydraulic pump for oil level and operational belt tension and condition.
6- Check gas input per manufacturer's operational chart.
7- Check condenser fan height, rotation and operation.
8- Check entire chiller for any potential fluid leaks.
9- Check water level in open fluid tank models.
10- Check operational temperature of the chilled water circuit.

7.18.3 Fan Coils & Air Handlers

1- Check blower motor operation and rotation.
2- Check blower speed and belt tension (when applicable).
3- Check 3-way valve operation and end switch (if applicable).
4- Check for a proper delivered air temperature (see note below).
5- Check for a proper water flow rate through the coil.
6- Check all supply and return air grilles, especially for any potential blockage of air flow.
7- Check for any potential fluid leaks at fan coil (s).
8- Check condensate drains for proper operation.

Special Note; Delivered Air Temperature
All chilled water cooling systems operate on a 10 degree temperature differential (Delta T or Δ **T**). A chiller, having a proper GPM flow rate and load, will cool the water down 10° F and when the water flows through the fan coil its temperature will rise 10° F. Proper air flow through any fan coil (air handler) may be checked by making a temperature test of the flowing air stream (return air into the fan coil verses supply air out of the fan coil). Two system operating factors are required for this test; 1- having a proper GPM flow rate through a fan coil, and 2- having a supply water temperature of at least 50° F or lower. As the air moves through a fan coil and across the chilled water coil, the air temperature should see a 15 to 20 degree temperature drop. If the temperature difference (Δ**T**) is less than 15° F, air is moving to fast across the coil and it cannot be cooled down properly. The blower motor's speed must be decreased. IF the Δ**T** is more than 20° F, air is moving to slow across the coil and it is being cooled down too much. The blower motor's speed must be increased.

7.19 Wrapping Thing Up

There are many other variables which can enter into the start-up and operation of any given system, but they will vary by system design and a chosen manufacturer's product. For this reason and purpose, there is ***ABSOLUTELY NO SUBSTITUTE*** for not having appropriate manufacturer literature. While there still may be many similarities between products, there is most likely, ***JUST AS MANY DIFFERENCES.***
Please, Please, do not make the fatal mistake which way too many people do, please read manufacturer's literature.

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A-7.2	Relay, Contactor, Starter Designs
A-7.3	Single In-Chiller or External Pump
A-7.4	Booster Pumping
A-7.5	Booster Pumping / Constant Circulator
A-7.6	Multiple Chillers / Multiple Loads
A-7.7	Chiller Capacity verses Load Demand
A-7.8	Process Cooling

A-7.1 Controlling a Water Pump's Operation

There are several methods by which a water pump may be controlled to operate and several factors could enter into making an appropriate choice. The horse power of a pump's motor will dictate whether a relay, a contactor or a starter must be used to operate a pump. There is always the option of just using a main disconnect for some pump's operation too (typically pumps which operate all the time). Then, depending upon the controlling method chosen (relay, contactor or starter), you will have to decide what will signal the chosen device in order to start the pump's operation.

The easiest answer to all these issues, is to use a chiller which has a manufacturer's supplied water pump. The manufacturer will have the pump's controlling circuit already installed and wired, and the chiller's typical 24 volt control circuit (R to Y) will be the signal to start the pump's operation. Unfortunately, this scenario may not be available all the time and now, you have to design a control system for the pump. I will first discuss the difference between a relay, a contactor and a starter and why one or another of these may need to be used. Then, I will discuss some controlling options (how to signal a relay, contactor, or starter). To do this, I will show some of the layout designs which were shown in chapter 6 and add controlling comments for each one. I sincerely hope this information will be helpful for you.

The main difference between a relay, a contactor or a starter, is the operational amp load which a device has to handle.

Relay = Small amp load operating devices (typically 30 amps or less). The normally open contacts (NO) will have a specific amp rating and it is important to choose a relay which has a proper amp rating for the load it will handle. Some relays come with both a NO set of contacts and a normally closed (NC) set of contacts. Most relay sizes and types are capable of being energized by several different voltages (24v, 115v, 208v, 230v, 460v). You must know the voltage of the controlling signal to make a correct choice for a relay's operating coil. This voltage logic for an operating coil, is identical for relays, contactors and starters.

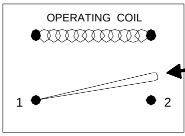
Contactor = Large amp load operating devices (typically 20 amps and up). These devices are also available in various sizes based upon the operating amp load. Be sure to choose a proper amp rated contactor for the motor be operated.

Starter = A Contactor + an Over-load Protector. Many motors require a separate and independent means of thermal over-load protection. A starter provides for this. Starters are also sized and amp rated for various loads, as with the over-load device. To choose a proper starter, it is always best to consult a good supplier.

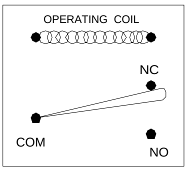
A-7.2 Relay, Contactor, Starter Designs

While there are many similarities in the design of these items, there are just as many differences. The following drawing shows the typical design of each item and the typical method by which they are labeled for wire connections.

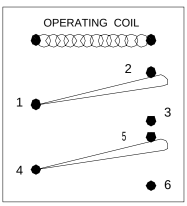
RELAYS



SINGLE POLE, SINGLE THROW = SPST

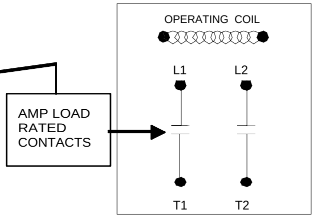


SINGLE POLE, DOUBLE THROW = SPDT

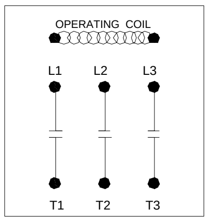


DOUBLE POLE, DOUBLE THROW = DPDT

CONTACTORS



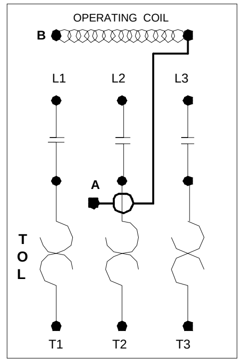
DOUBLE POLE, SINGLE THROW = DPST



3 POLES, SINGLE THROW TYPICALLY USED FOR 3 PHASE ELECTRICAL DEVICES

DPST = SINGLE PHASE OPERATED DEVICES

STARTER



3 POLES, SINGLE THROW CONTACTOR "WITH" **T**HERMAL**O**VER-**L**OAD PROTECTION ADDED.

TYPICALLY USED FOR 3 PHASE OPERATING DEVICES WHICH DO NOT HAVE OVER-LOAD PROTECTION, OR THEY REQUIRE ADDED PROTECTION.

TOL's ARE SIZED PER STARTER BASED ON THE OPERATING AMPS OF THE CONTROLLED DEVICE.

TERMINAL CONNECTIONS, RELAYS

Terminals, 1, COM and 1- 4 are used for the main power source which the relay will deliver to a device to make it operate.

Terminals 2, NO an 3 - 6 are normally open connections and when the relay is energized, these contacts will be closed to deliver the power to the device.

Terminals NC and 2 - 5 are normally closed connections and they will be opened when the relay is energized. Typically used to stop one operation when another operation is started.

e.g. one set of contacts in the dpdt relay can be used to start a device and the other set of contacts can be used to stop a device.

TERMINAL CONNECTIONS, CONTACTORS & STARTERS

Terminals L1, L2 and L3 (Line) are used for the main power source which is to be delivered to a device to make it operate.

Terminals T1, T2 and T3 (Load) are used for delivering power to the operating device, when the contactor closes it contacts.

Starter : when operational power is delivered to the device, the thermal over-loads will monitor the amp draw of the device, and should any problem cause a higher than normal operational amp draw, the overloads will shut down the starter. Part of the operating coil's power circuit is controlled through a NC contact in the over-load device. The operating coil's wires will be connected to terminals **A** and **B**.

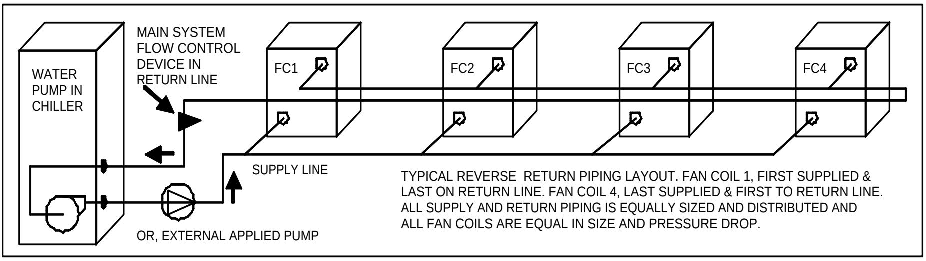
OPERATING COILS (ALL RELAYS, CONTACTORS & STARTERS)

All of these relays, contactors and the starter, may be purchased with several options for the voltage required to power the operating coil.
Typical coil operating voltages are;
24 volts, 115 volts, 208 volts, 230 volts and 460 volts.

ELECTRICAL CONTACTS OF ALL RELAYS, CONTACTORS & STARTERS

Every one of these devices are available in a wide range of amp loads;
1 to 30 amps typical for a relay, 20 to 200 + for contactors and starters.
It is very important to purchase a relay etc. which has an appropriate amp rating for the device it will be operating (e.g. amp rating of device + 25 %).
Overloads may be sized a little different. It is always best to consult a good supplier for all over-load protection devices.

A-7.3 Single In-Chiller or External Pump



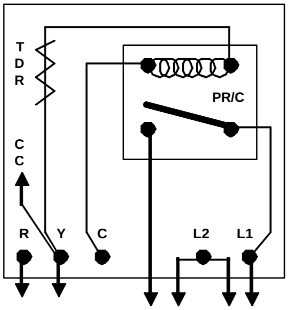
1- IF, a manufacturer provides a chilled water pump in their chiller, your worries are over. The manufacturer will have provided all the controlling options for the pump and all you have to be concerned with is the chiller's R to Y operational circuit. But, IF there is no pump in the chiller, or the chiller's supplied pump is not large enough for the designed system, you now have to use a separately purchased external pump.

2- **NO CHILLER PUMP:** a water pump must be sized properly for the system and the operational amp draw of the pump's motor must be known. You must decide whether to use a relay or contactor (R/C) based on the motor's operating amps. You must also choose a coil voltage for the (R/C). Because the chiller will be controlled to operate by a 24 volt control circuit and if water flow is only required when the chiller is signaled to operate, it would be best to use a 24 volt coil to operate the R/C. This 24 v coil will be interlocked with the chiller's R to Y circuit. ***Note: Always be sure to check a manufacturer's literature regarding any time delayed shut down requirements for a pump.*** Remember, you must provide the operating power supply for the water pump.

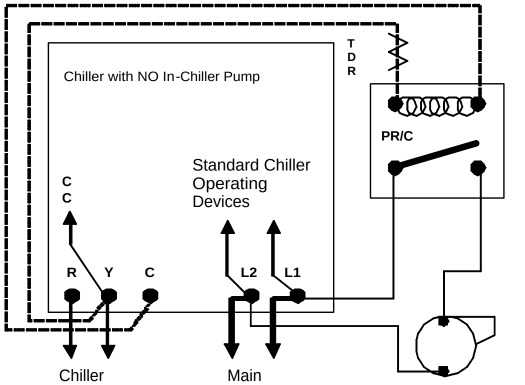
3- **REMOVING IN-CHILLER PUMP:** you must size and purchase the pump and you must know the new pump motor's amp load. Then, check the manufacturer's literature for the chiller. It may be possible, that the new pump can operate through the chiller's existing pump circuit (in-chiller pump's amp draw, verses new pump's amp draw). Or, you can purchase a R/C for the new pump and use the chiller's pump circuit to operate the R/C. This option could create two options; 1- use the chiller's pump R/C to energize your R/C (this will require a operating coil voltage equal to the in-chiller pump's voltage), or 2- replace the in-chiller R/C with your new R/C and use the chiller's control circuit to energize the new R/C (this will typically mean a 24v operated coil). IF, a time delayed pump operation is required, interlocking with a chiller's control system will cover this need. ***Note: depending upon the new pump motor's amp draw, you may have to have a new power supply.***

A-7.3.1 Wiring Diagrams for A-7.3

Chiller with In-Chiller Pump



CC = Chiller Control Circuit
PR/C = Pump Relay or Contactor 24 volt operating coil
TDR = Time Delay Relay, If Applicable



NOTE: Main power supply must now be sized for the chiller "and" the amp load of the water pump too.

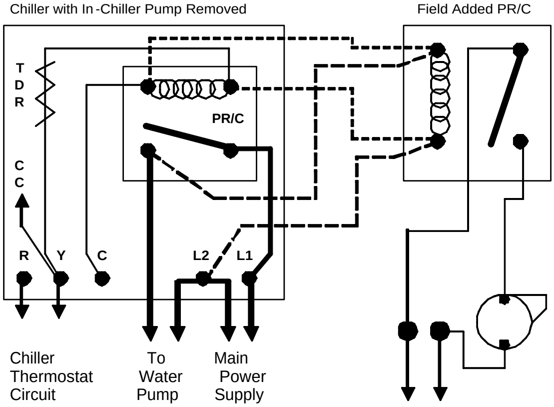
.... = Field installed 24 volt interlocking control wiring for the field added relay or contactor.

PR/C sized for amp load of the new pump.

TDR added to PR/C if needed per manufacturer's literature.

Chiller with In-Chiller Pump Removed

Field Added PR/C



Depending upon the amp load of the new water pump, "and" the amp rating of the chiller's PR/C, you may be able to just increase the water pump's wiring size and the size of the main power supply for the chiller.

Optional:
New independent power supply, sized for the amp load of the new pump.

Controlling Options for Added PR/C

Option 1:
Use the chiller's PR/C high voltage contact circuit to energize the new field added PR/C. This will typically require a 208/230 volt operating coil for the new PR/C. Field wiring indicated by a dashed line.

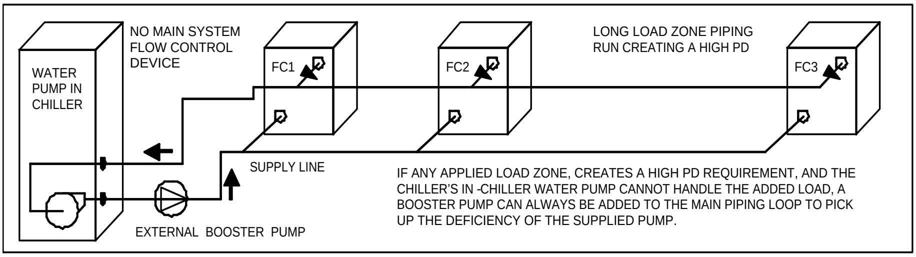
Option 2:
Use the chiller's 24 volt control circuit to energize the new field added PR/C.
The new PR/C may even be able to be located in the chiller's control panel in place of the manufacturer's supplied PR/C. This option requires the new PR/C to have a 24 volt operating coil. Field wiring for this option is indicated by a dotted line.

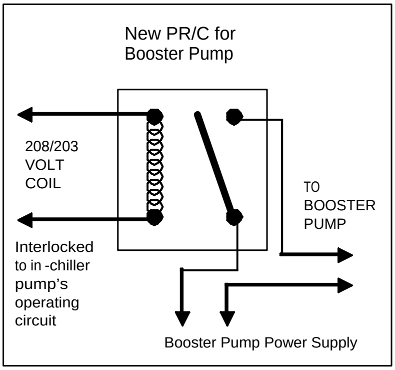
SPECIAL NOTE:
All wiring and main supply power logic noted on this page is for single phase applied power which uses two hot legs typically notes as L1 and L2.

3 Phase wiring and supply power will be noted on another page.

NOTE: Please note that the TDR (if required) will still be used for the water pump's controlling circuit, no matter which option is chosen.

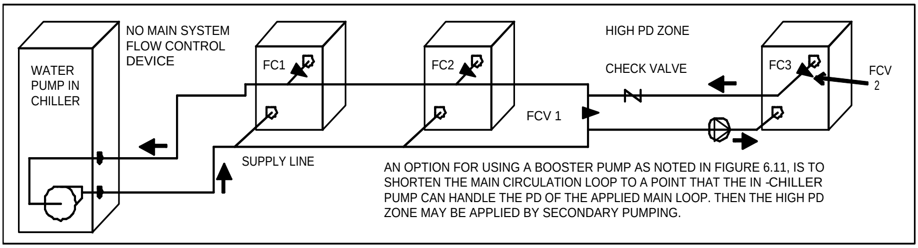
A-7.4 Booster Pumping





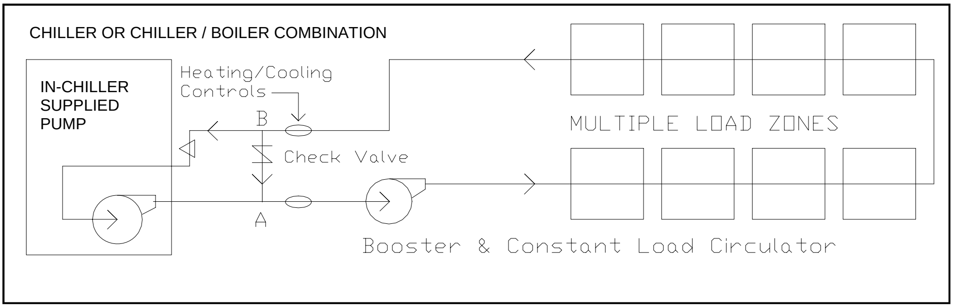
The booster pump, applied as shown above, will be required to operate when the chiller's in-chiller pump is operating. By installing a PR/C for the booster pump and having an operating coil voltage which matches the in-chiller pump's voltage, the new booster PR/C can be energized when the chiller's control circuit signals the in-chiller pump to operate. When the in-chiller PR/C powers the in-chiller pump, it can power the booster's PR/C to start the booster pump's operation too.

Some systems may have a booster pump being applied just for a single zone due to a high PD factor for just the one load zone. This can create a couple of issues; 1- how to energize the booster pump's operation, and 2- how to signal the chiller to ensure it is operating?

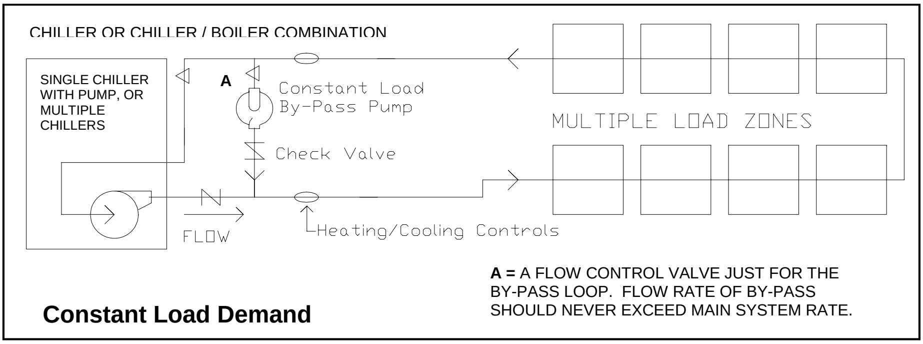


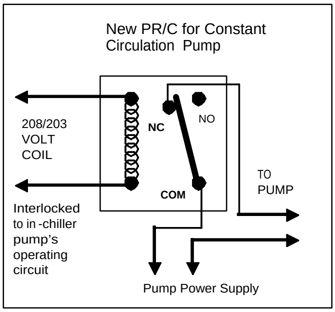
Note; This particular need and logic assumes wild coils at all load zones (no 3-way valves). 1- Use this fan coil's 24 volt circuit to energize a DPDT PR/C. Use one set of contacts for the booster pump's high voltage operating circuit and 2- use the other set of contacts to close the interlocking control circuit for the chiller's operation. "IF" the chiller system's water circuit was controlled to operate constantly (continuous controlled temperature loop) , you would only be concerned with controlling the booster pump's operation (24v coil, SPST PR/C).

Booster Pumping / Constant Circulator



This booster pump's operation performs two functions; 1- It aids the in-chiller pump's operation (increased Ft Hd) and 2- It keep the water system in constant circulation when the in-chiller pump shuts off. This means the booster pump will operate all the time, and this means that NO PR/C will be required. The booster pump will be directly connected to a power switch device (appropriate for amp load of pump). The chiller's operation will be controlled by the field applied Cooling and/or Heating control system. Some applied systems may require a constant circulating water loop, but it does not need to be applied as a booster too.

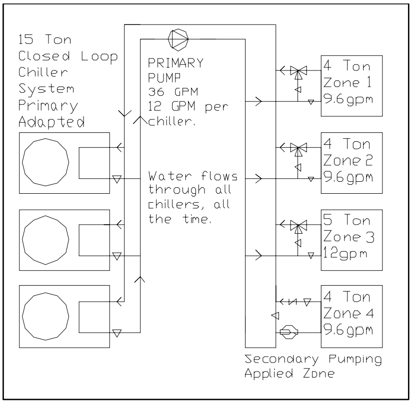




This applied constant circulating pump must be OFF when the in-chiller pump is operating and it must be ON when the in-chiller pump is off. The PR/C chosen must now be a SPDT device which has a normally closed contact option. The constant circulating pump will be wire to operate through this NC circuit and the in-chiller pump's operating circuit will control the new PR/C operating coil. When the in-chiller pump is operating, the PR/C is powered, opening the NC circuit and the circulator shuts off.

When the in-chiller pump shuts off, the PR/C is de-energized and the circulator's operation is started again.

A-7.6 Multiple Chillers / Multiple Loads



As the number of applied chillers increases, so will the total GPM requirements of the system. As the number of load zones increases, so will the total length of the applied piping system and the total PD of the designed system. This means that any applied water pump will now have a much higher potential for having a fairly large horse power motor. Depending upon the size of the pump's motor, and/or the power requirements of the chillers themselves, this could mean a 3 phase electrical power supply.

So, the controlling issue for the applied water pump, could now be a single phase operational power requirement, or it could be 3 phase. Larger horse power motors normally require a contactor for On/Off controlling. Also, IF the motor is 3 phase power operated, there is a good chance that it will require a starter due to the need for over-load protection. Last, I have seen some new water pumps on the market which have speed controls built right into the pump's motor (variable speed converter on the side of the motor). These pumps, un-like conventional single speed pumps, cannot operate by using a single controlling hot leg (L1 circuit). The ones I have seen, all required controlling of both hot legs (L1 and L2 being simultaneously energized).

There are several options for this water pump depending upon some variables for the pump motor's; 1- Horse power rating (total amp load). 2- Single phase or 3 phase power. 3- Constant operation or On/Off motor cycling.

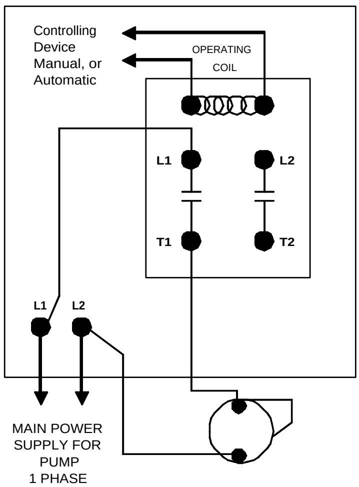
1- Total Amp Load: some motors with small amp loads, may be applied just by using a properly sized disconnect device. But, many motors will require a contactor due to a higher amp load and a control circuit must be used to energize the contactor (constant operation or On/Off cycling of pump).

2- 1 Phase verses 3 Phase: many single phase motors can be properly operated by controlling only one power leg, but others will require controlling of both hot legs. 3 phase motors normally require controlling of all 3 hot legs and over-load protection is normally required.

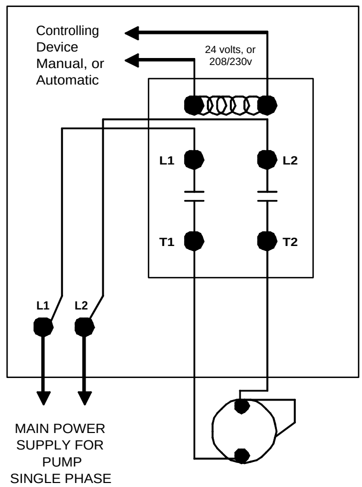
3- Constant Operation verses On/Off Cycling: any motor can be applied for constant operation or On/Off cycling. A contactor could just have a manual On/Off switch added to the contactor's operating coil, or a automatic controlling circuit would be used. Starters are available with a manual On/Off switch right on their housing assembly, or they can be wired for automatic controlling by an external control system.

A-7.6.1 Wiring Diagrams for A-7.6

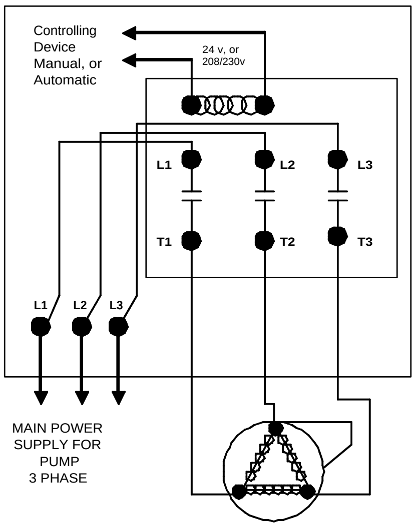
Contactor applied for the operation of a single hot leg (L1)



Contactor applied for the operation of both hot legs (L1 and L2)



Starter applied for the operation of a 3 phase pump motor.

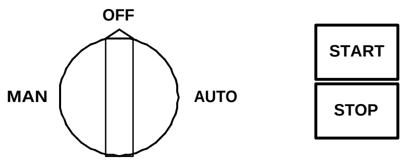


CONTROLLING DEVICE OPTIONS:
FOR CONTACTOR/STARTERS = C/S

1. One option is to use a simple manual On/Off Switch (typically used for a pump which will operate all the time).
2. For automatic operation, interlock a C/S's operating coil with the system's 24 volt controlling system (requires a 24v operating coil on C/S).
3. Depending upon the amp load of a C/S's coil, and the available power from the 24v source (transformer), use a small 24v operated relay and use the relay's contacts to close a high voltage circuit to operate the C/S (C/S must now have a 208/230v coil).
4. A manual switch can always be applied to a high voltage circuit too. This will help to reduce the 24v load on a transformer.

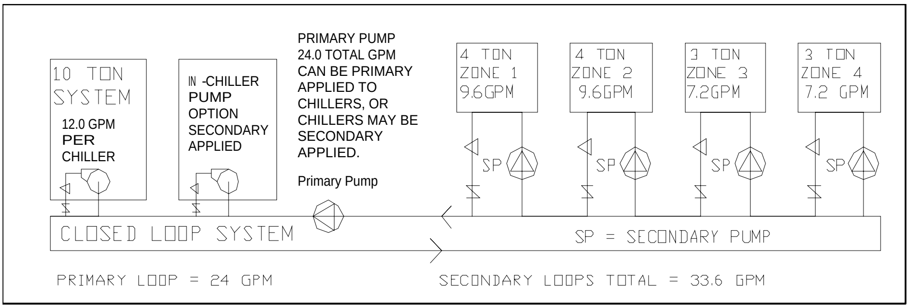
Note: some installers have a way of adding several 24v controlling devices without ever considering the amp load on the transformer (it's just a 24v device right). Wrong ! Low voltage loads can add up fast too, and this can burn up a transformer and/or 24v coil fast, if an amp load gets to high.

Starters are available with Start/Stop Buttons, or a Manual Switch which can be set for a desired operation.



A-7.7 Chiller Capacity verses Load Demand

Many designed systems could have several pumps being applied to one system, especially for systems being designed around Primary/Secondary pumping. This means that every pumping circuit (every pump) must have its own means of being operated.



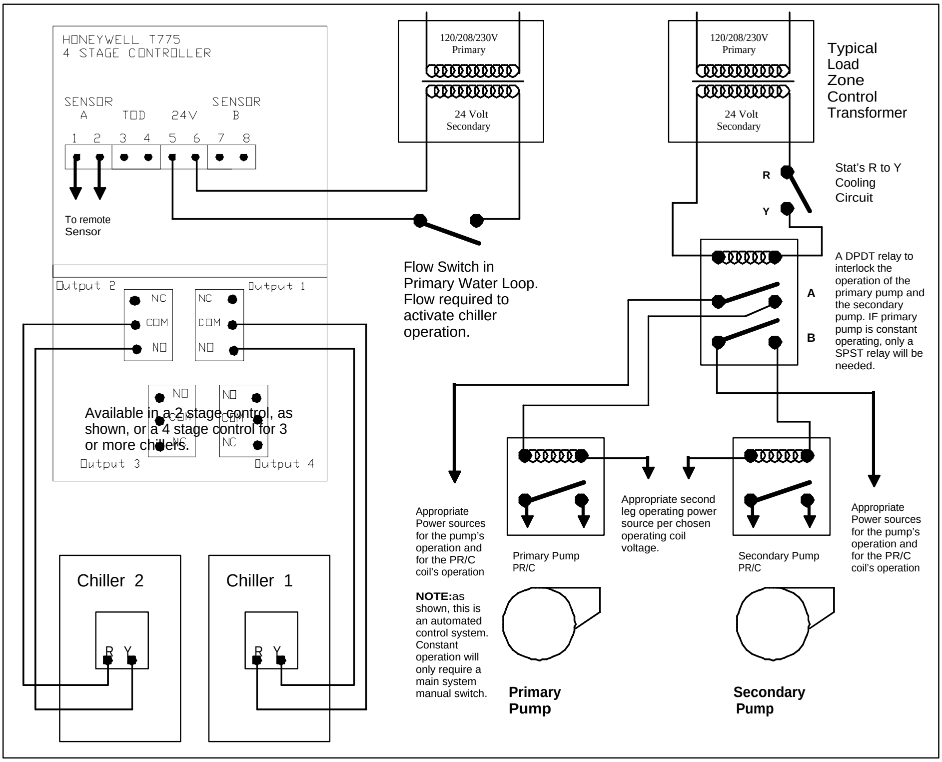
The above drawing shows a system with seven (7) pumps. One main primary pump and six secondary pumps. Because every chiller, main loop and four secondary loops all have their own water pump, the size of each pump will have a high potential for each one to be a relatively small pump with a small horse power rating. Only the main primary pump will have a potential for having a higher horse power motor.

Chillers: “If” the chillers have a manufacturer supplied pump, their controlling needs will be handled. A staging control, typically applied to multiple chillers, will control a chiller’s R to Y operating circuit and the manufacturer’s pump controlling circuit will control the pumps. “If” a water pump must be added, and a PR/C must be added (see A-7.3).

Primary Pump: A primary pump must be sized properly for the PD of the primary loop. The operation of the pump must be determined (On/Off Cycling or Constant) which for the above system will most likely be a constant operating pump. Primary pump controlling was discussed on A-7.6..

Secondary Pumps: Basically, all secondary applied water pumps will be controlled by the control system which operates the load zone (or chiller) to which the secondary pump is applied. The PR/C must be able to handle the amp load of the pump’s motor and the PR/C’s operating coil’s voltage should match the voltage of the load’s control circuit. Secondary loops do not normally require 3-way valves because no water will flow through the circuit unless the secondary pump is operating. The pumps can simply be interlocked with a thermostat’s R to Y circuit (24 volt). But, there may be times when a control system needs to provide total system interlock, flow switch back-up to prove primary pump operation and to ensure some load for the chiller’s operation (see A-7.7.1).

A-7.7.1 Wiring Diagram for A-7.7



Please note contacts **A** and **B** on the interlock relay. "IF" the primary pump's operation is to be automated (Off unless a zone calls for cooling) one set of contacts (**A**) per relay must be parallel wired for all applied relays (zones). Contact **B** will only be used for the zone to which it is applied, for that zone's secondary pump. "IF" the primary pump is controlled to operate all the time, this need can be omitted and a single contact relay may be used for the secondary pump. The primary pump's flow switch is an option, but it is a good one. You really do not want chiller operation with no flow in the primary circuit. Each zone's stat will; 1- Energize the interlock relay (R to Y) and 2- energize the blower relay (R to G). The interlock relay will start the primary pump (**A**) and that zone's secondary pump (**B**). Provided water flow is established in the primary loop, the flow switch will energize the staging control and the chiller's operation will be started. Provided any zone is calling, the chillers will maintain a proper chilled water loop temperature through the staging control.

Note: This is but one method of many which may be applied to this type of system.

A-7.8 Process Cooling

Process cooling loads are almost always designed around primary/secondary pumping, "AND" the primary loop is almost always designed to operate all the time. This means that the primary pump will only require a properly sized relay, contactor or starter and some means of manually controlling that device will be needed. This need has been mentioned and discussed in the previous pages.

The secondary pump's operation will be controlled by the load zone's operational requirements. Some controlling item in the load's control system, must be used to energize the relay, contactor or starter chosen for the secondary pump. For process loads, the secondary pump could be operated constantly, or it may be automated. The logic which has been provided should be sufficient enough for you to determine your needs and to control them.

There are many, many controlling options for chilled water applied systems. The controlling designs I have shown are not the only way of doing things. Every body has an opinion on a good control system and that's great. I am always open to new and better ideas. BUT, no matter how your controlling system is designed, there are a few items which you must always remember about chilled water systems.

1- Chillers should never operate without having water flowing through them.

2- Chillers have a specific flow rate requirement which must always be correct (minimum mandated flow rate).

3- Some chillers have a post operational cool down period which mandates flow.

4- "IF" item 3 exists for any chiller, and
"IF" an external pump is applied to any chiller, and
"IF" a chiller's time delay requirement can not be interlocked from the chiller,

A *FIELD ADDED* TIME DELAY RELAY MUST BE USED !

Chapter 8- The Past, Present and Future

Radiant heating has been around for ages (well maybe not that long). Hydronticists and Radiantologists were installing heating systems long before anyone ever though of a chilled water cooling system (save a polar bear). The question which I still cannot fully understand is, “Why more hot water heating people don’t, get involved with chilled water cooling?” “IF” WetHeads have learned the secret to good water piping systems, then why let the AirHeads sell and install 50 % of the market?

Small Chillers, ideal products for residential and small commercial applications are entering the market place almost yearly, and many manufacturers are offering some really neat and new fan coil systems which do not require duct work. Some gas-fired chiller manufacturers have also offered products which provide both chilled water and hot water (chiller/boiler combinations). There are some other manufacturers who are working on gas-fired chillers which will be heat pump systems. Yes, the future is changing fast and so should you.

Show me a new home today, which has an even and equal heating/cooling load for the entire home. There haven’t been any of these for quite a while. Radiant heating people have prided themselves in the fact that they can offer one of the most comfortable, versatile and efficient systems money can buy.

High priced ? You bet ! Cost effective ? You can count on it !

Now, it’s time to add in the only PLUS left.
A Comfortable, Effective and Highly Efficient Chilled Water Cooling System too.

Multiple heating loads, zoning, valving, mixing and matching water temperature and flow to provide the best heating system money can buy, is almost the registered trademark of radiant heating people and their industry. They believe it, they live it, they eat it and they sleep with it. Quite comfortably I might add. Being the best you can be, should not stop here, especially when there is so much more to give to your customers. Whether you know it or not, you’ve been installing chilled water cooling systems for ever too. You just forgot to turn down the temperature dial and you forgot all those neat fan coils in lieu of some other end use items. The chilled water air conditioning industry needs your expertise, your gumption, your determination, your go power and there should be no reason why you, couldn’t use some extra profit margin either. It just might provide two (2) pats on the back, instead of one !

Final Closing Comment:

Many people have criticized me for the simplicity and plainness of my writing style and presentations. But, many individuals who have attended my training classes over the years, have complimented and praised me for this very same thing. Their success from my classes and my success over the years can be expressed very simply;

“Knowing and Sticking To, The Basics”.

I am not saying that this industry doesn’t have any difficult and/or highly technical issues, it does. I am not saying that you will never come across any of them either, you will. Many parts of a job may require formulas, calculation, conversions, etc. and knowing what to do and/or how to handle them will be very important to your success. But for me, if and when they should pop up and if I don’t know the answer, I certainly know who to ask.

A question I have often asked myself over the years is, “Why did I spend so much time learning so much specific technical information, when I have never used very much of it over the years” ? Common Sense and the Basics, has been and most likely always will be, my formula for success. Every person has an opinion about something, and the last thing I would tell you is that I know everything. When I have asked people in my classes, for their opinion and/or ideas about something, I typically do not get a response. Yet on many occasions, I do get feed back from some other people who are expressing comments and/or opinions that others have said about my thinking and/or logic. Unfortunately, the person expressing his/her thoughts and I too, have both lost. Had they taken the time to talk directly to me, maybe we both could have learned a whole lot more. I love a challenge, I love discussion, I love change, I love to find better ideas and I will be the last person to say that there is no better way.

I have been in this industry we call heating and cooling since 1967, and if there is but one truth which I have learned, it’s that I am still a beginner and I still have a lot to learn. Being born in, raised in and having lived my entire life in the state of Michigan, I have heard this saying more times then I care to remember; “If you don’t like the weather in Michigan today, just wait until tomorrow, it’s sure to change”.

B I N G O !

The Beginning.

P.S. The next time you’re out on the job, and should you think you’ve heard some funny noises, be careful, there just may be a Hydronawanchie or Radiawaturchie watching you.

IT'S HERE,

AND HERE,

AND HERE.

IT'S ALSO HERE,

Where's

The

Chilled

Water ?

AND HERE.

YES, IT'S HERE,

& EVEN HERE TOO.

AND THIS

IS THE BEST,

HERE TOO !

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This author would like to express his sincere appreciation to the following companies[1] who have graciously granted their permission to allow their company's name, product's name (s) and/or pictures of their fine products to be included in this book.

Arkla-Servel: Arkla Industries was one of the first manufacturers to produce a gas-fired, air-cooled, absorption cycle chiller in the late 1960's, and their chiller is the only gas-fired chiller which is still being manufactured and currently marketed (new owner, see Robur).

Bell & Gossett: (Morton Grove, Illinois) B&G is a division of ITT® Fluid Technology Corporation and they manufacture many, many great products for hydronic applied systems. I have used B&G products for many, many years with great success and satisfaction. B&G also just happens to have one of the finest distributors, in and for the state of Michigan.
(www.bellgossett.com) (www.mcdonnellmiller.com)

Bryant Corporation: Bryant® was the first manufacturer to produce and market a gas-fired, air-cooled, absorption cycle chiller in the early 1960's. Bryant® a division of the Carrier Corporation is also well know for being a manufacturer and leader of many other fine HVAC products. (www.bryant.com)

Cooling Technologies: Cooltec is an up and coming manufacturer of a new line of gas-fired, air-cooled, absorption cycle chillers. I have had the pleasure of doing some consulting work for this fine company. (www.coolingtechnologies.com)

Dow Chemical Company: (Midland, Michigan) Dow is a leading manufacturer of exceptional HVAC heat transfer fluids (antifreezes). I have used Dow's products for almost 30 years now and I know of no better product. (www.dow.com)

Griswold Controls: (Irvine, California) Griswold manufactures many fine controls and valves for hydronic applied systems, including specialty flow control devices and flow valves. I have used Griswold's products with great success. (www.griswoldcontrols.com)

1- PLEASE NOTE: Even though these companies have granted their permission for inclusion in this book, this does not necessarily mean, or imply, that any of them indorse the content of this book, or that they necessarily agree/disagree with the book's contents. I, the sole author of this book, take full responsibility for this book's content. The good content, the bad content, the questionable content, and maybe even a few smiles which may be developed at some point during your reading.

ACKNOWLEDGMENTS

Honeywell International, Inc.: (Freeport, Illinois) Honeywell is a major leading manufacturer in and for the HVAC Industry. I have used many, many of Honeywell's great controls over the years and they have provided exceptional operation and performance. I just love their solid state staging control. (www.honeywell.com)

LASCO Fittings, Inc.: (Brownsville, Tennessee) Lasco is a manufacturer of fine PVC Piping and Fittings which are highly applicable for chilled water systems. I want to personally thank Lasco, because I finally have a good friction chart for PVC. (www.lascofittings.com)

Magic Aire®: (Wichita Falls, Texas) Magic Aire is a division of United Electric Company, LP. Magic Aire also manufacturers an exceptional line of fan coils, air handlers, a-coils and horizontal coils. I just love their roof top air handler which is typical roof curbing adaptable. (www.magicaire.com)

Multi-aqua®: (Miramar, Florida) Multi-aqua manufacturers a line of electric chillers and some really, really neat and aesthetic pleasing fan coil systems (don't forget the remote control). To me, this neat product is really addressing our future's needs. (www.multiaqua.com)

Peterson Equipment Co, Inc.: (Carrollton, Texas) Peterson is the manufacturer of those really neat Pete's Plugs®. Yes, those in-expensive, time saving devices which allow for easy pressure/temperature readings.

Robur Corporation: (Evansville, Indiana) Robur is the current owner and manufacturer of the Servel line of gas-fired, air-cooled, absorption cycle chillers, which were first produced by Arkla-Servel. (www.robur.com)

Servel™: Servel is the registered brand name being used by the Dometic Corporation (a line of gas-fired refrigerators) and the Robur Corporation.

Wessels Company: (Greenwood, Indiana) Wessels is the manufacturer of those really neat stand-alone, auto-fill systems for using with water/antifreeze fluid systems. They also manufacture many other products for the hydronic industry. (www.westank.com)

Williams, "THE COMFORT PRODUCTS PEOPLE": (Colton, California) Williams is a major manufacturer of fine fan coils and air handlers. A really neat concept for some of their fan coils which I have seen, is their approach to serviceability and maintenance for their products. (www.williamscomfortprod.com)

ACKNOWLEDGMENTS

Photos, Illustrations & Drawings: Unless otherwise noted, all photos, illustrations and drawings have been taken by and produced by the author of this book.

SPECIAL THANK YOU:
This author would like to personally thank the;

Hydronawanchie Tribe and the **Radiawaturchie Tribe,**

for a really neat night of sweet dreams.

Final Comment:

Hug Your Enemies,
Kiss Your Friends,
Tell Someone, You Love Them,
Daily.

It Is ....
The Little Things in Life
That Count !

JIT PRODUCTIONS

Many times, a writing of words,
is nothing more than
Life's frustrations,
which vanish in death.

Yet, at other times,
these same words,
may find their way to stand,
the test of times.

At least I shall rest in peace,
assured of but one truth,
I shall have accomplished one !

RADIANT COOLING:

Radiant cooling has been successfully used for some years now, but it has also been limited in its use and desirability due to a moisture factor, a room's dew point. Almost every person has experienced the effects of radiant cooling, having entered a cement block building or a large cement floor area following a cool night. Radiant cooling has been applied more by ceiling devices, than it has by floor devices. Floor moisture issues can be a double hazard issue; 1- creating potential slippery conditions due to moisture production, and 2- creating damaging issues for any product being used on the floor.

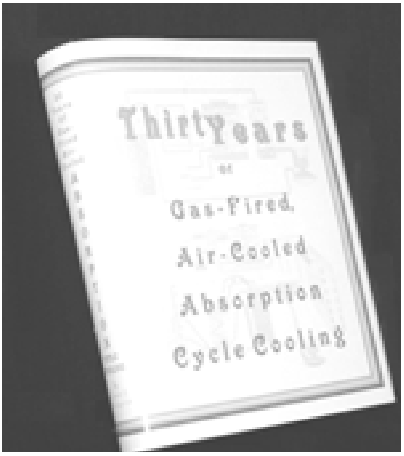
The secret to a successful radiant cooling system, is to keep a radiant device a few degrees warmer than the dew point of the room. This will prohibit the production of condensation on the device and its side affects. The down side is the managing of the chilled water's temperature. New radiant products being developed for chilled water cooling purposes, are also incorporating moisture sensors to change and adjust the water's temperature to prevent condensation.

Even if radiant cooling is possible and/or desired, some type of humidity control must also be used. This typically means a standard forced-air cooling system. On the plus side, and in conjunction with a radiant cooling system, this forced-air system does not need to be sized as is typically done for a standard forced-air cooling only system. A supplemental system can be down sized to address only the added humidity control conditions.

In Chapter 2, page 12, I provided you with several Web Sites where you may search out information on radiant cooling systems and its logic. Some of these systems have just recently entered the market place and I am sure there will be many more to come. Chilled water cooling systems being forced-air applied and/or radiant applied, has the highest potential for offering you and your customers, the same comfort and efficiency which radiant heating systems are renowned for.

NOTES:

MORE BOOKS BY -J. ISRAEL TURNQUIST



THIRTY YEARS OF GAS-FIRED, AIR-COOLED, ABSORPTION CYCLE COOLING

This author had a first hand introduction to this new cooling technology, when it was introduced in the late 1960's. The original technology and equipment design would last for approximately 30 years, when in 1999, a new higher efficiency technology and design was introduced. This author worked with and on this equipment for over 30 years, being first involved with its installation, servicing, repairing and maintenance. The author then devoted his time to selling, designing and engineering cooling systems for this equipment and his dealer/contractor network.

This book (520 pages), covers this equipment's (Servel Gas-Fired, Air-Cooled, Chillers & Chiller-Heaters) first 30 years of existence, providing anything and everything, anyone might care to know or learn. From the absorption cooling cycle, to equipment manufacturing, to designing and engineering systems. The book also contains many chapters covering installation, servicing, repairing and maintenance.

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