Chapter 5- Water Pumping Basics

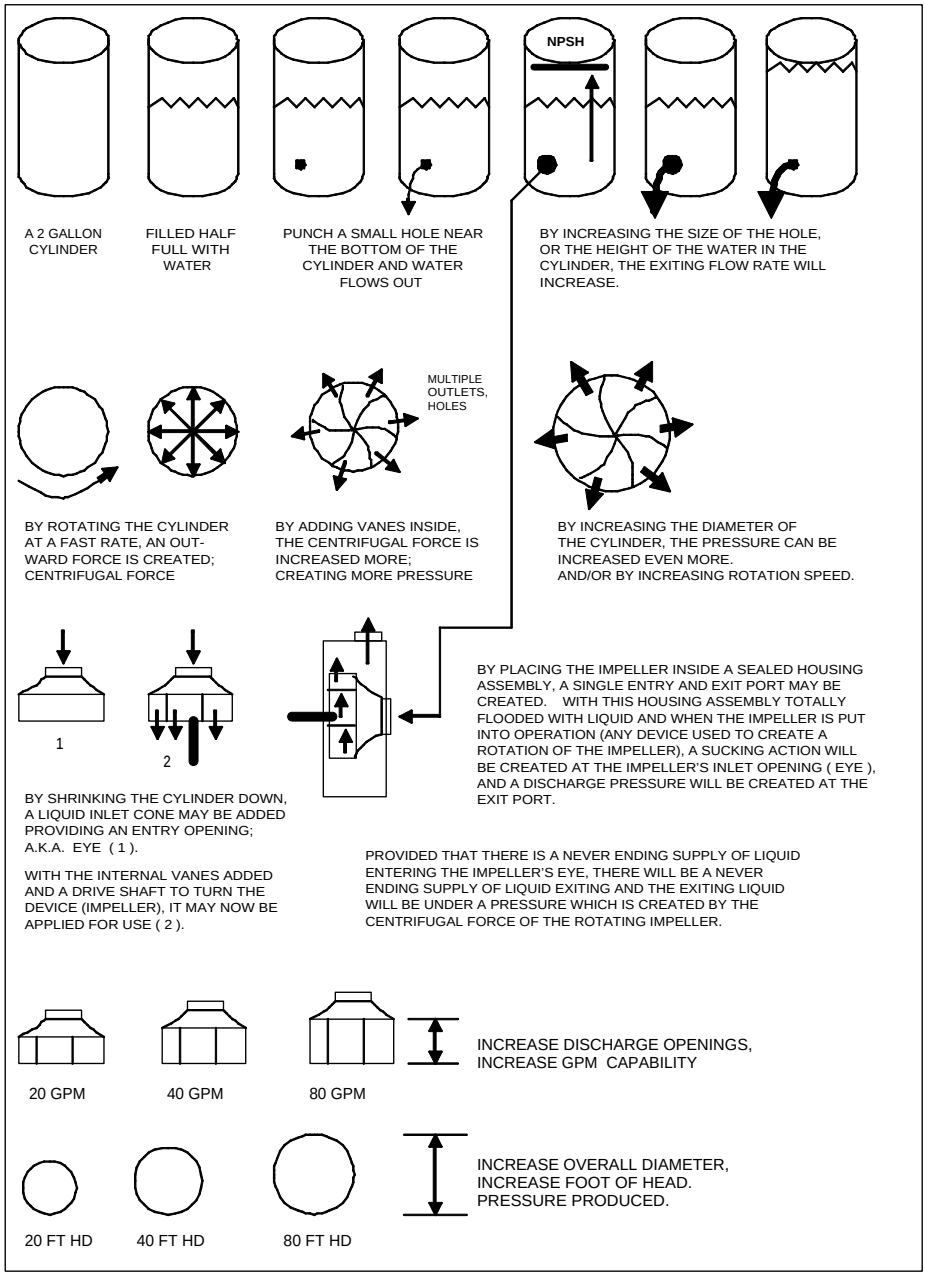
Many people do not know that water pumping has its beginnings traced back to Ancient Times[1]. Back then, water pumping was called "Aquadirecticating"[2]. Ancient Hydronticists, called "Cavaquaductors"[3], were among the first humans to start harnessing water for a useful purpose. It wasn't until many 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.

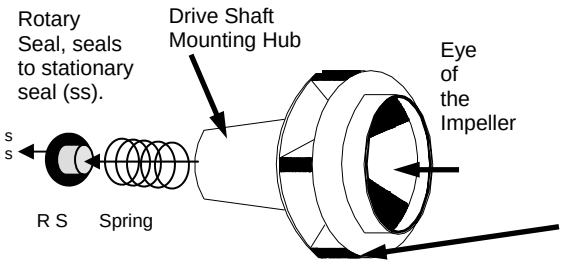


FIG 5.2
Typical Impeller

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.

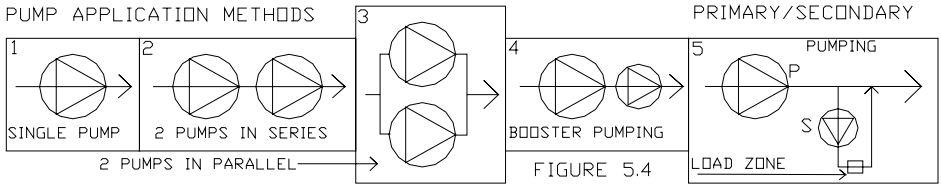


FIGURE 5.4

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.