Application Manual

AM - MAC

Mini Chiller

McQuay®
Air Conditioning

Engineered for flexibility and performance.™

Contents

Introduction

The air-cooled mini chillers form part of a complete integrated water hydronic system with the chiller water fan coil units. The range of capacity from 30,000 Btu/hr to 150,000 Btu/hr (8.79 – 43.96 KW) makes them suitable for various applications:

- Office Rooms
- Private Houses
- Business Rooms
- Club, Pubs, Coffee Houses
- Hotels
- Restaurants
- Process Cooling

The advantages of using these chillers are:

1. Due to its compact design, the mini-chillers require a smaller space for installation. The design also allows for flexibility in design to meet various types of application requirements.
2. The amount of refrigerant used is small compared with other split and multi-split direct expansion systems, i.e. they are more environmental friendly.
3. There is no necessity to use cooling towers.
4. No refrigerant is used in the occupied space.
5. The usage of water as the cooling medium allows for excellent load variability with minimal system complexity as against equivalent VRV systems.
6. Ability to have long piping distances.

A water hydronic system can be classified as a close or open system.

Definition: A close water system is one with no more than one point of interface with a compressible gas or surface. *[ASHRAE handbook: 1996* System & *Equip.]*

The basic design of the mini-chiller is for a close system. However, a modification for an open system is possible.

The close hydronic system will consist of the following fundamental components:

a. Source

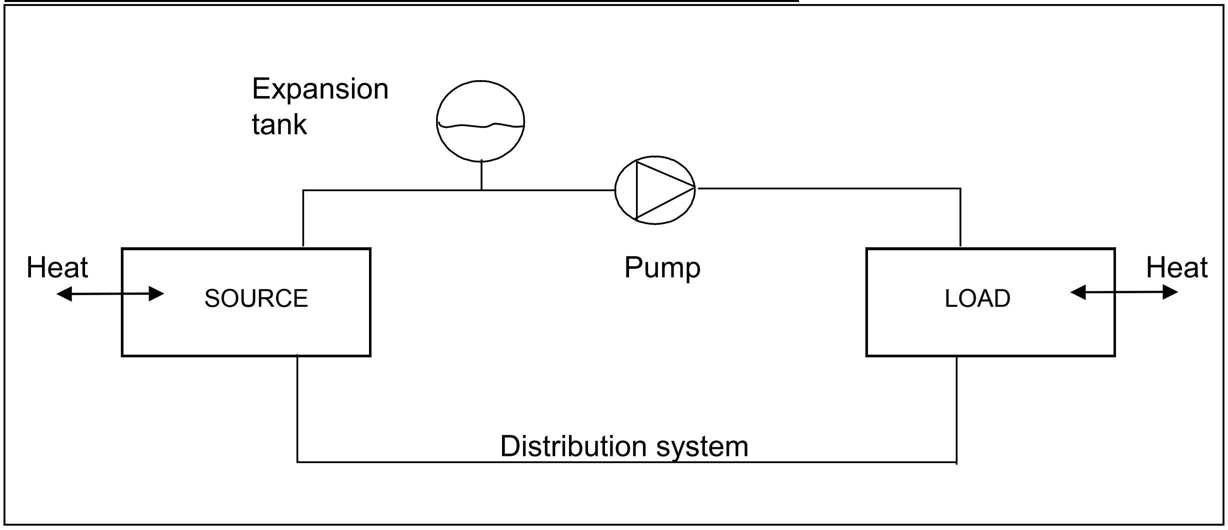
b. Load

c. Expansion Tank

d. Pump

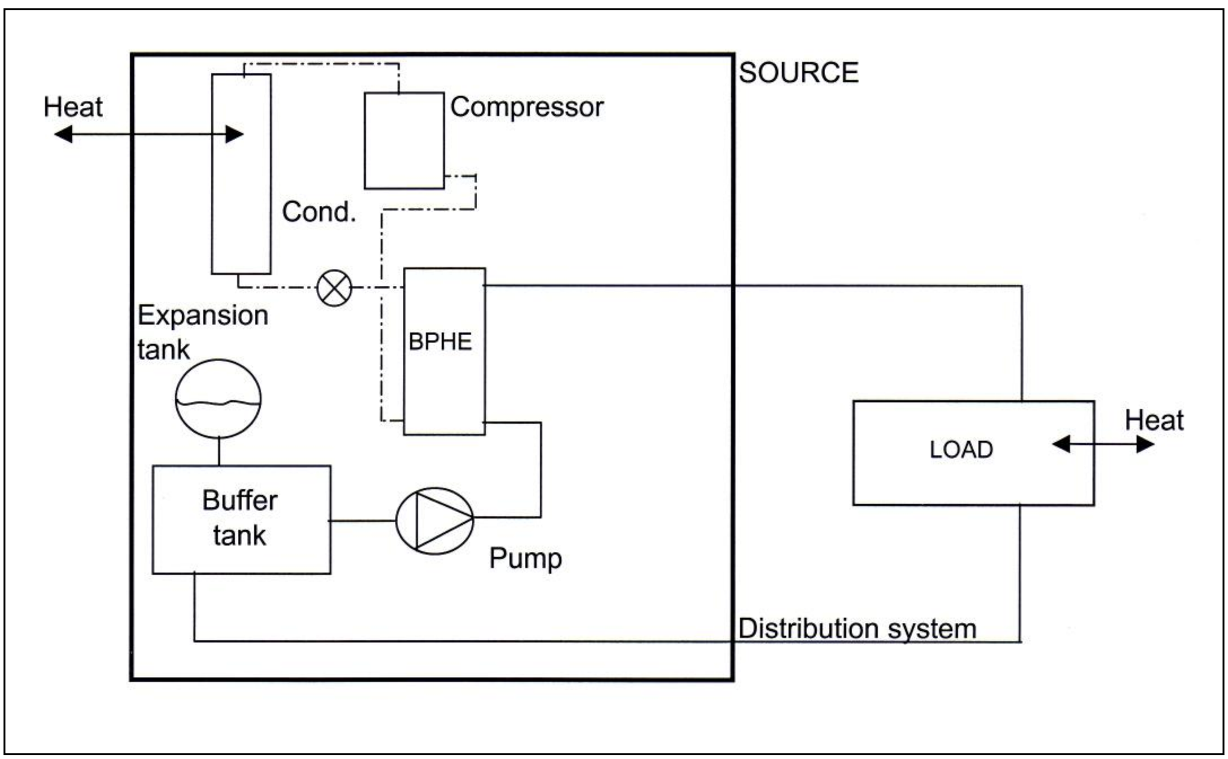
e. Distribution System

Schematic diagram of the basic close hydronic system:



In the mini chiller, the source will comprise of the refrigeration circuit, i.e. compressor, expansion device, condenser and evaporator. A brazed plate heat exchanger (BPHE) is used as the evaporator to produce the chilled water.

A built-in water tank is also provided in the mini chiller to act as a buffer storage. See next page. For integration, both the expansion tank and pump are incorporated together into the mini chiller. Hence, the schematic diagram of the system becomes as follows:



If both chilled water and hot water are required in the system, a mini chiller with a ***reverse cycle operation*** will be used. The unit will have an additional 4-way valve and accumulator for this purpose.

It is by such integration of components of the hydronic system that the mini chiller becomes compact. Installation of the chiller will thus only involve:

1. The chiller mounting
2. Indoor fan coil unit installation
3. Water piping installation between the chiller and fan coil unit
4. Electrical wiring connection

This manual is written with the purpose of providing guidelines as to the installation and operation of the hydronic system; i.e. both the chiller and fan coil unit. Application design guidelines will also be discussed. Selection criteria of piping, valve, pump and other equipment are also given. Examples of such complete installations are as shown in the following pages. This manual will give some technical information and details on how such installations are designed and done at site.

In general, there are three series of mini chillers available:
a) A series (from 30,000 Btu/hr [8.79 kW] to 50,000 Btu/hr [14.65 kW])
- double stack design, with built-in buffer tank

b) B series (from 75,000 Btu/hr [21.98 kW] to 125,000 Btu/hr [36.64 kW])
- double stack design, with built-in buffer tank

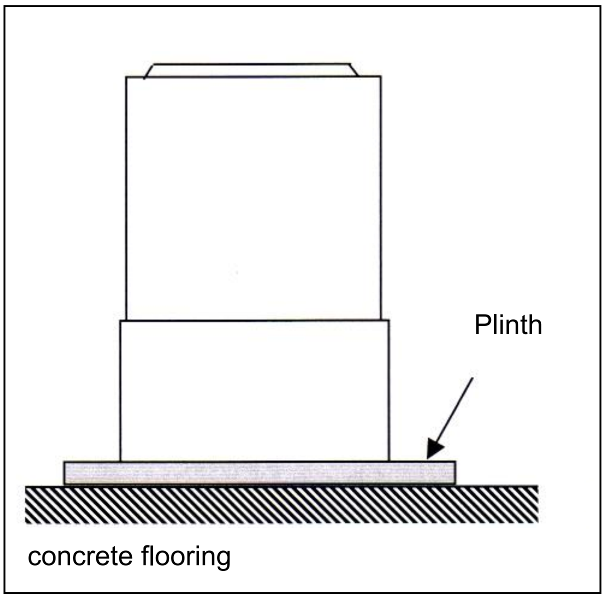
c) C series (from 80,000 Btu/hr [23.45 kW] to 150,000 Btu/hr [43.96 kW])
- monoblock design, without buffer tank

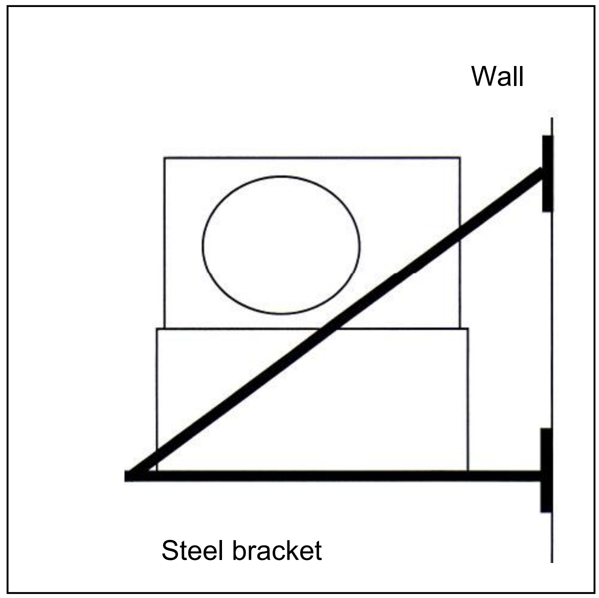
This manual must be used in conjunction with the **Technical Manual** and **Installation and Operation Manual (IOM)** of the mini chillers and chilled water fan coil units.

Section 1: Chiller Mounting

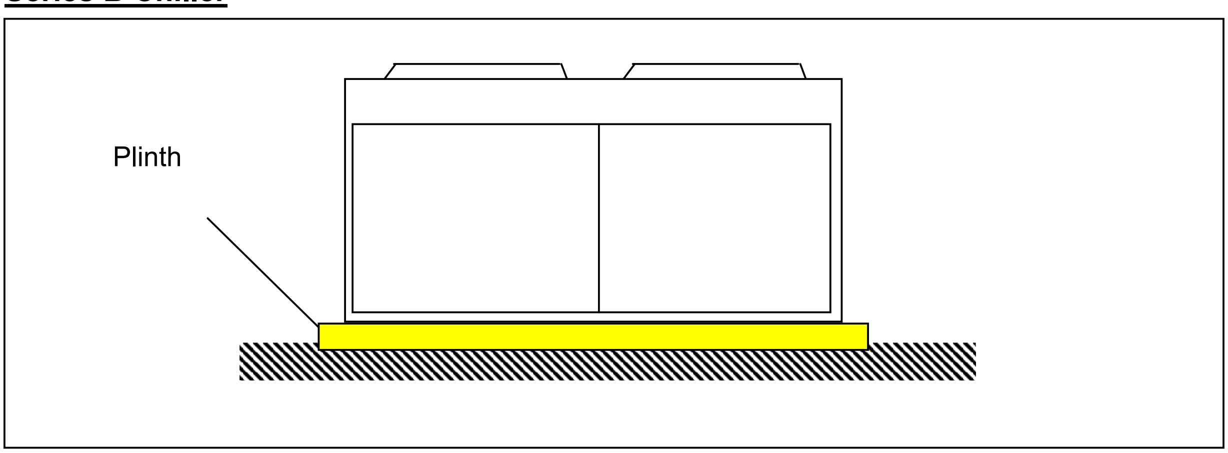
Care must be taken to locate the air-cooled chiller at the proper place. Ensure sufficient clearance around the unit to allow proper air flow and to facilitate access for maintenance. Location of the units must also prevent short-circuiting of the discharge air. Do not block any air passage in and out of the units.
Please refer to the corresponding Technical Manual for further information.

The chiller unit must be placed on a firm surface, e.g. concrete flooring, slab or plinth. Due to space consideration, the chiller may be mounted onto a steel bracket which is secured to a firm surface, e.g. brick wall, concrete wall or a steel structure.





Series B Chiller



Such brackets must have sufficient strength to carry the weight of the chiller unit. It is recommended that angle bars (e.g. 38mm*38mm*3mm^{t}) or hollow section bars (e.g. 25mm* 50m*2mm^{t}) to be used for fabricating these brackets.

These brackets must also allow clearance for removal of service panels for maintenance purposes.

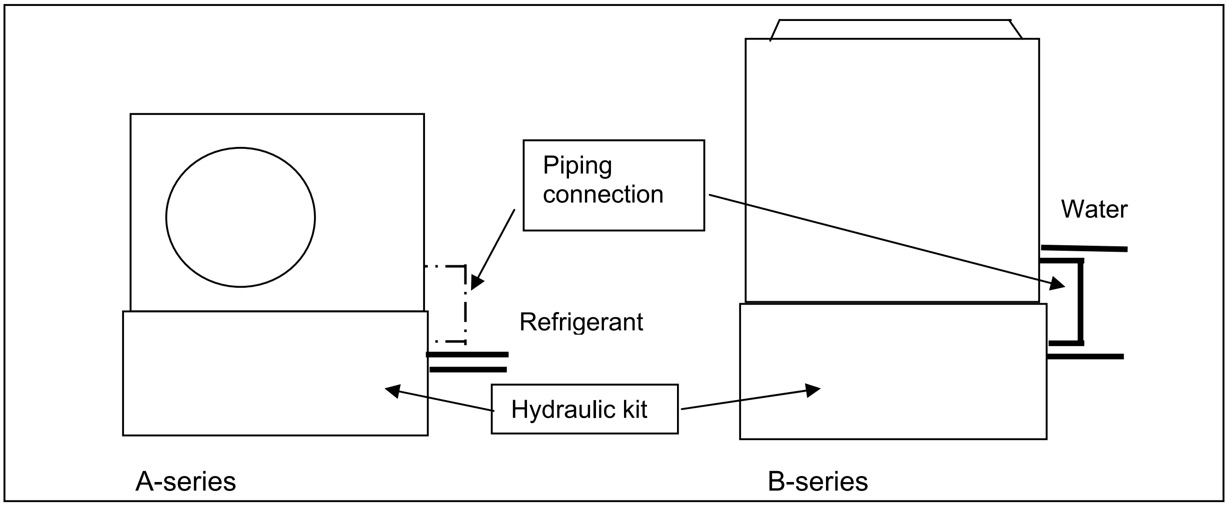
In any case, it is vital that the chiller unit is secured firmly onto the concrete floor/slab or steel bracket by using studs, wall plugs or bolts/nuts at the four (4) mounting holes located at the base plate of the chiller. The weight of the chiller unit and the water pipe connections are not sufficient to prevent unit movement should any sudden impact or strong vibrations occur in the unit. Failure to do so may cause the water pipes to deform and break.

It is further recommended that rubber isolation pads (1/2" thick) to be placed beneath each mounting hole to prevent excessive vibration and noise. If necessary, isolating springs can also be mounted.

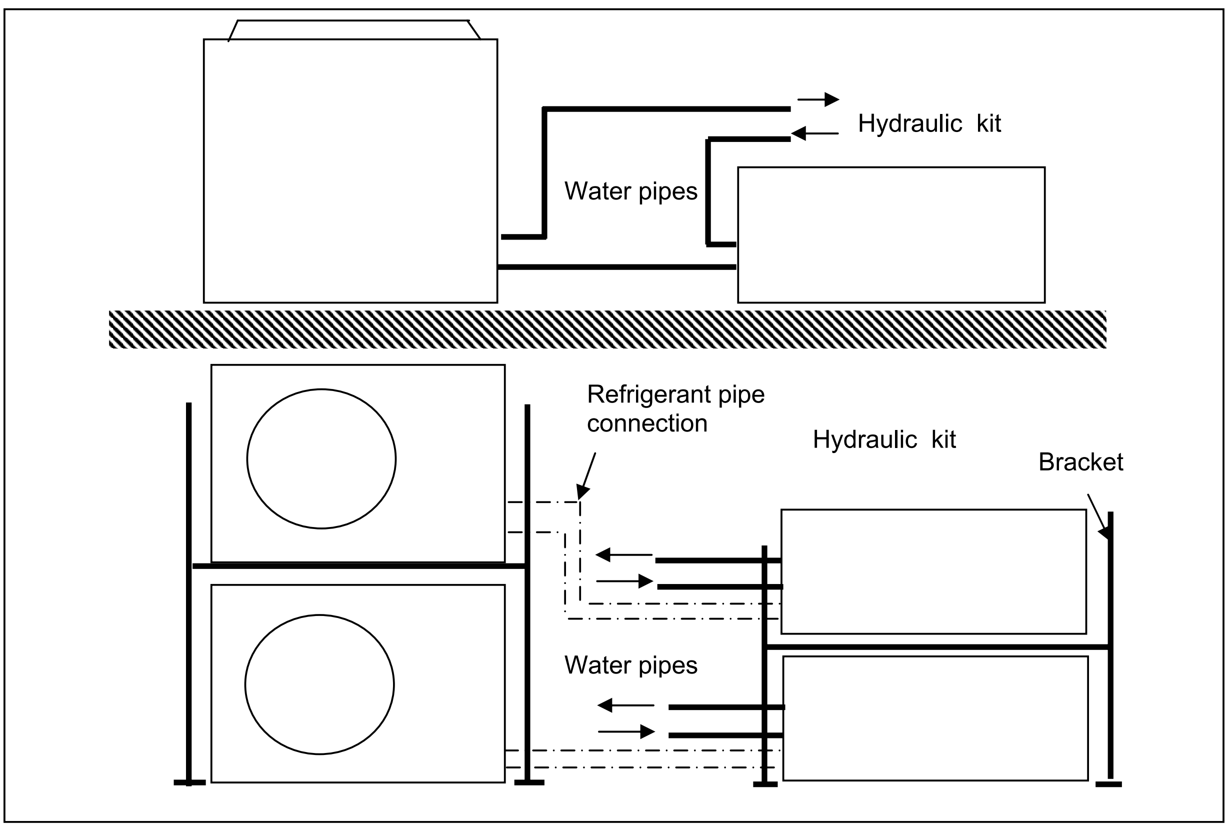
The following pages are examples of these isolation pads and springs.

Special installation:

The A and B series mini chiller units have been designed with the refrigerant circuit located in the top compartment and the hydraulic kit in the bottom compartment:



In some special installations whereby the available space (especially the height) is not sufficient to install the chiller, it is possible to to detach these two compartments and install them side by side. This is especially useful when there are multiple units which are stacked together with a steel bracket.



For the A-series type of mini chiller, the inter-connecting pipes between the two compartments are the refrigerant pipes. For the B-series type, there is a water pipe in between the two compartments.

Therefore, the detached installation of the A-series mini chillers is very similar to the installation of a *split type air-conditioning* unit.

	Refrig. Pipe size	
	Liquid	**Gas**
AC 040A	3/8"	¾"
AC 050A	3/8"	¾"
AC 058A	½"	¾"

Note:
Gas line to be insulated with tube insulation. Use the correct size for each pipe, thickness ¼"

Take care of the following items [for detached A-series installations]:

	Maximum pipe length,m
AC 040C	20
AC 050C	20
AC 058C	20

a) Do not allow excessive refrigerant pipe length between the two compartments. Always choose the shortest path. Long piping will cause high pressure drops and reduces the capacity of the system. Use the following recommendations:

	Maximum elevation, m
AC 040A	10
AC 050A	10
AC 058A	10

b) It is possible to have the hydraulic kit higher or lower than the refrigerant compartment. Do not allow excessive elevation between these two compartments. Use the following recommendations:

If the elevation exceeds the above recommendations, care must be taken to ensure sufficient oil *return* to the compressor. Use oil traps (one every 30ft height interval) or oil separators, if necessary.

c) The longer pipe lengths will require more refrigerant charge for optimum performance.

Recommendation: Additional 50g (R-22) for every 1 meter of connecting pipe length. Similarly, additional refrigerant oil charge may be required.

d) Use as few bends as possible in the pipe run. Each bend will cause extra pressure drop and reduces the capacity of the system. Do not use more than 10 bends. For both A and B-series chillers, locating the hydraulic kit at a far distance will also mean having a longer water pipe length. This will incur a higher pressure head to the water pump in the chiller unit. If not careful, this will reduce the water flow rate through the system and may cause system failure, e.g. water freezing, compressor tripping.
Furthermore, the longer pipe will increase the cost of installation.
Always look for the closest possible locations for these two compartments.

External drain pan

In some instances, it is necessary to install an external drain pan beneath the unit to collect any condensate water from the chiller unit. This is especially so for the heat pump versions ,where water will condense on the heat exchanger coil during the heating mode. Further more, a lot of water will flow out during the defrost cycle.

Such external drain pans are needed when the chiller units are installed inside a plant room where it is not appropriate for the floor to be wet. *(Note A)*

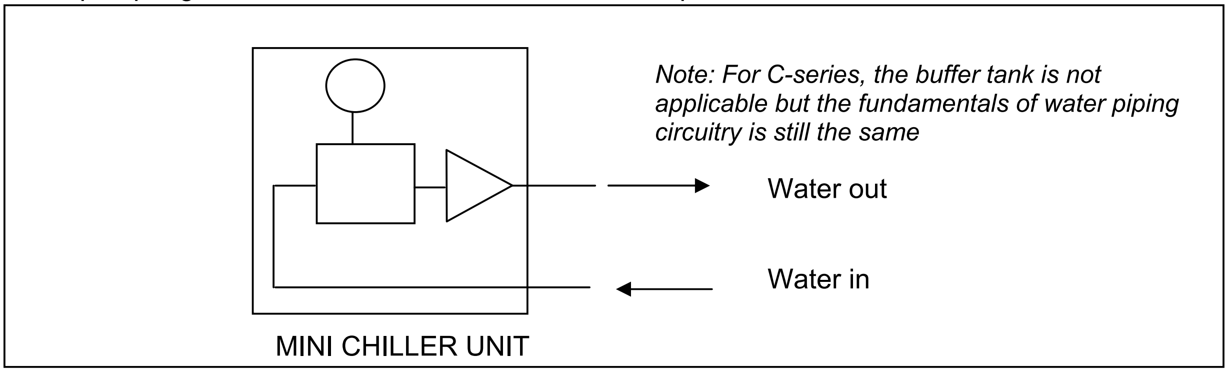
It is recommended that the drain pan to be fabricated out of galvanised iron (GI) sheet metal, at least 0.8 mm in thickness. Allow the drain pan depth of about 20mm.

This external drain pan should be laid out on the floor first before placing the entire chiller unit on top of it. It is recommended that the chiller unit to be raised up by 20 - 30mm from the drain pan so as to prevent rusting of the chiller base pan.

Note A: Caution! Please ensure adequate ventilation in the plant room else the chiller unit may trip.

Section 2: Water Pipe Circuit

We have seen that the mini chiller has an integrated buffer storage tank, expansion tank and water pump together as one unit. Henceforth, we will represent the unit as such:



In this section, we will look at the various piping circuits which we can use to connect the chiller unit with the load fan coil units.

There are many different piping circuit configurations which can be used, depending on:

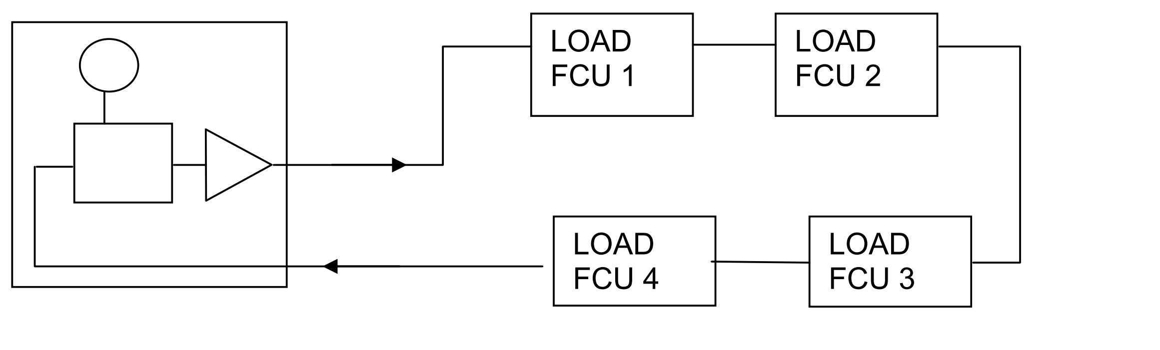
a) the geometry of the building
b) the available space for installation (e.g. the dimensions of the plant room)
c) the economics of installation
d) loading capability requirements

The general rule of thumb in designing and determining the piping circuit network is: **KEEP IT SIMPLE!**

The more extensive a pipe network is, the more complex it is and it becomes more difficult to analyse and control.
In general, there are 4 types of this pipe configuration:

1. Series
2. Diverting
3. Parallel direct return
4. Parallel reverse return

Series Circuit:



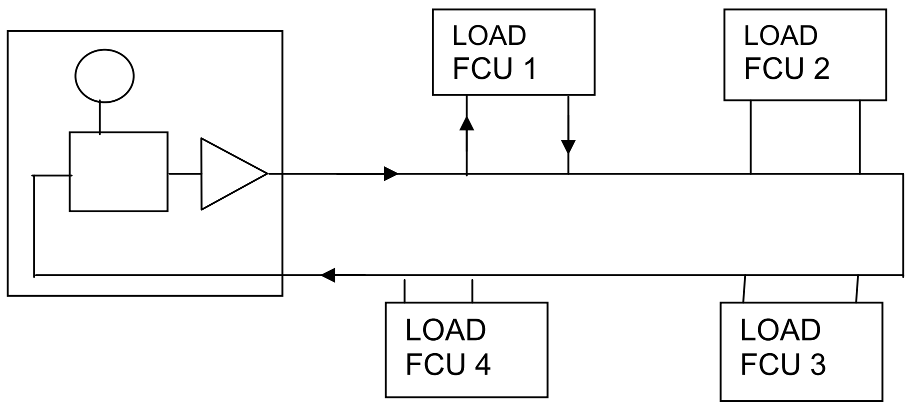
Advantages:

i. Lower piping cost
ii. High water temperature drops

Disadvantages:

i. Each fan coil loading cannot be controlled separately

Diverting Circuit:



Advantages:

i. Allows individual control to each fan coil unit

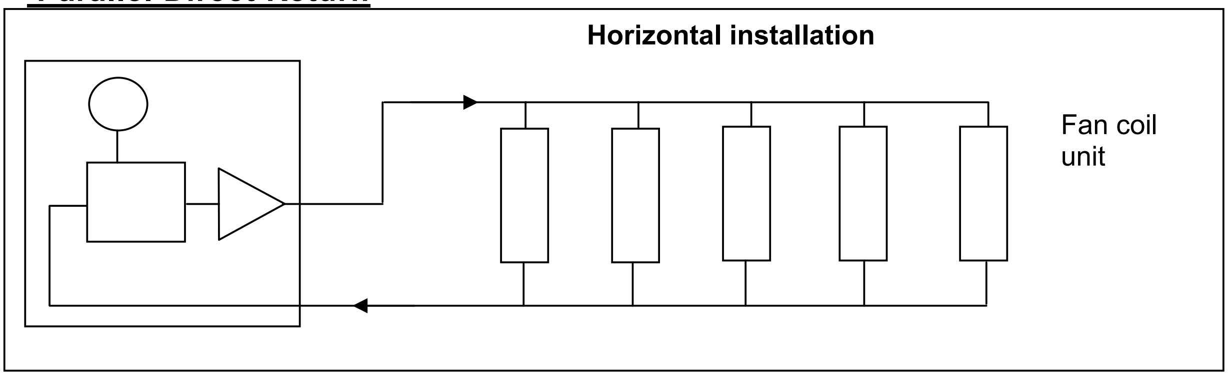
Disadvantages:

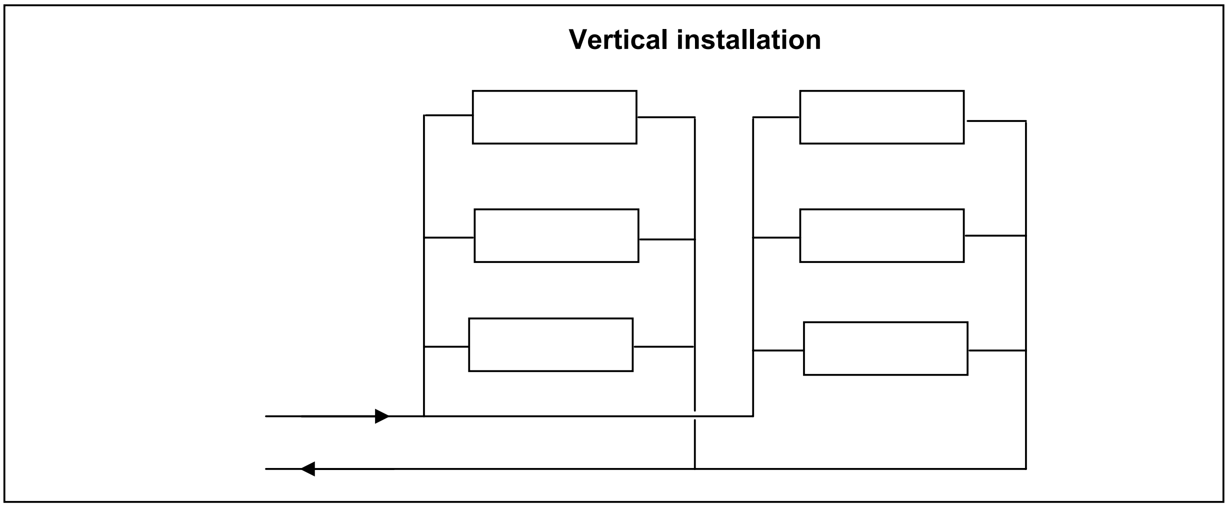
i. Only fan coil units with low pressure drops can be used
ii. Due to low water velocity in each fan coil, an air vent is required for each fan coil
iii. Higher installation cost
iv. Water entering temperature for each fan coil is different, i.e. it gets higher further away from the source

However, both the *series* and *diverting* circuits are seldom used in hydronic systems. The more commonly used are the parallel circuits because they allow the same water temperature to be available to all fan coil units.

It is recommended that the parallel circuits to be used in the installation of the mini chillers with the fan coil units.

Parallel Direct Return



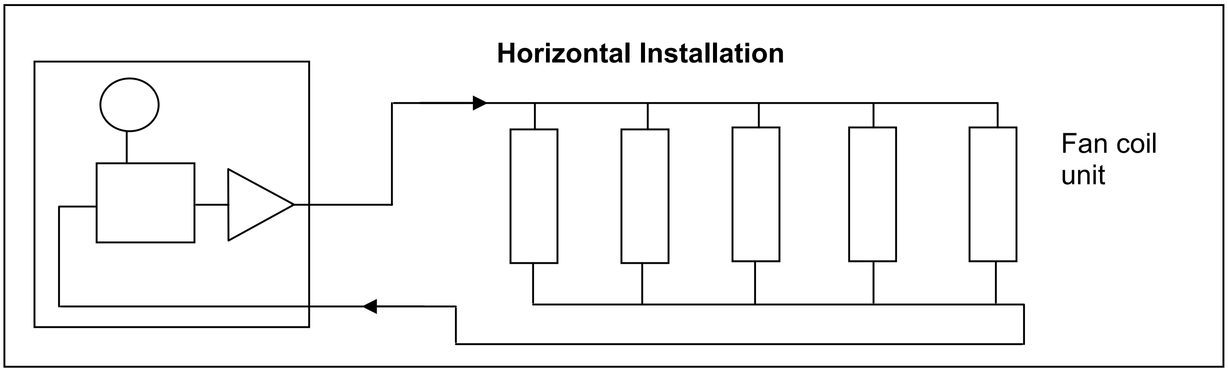


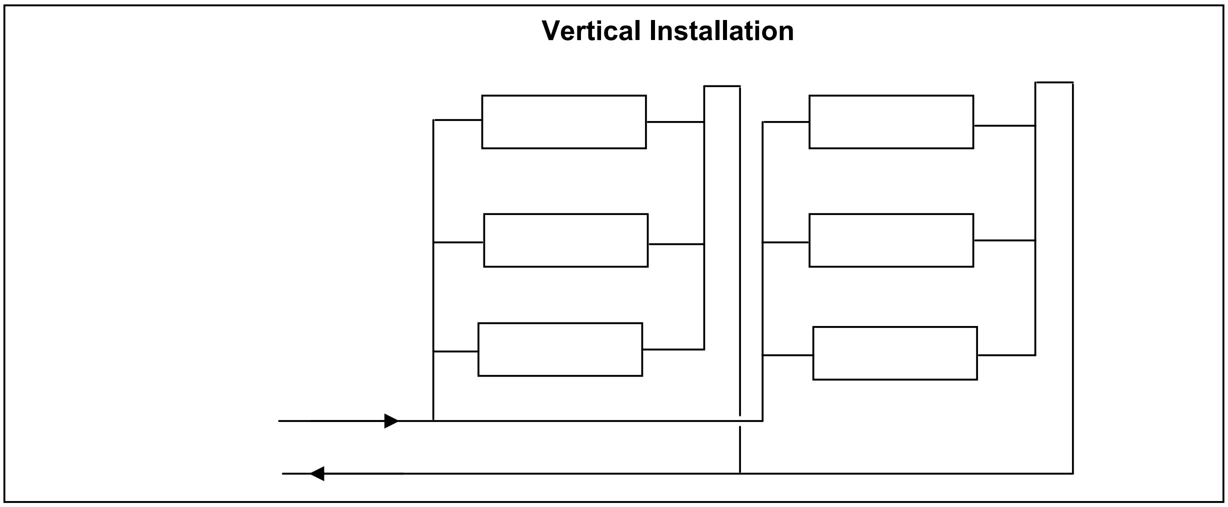
The basis for the design is *"First In - First Out".*
In this system, the length of supply and return piping for each fan coil is unequal. This will affect the water flow rate through each individual load. Proper balancing is required to provide adequate water flow rate for each fan coil.

Nevertheless, the cost of installation is lower compared with the reverse return configuration due to the shorter pipe length needed. Therefore, this method is more economical for installation of fan coils with different pressure drops and balancing valves are used.

This method is also suitable for open system applications whereby the return from the fan coil loads are discharged into a external tank.

Parallel Reverse Return





The basis for the design is *"First In - Last Out".*

In this installation, the supply and return water pipes or of nearly equal lengths. Thus, it seldom requires balancing of water flow rate for individual fan coil unit. If required, this balancing will be easier.

This method is recommended if all the fan coil units have the same or nearly the same pressure drops.

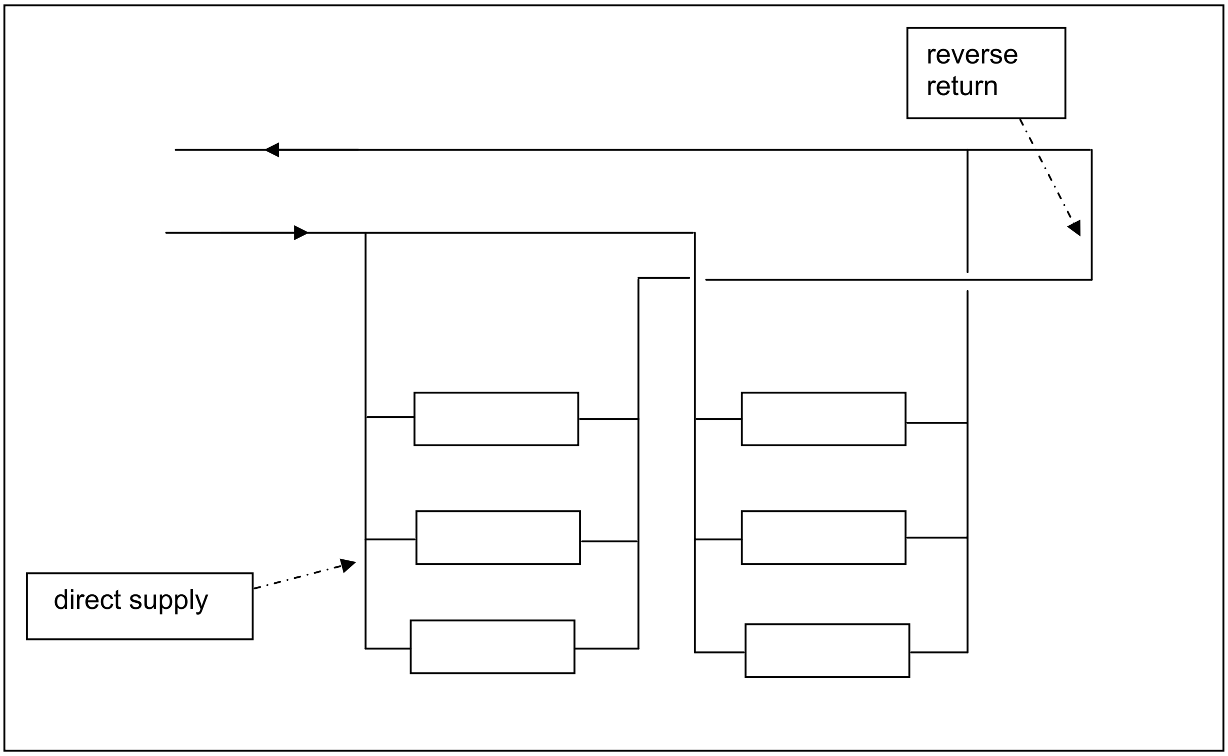
Another advantage of this reverse return system is a reduction of the working pressure drop across any balancing valves used for the fan coil units.

However, such a system is not recommended for high-rise buildings because of the vertical weight of the extra piping required. In such instances, it may be more practical to use direct return systems.

The extra piping also does not give any advantage in open system applications because the same atmospheric conditions exist at all open points of the system.

Parallel Reverse Return Header, Direct Supply Rise

This is a variation of both the direct and reverse return systems, whereby it is not feasible to have a full reverse return piping.
Instead, only the return header is in reverse, whereas the supply to the individual fan coils are in direct configuration.

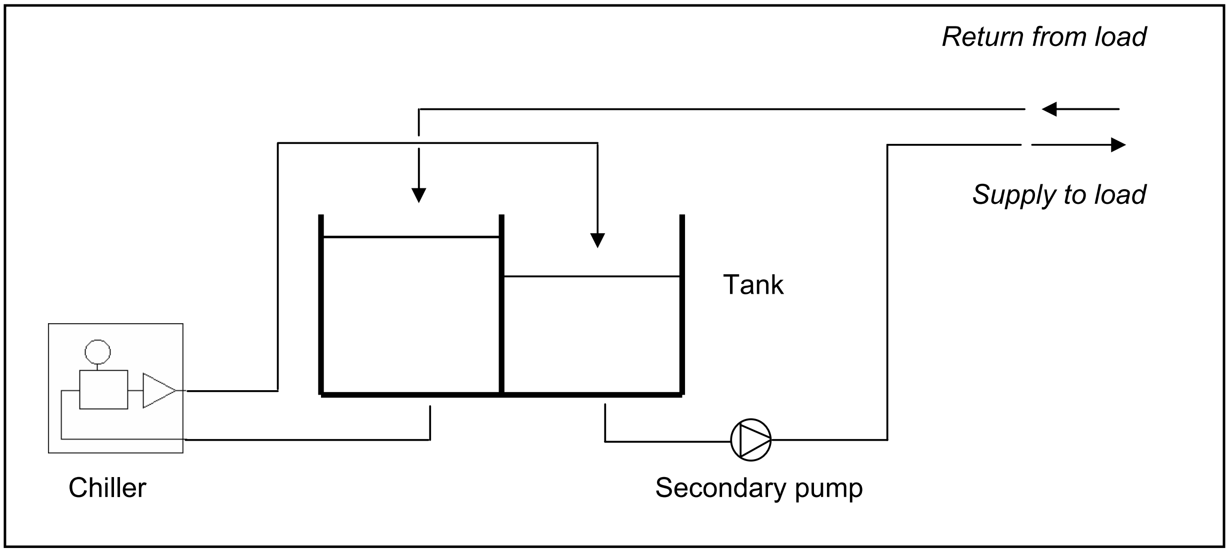


This method will have the advantage of lower installation cost with some benefits of a better water balanced system.

Balancing valves are required for each fan coil unit for proper flow balancing.

Close System vs. Open System

The mini chiller has been designed with an application for a close water piping system. However, it is still possible to use the unit with an open system by means of an additional buffer tank.



In such a system, the chiller will discharge the chilled water into the tank while a secondary external pump will then pump the water to the fan coil units.

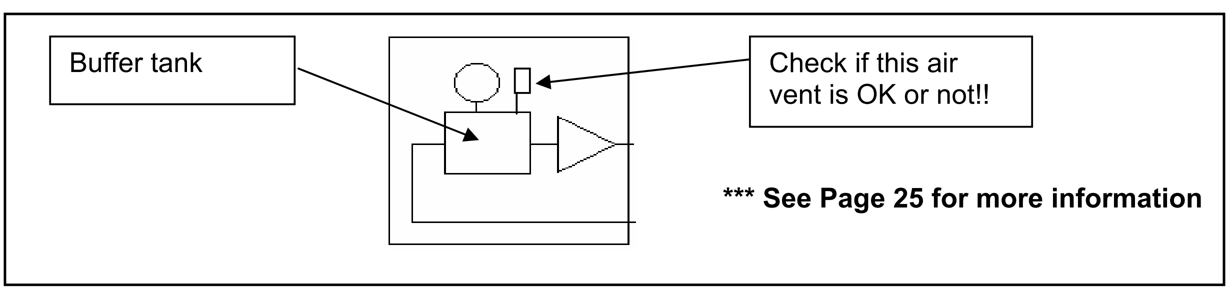
It is recommended that the tank to have a baffle plate in between to isolate the two return water from the chiller and fan coil load. This will prevent the hotter return water temperature from the load mixing with the cold chilled water from the chiller.

Such a method is suitable for:

- multiple chillers operation
- multiple secondary pumps supplying chilled water to several zones

The water volume in the tank can also be sized to act as a storage to provide cold water to the fan coil units. By doing so, the chiller may be cycled-off for longer periods of time, hence saving energy costs.

However, since this is an open system, there is a higher chance of air entering the water. Care must also be taken to ensure there are no leakages along the pump suction line else air will enter the system. The air will be drawn into the buffer tank and accumulate there. This may affect the water flow rate and trip the chiller unit. Always ensure the automatic air vent on the buffer tank is operating properly to release any trapped air.



*** **See Page 25 for more information**

Primary - Secondary Pump System

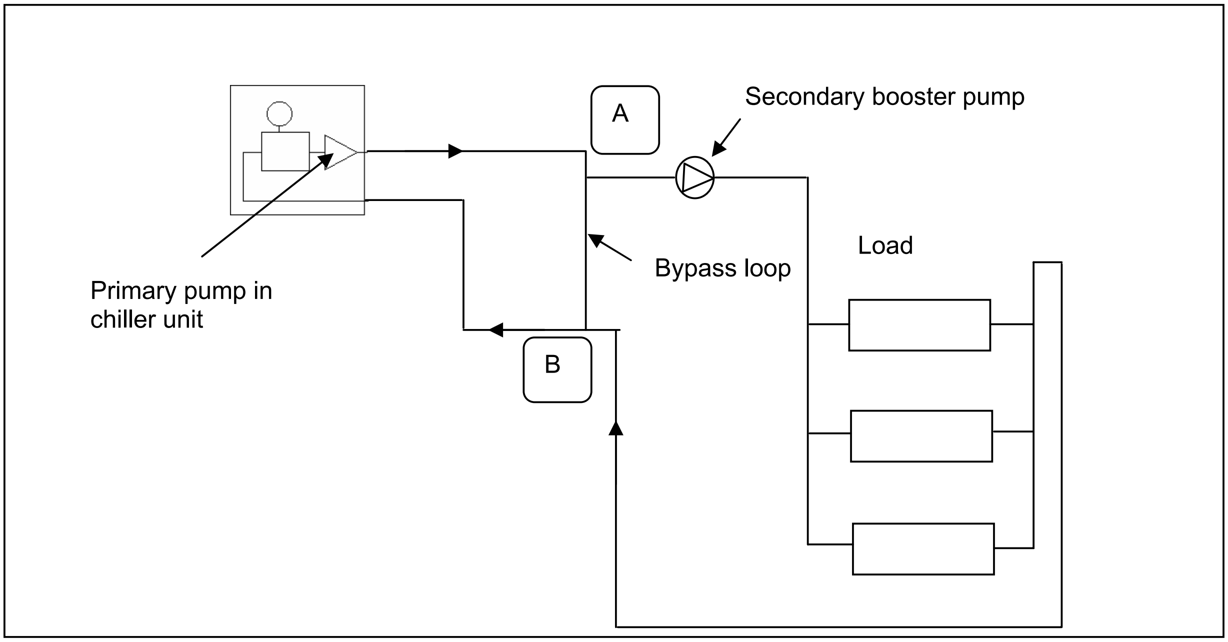
There may be instances when the integrated pump in the mini chiller is not able to deliver the required head pressure to the load in a close piping system.
To overcome this problem:

1. Change the water pump with a higher head pressure capability.

   Please consult with the factory as to the requirements. Calculate the required head pressure and select suitable replacement pump.

2. Install a booster pump.

   It is recommended that this booster pump to be installed as a primary - secondary system; as follows:



More than one secondary pumps can be installed together, e.g to serve several zones.

There are two drawbacks to this system:

a) Cost - additional two or more pumps are required

b) The bypass chilled water is sent back to the chiller unused

Keep the bypass loop as short and large as practical possible. Do not put any valve in this loop. This is to minimise the pressure loss between the entry and exit points of the loop.
However, this length must be sufficient to prevent recirculation turbulence.

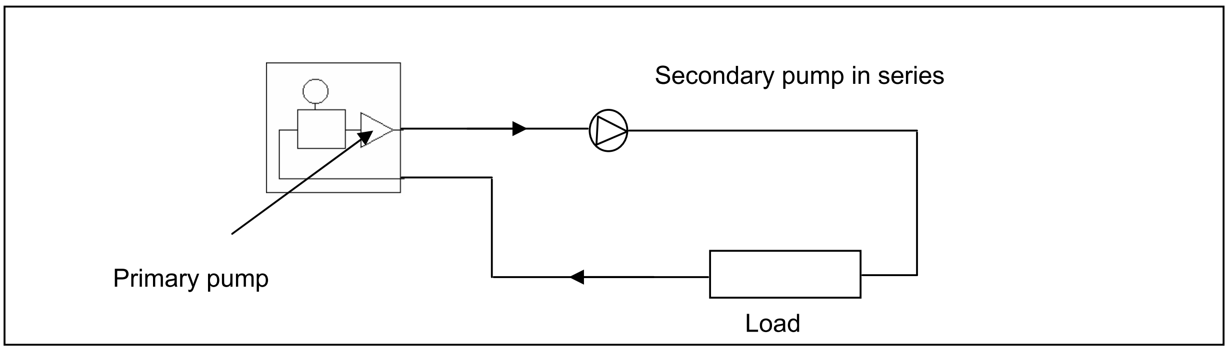
The temperature of water entering the load will depend very much on the sizing of the secondary pump.

1. If the capacity of primary pump = secondary pump, there will be no flow in the bypass loop. Hence, the water temperature entering the load will be equal to the water temperature leaving the chiller.

2. If the capacity of primary pump > secondary pump, there will be a nett flow down the loop and returned to the chiller unused. Therefore, tee A becomes a diverging tee and tee B becomes a mixing tee. The water temperature entering the load will also be equal to the water temperature leaving the chiller. However, the water temperature entering the chiller will be colder due to mixing of the unused chilled water at tee B.

3. If the capacity of primary pump < secondary pump, there will be a nett flow up the loop from B to A. Thus, tee A becomes a mixing tee and tee B becomes a diverging tee. Then, the water temperature entering the load will be in between the water temperature leaving the chiller and the water temperature entering the chiller.

There may be installations using pumps in series to boost the head pressure.
But this is not recommended due to a high chance of wrong pump sizing which can cause damage to the pumps themselves.



For this to work properly, both the primary and secondary pumps must be of the same capacity. Else, the greater capacity pump will overflow the lesser pump and cause:

a. Cavitation problems to the lesser pump.

b. Excessive pressure drops across the pump itself.

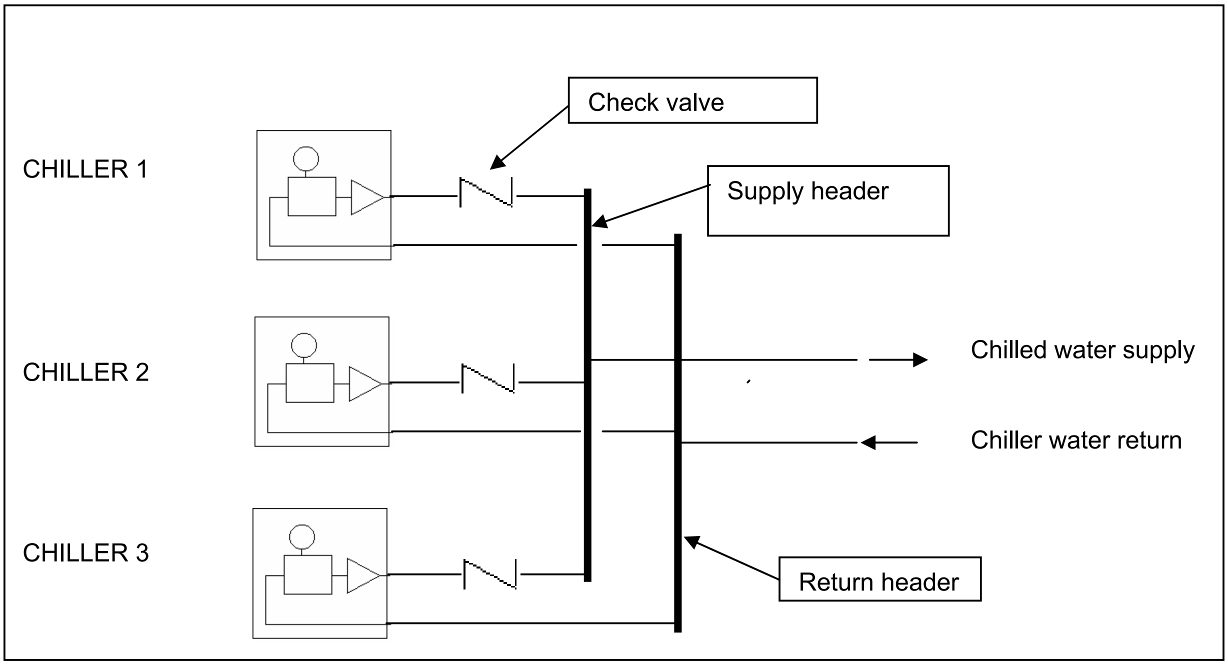
c. The extra head pressure build-up may cause damage to some of the components in the chiller itself.

Multiple Chiller Installation

In most cases, one single chiller will not be sufficient to provide the cooling load of a system. Several chillers must be combined together to give the required loading.

Generally, these chillers will be installed together in *parallel.* There are several ways to do this:

1) Common Supply and Return Headers



This method is most preferred and commonly used because of the lower cost and ease of installation.

Each chiller is normally set at different return water temperature to facilitate load staging. As the temperature becomes colder, the chillers will switch off one by one.

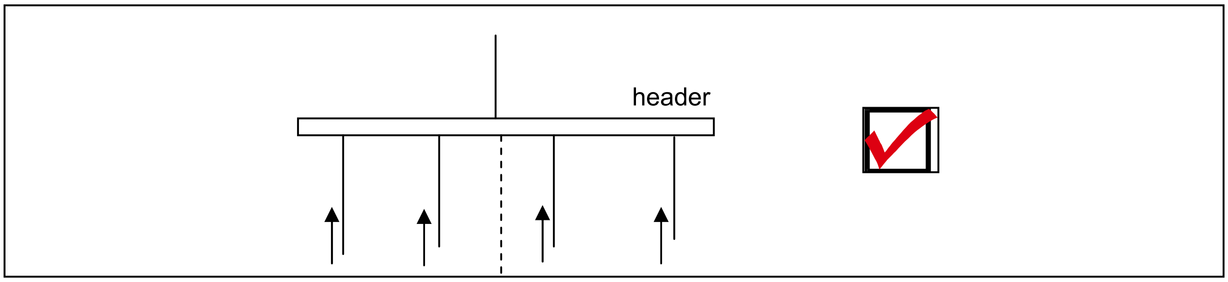
Generally, the header pipe size is larger than the supply and return pipes, e.g. one or two size larger. This is to have a low pressure drop along the header. Check valves are usually located along each chiller supply pipe to prevent back flush of water once the chiller is switched off. Such back flow may damage the water pump.

However, this method has several drawbacks:

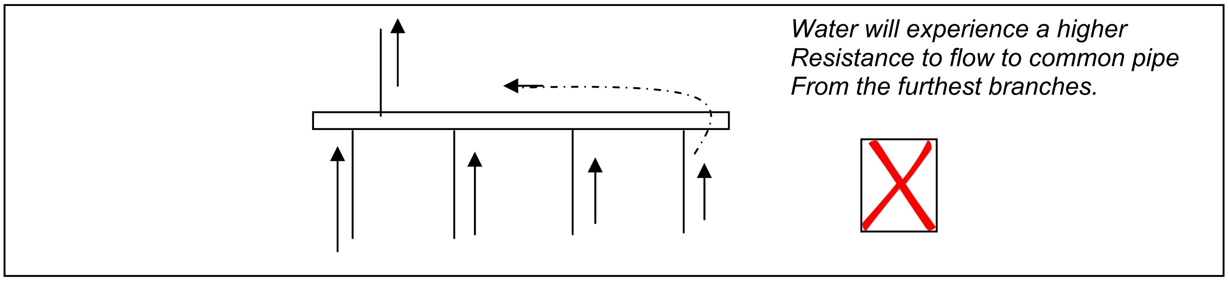
a) Proper balancing of the water flow rate through each chiller is crucial.
b) If any one chiller is off, the water flow to the load will be affected. So much so that during low load conditions, when the return water temperature is cold, and all the chillers have cycled off, no water will be pumped to the load. To overcome this problem, it is necessary to wire the chiller controls for continuous pump running as long as one fan coil unit is in operation. See Section 11.

c) Since all the water is pumped into one supply line, there is less flexibility in zoning the water distribution. The pump head may not be sufficient to deliver water to zones of high pressure losses, e.g. at the furthest end of the pipe system.

Because of the importance of water flow balancing among all the parallel chillers, the design of the header is very important.
Place the common pipe near the center of the header pipe. This will help to balance the water distribution between the left and right sides of the header.

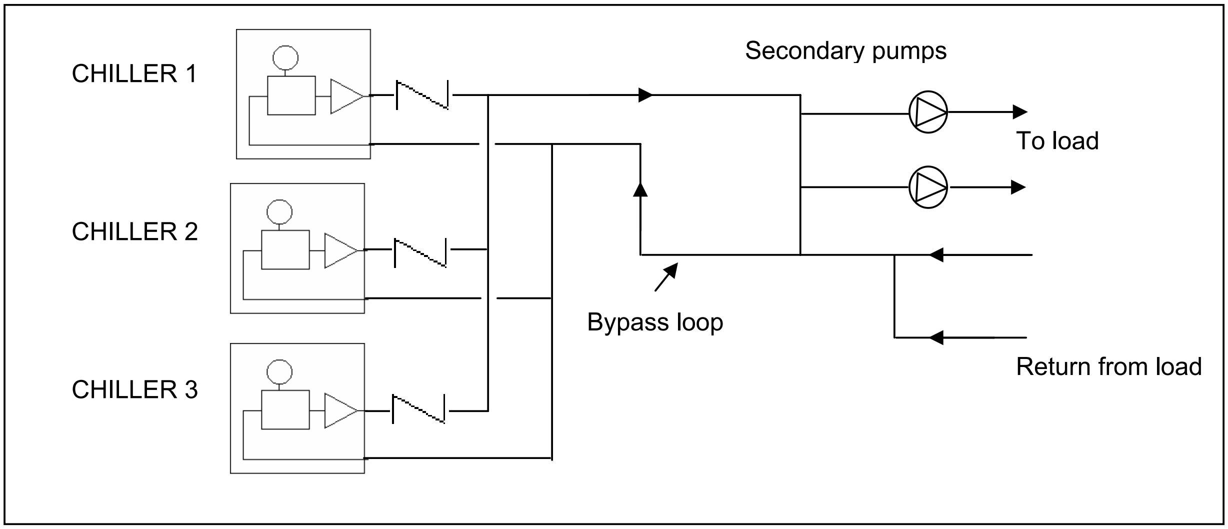


If the common pipe is at one end of the header, water from the branches at the other end of the header will find more difficulty to flow into the common pipe.



Balancing valves must be installed at each supply branch to ensure adequate water flow rate through each chiller unit.

2) Primary-Secondary System



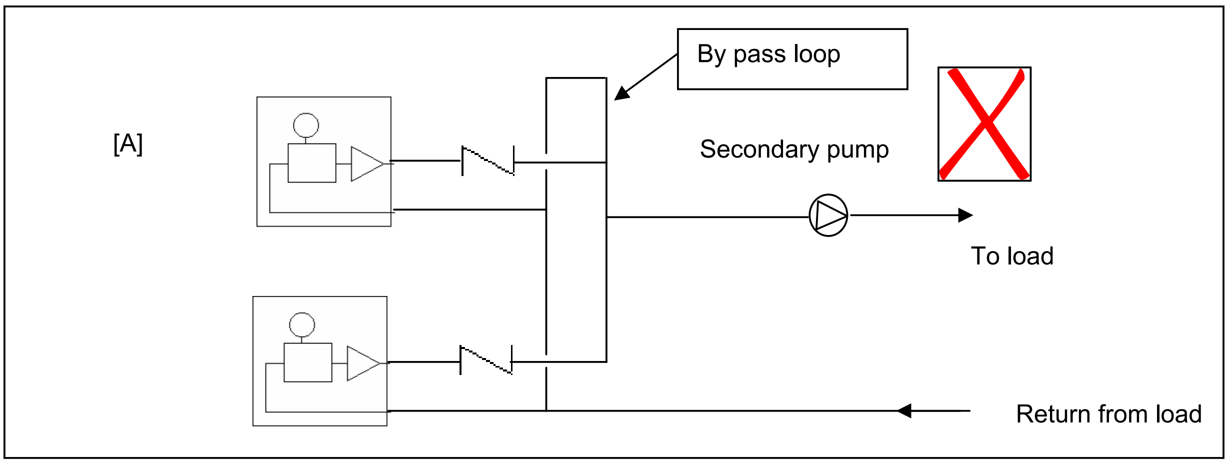
In this method, the load side of the system is isolated from the chiller side. Chillers of different capacities can be installed together without much balancing problems and effect on the supply flow rate to the loading. It just requires individual balancing of the flow rate through each chiller by using the balancing valves. Check valves and balancing valves are recommended to be installed for each chiller supply pipe.

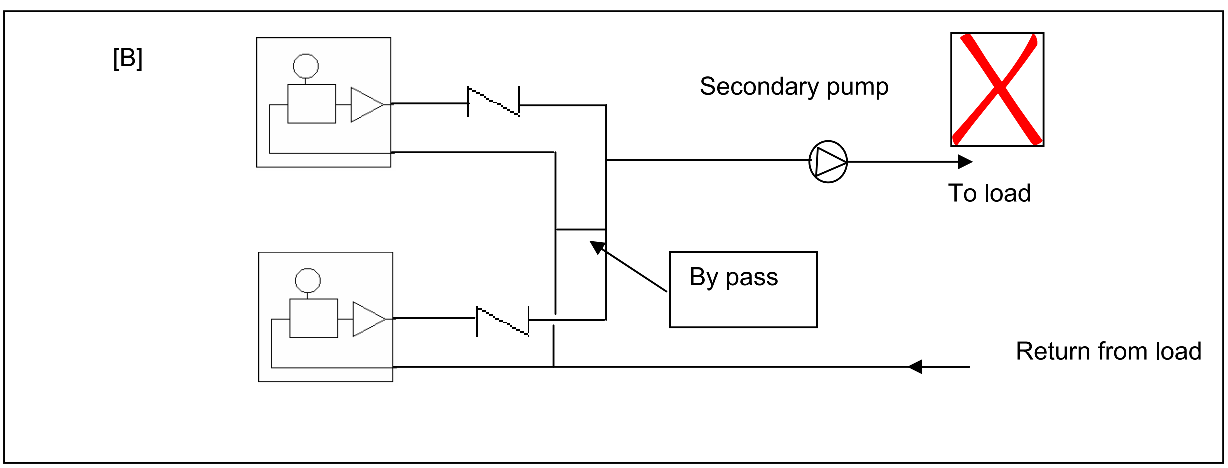
The secondary pump alone will handle the flow and pressure requirements of the loads.

Because of this secondary pump, the sequencing of the chillers will not affect the water supply to the load when any of the primary pumps switches off. Several secondary pumps can also be installed to the bypass loop to serve several zones. This creates flexibility of installation.

The only drawback to this method is cost. The piping network is more extensive and additional water pumps are required.

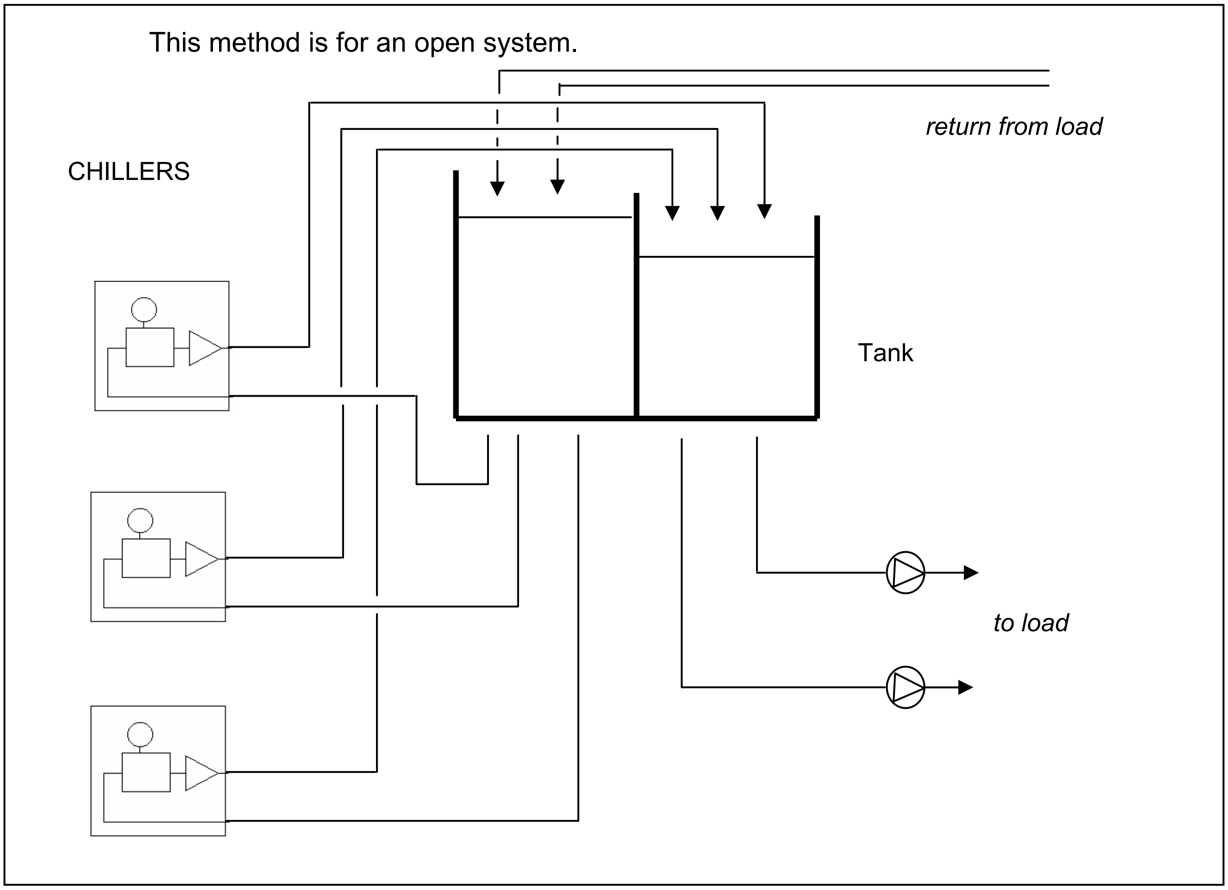
It is important that the bypass loop is located correctly. The following two are questionable variations to the above method:





For both method [A] and [B], the return water temperature for the multiple chillers will not be the same due to mixing. This will cause inefficiencies and energy wastages to the chiller operation.

3) Common Tank System



As seen from the diagram, each chiller and secondary pump forms its own individual pipe circuit. There is no cross flow among each of them. This has been achieved with the common tank which acts as a buffer storage tank.

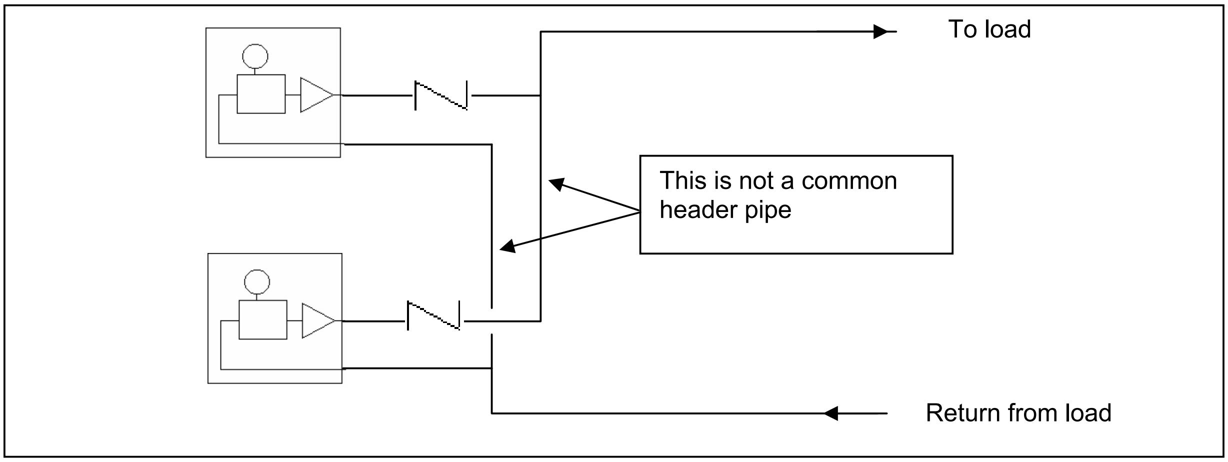
Therefore, there is no need of check valves. Normal globe valves will suffice to ensure proper water flow through each chiller.

Usually, the tank is at a higher elevated position, to allow gravity feed of water to the chillers and pumps.

This method is most expansive to install due to the additional piping and tank required for the system.

Please refer to Page 14 for cautions during installation and operation.

4) In some instances, variation to method (1) have been used whereby common headers are NOT installed to the multiple chillers. Instead, the chillers are connected together with one supply and return pipe only.

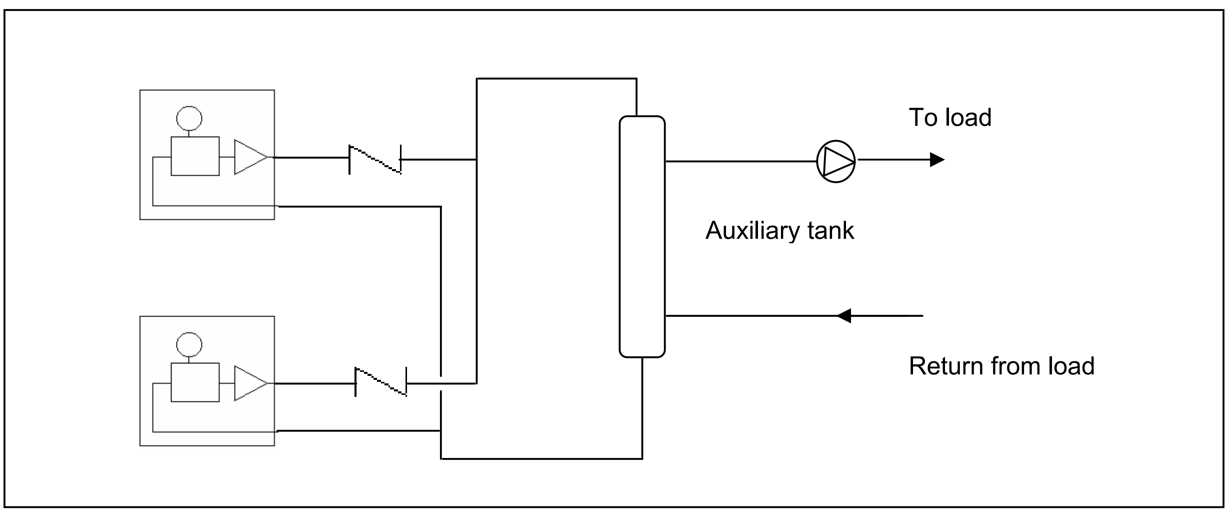


This method is still possible but there will be higher pressure drops along the common pipe lines. It is recommended that a larger pipe size to be used along this common line to reduce the friction losses.

Water flow rate tends to be faster at the tee nearest to the main supply lines due to lower friction. Therefore, proper balancing to ensure sufficient distribution to each chiller is vital.

A *First In - Last Out* arrangement between the supply and return lines may be useful to reduce the problem of distribution.

5) Another variation to the primary-secondary system mentioned in (2) above, is to use an auxillary tank to replace the by-pass loop. By using this tank, we can ensure a minimal pressure drop between the entry tee and exit tee of the secondary circuit.

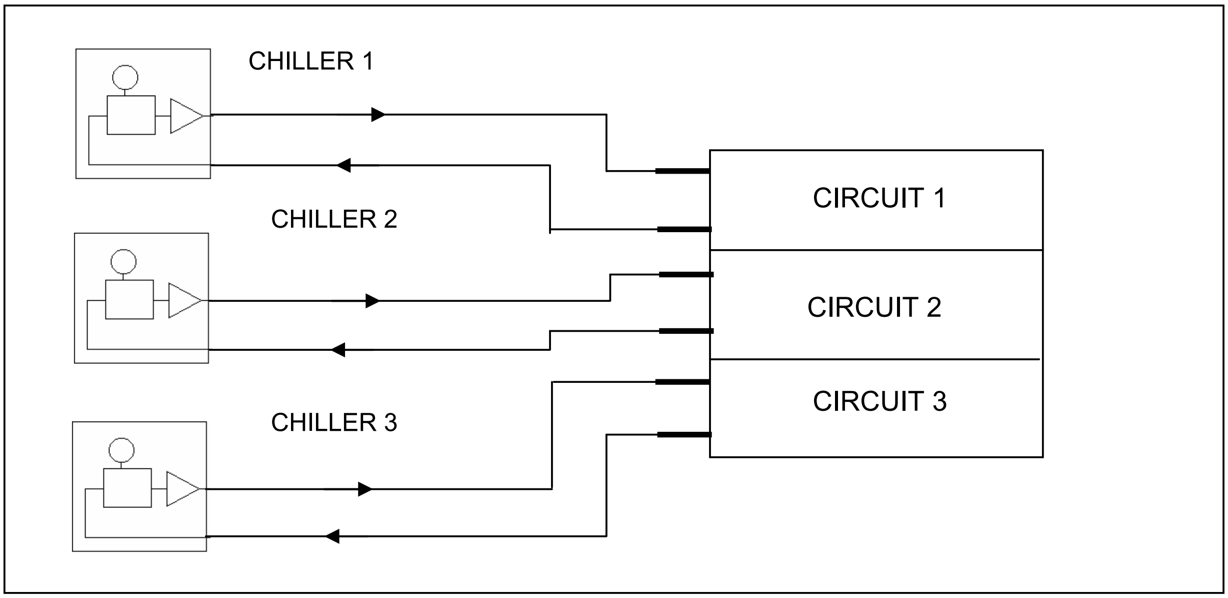


Multiple Chiller, Single Fan Coil Load With Multiple Circuits

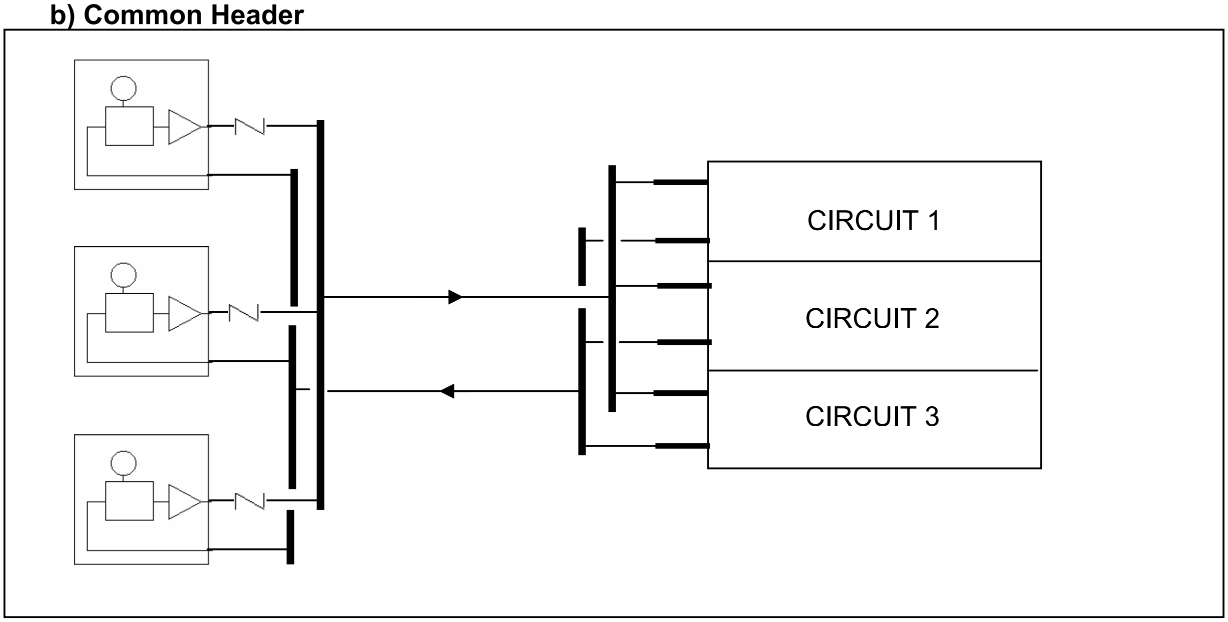
There are instances where several chillers are used to supply the chilled water to a large single fan coil unit. Each chiller will serve one of the multiple circuits of the heat exchanger coil in the fan coil unit.

There are two ways to install the pipe circuits for this system:

a) Individual Circuiting



b) Common Header



The first method has more extensive pipe works. But the water side flow control is easier and there is less pressure drop. Globe valves may be needed to ensure sufficient flow rate. Check valves are not required.

Due to the header pipes in the second method, check valves are needed for each chiller. Globe valves or balancing valves are also needed for each chiller for water balancing. All the pumps will operate in parallel and a higher water pressure drop is expected. Furthermore, balancing valves are also required in each circuit of the fan coil unit for proper balancing of the entire coil.

Nevertheless, if any one of the chiller is OFF, the second method will always allow an even water distribution to the whole heat exchanger in the fan coil unit. In the first method, hot air will by-pass through the portion of the coil which the chiller is OFF.

Make Up Water Supply

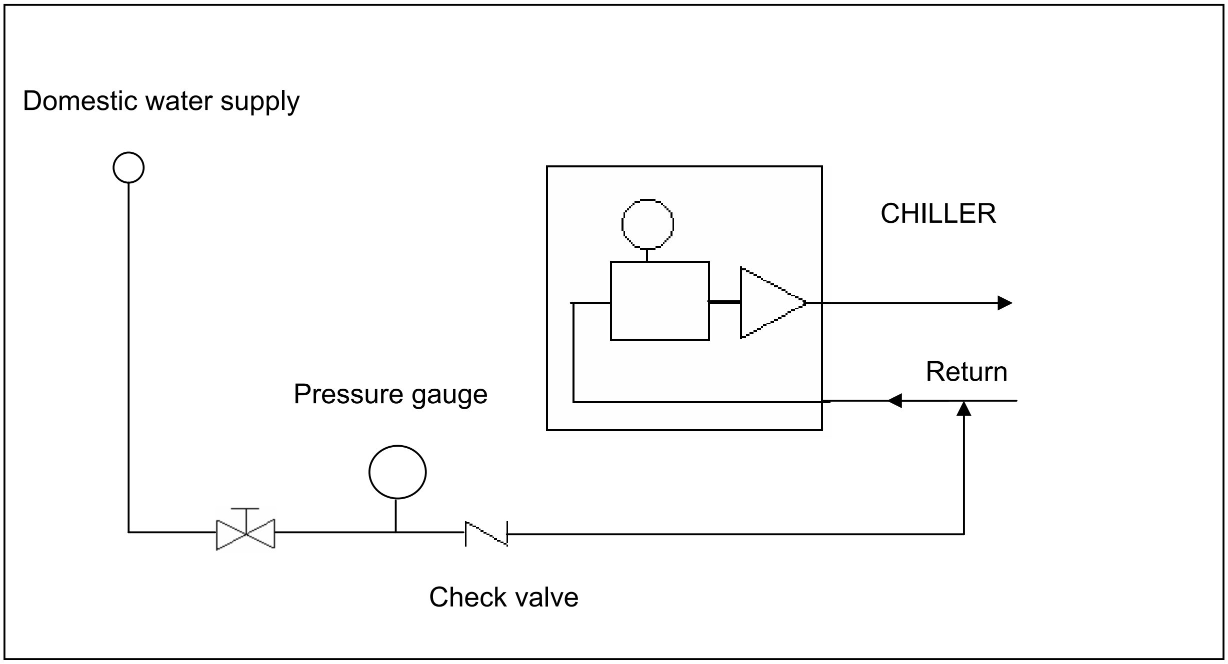
The make up water supply is used to refill water back into the hydronic system in the event of:

a) Leakage in the system
b) Maintenance service

The supply is usually from the main domestic pipe and it is usually connected to the water return pipe of the pump; due to the lower pressure which will assist in "sucking" in the water. However, should the pressure in the main supply pipe is lower than the pressure in the return pipe, water will not enter the system. Rather, switch off the pump and allow the mains pressure to fill the system. In view of this, it is necessary to install a check valve along the make up supply pipe to prevent back flow out of the system.

Other equipment which can be installed (optional) along the make up supply pipe:

a) Pressure gauge
b) Safety relief valve - to prevent over filling [see Section 10]
c) Pressure regulating valve
d) Filter element [see Section 9]
e) Water meter



Loop Piping Installation

One of the main advantages of using mini chillers is the ability to have long water piping installations. However, it is important to check that the water pump head pressure capability is adequate to pump the water through the pipe network. The longer the pipe length is, the higher is the pressure drop. If the pump head is insufficient, it may be necessary to change the water pump itself. See Section 5.

With such installations, it is also important to check the condition of the automatic air vent valve. A high pressure drop along such pipe network may result in the return water to have a negative pressure (i.e. suction vacuum pressure in the buffer tank). Due to the mechanism of the air vent, air will be drawn into the buffer tank itself! This in turn will cause the pump to be air-locked. A symptom of such condition is that air will always be purged out of the tank when we manually open the air vent.

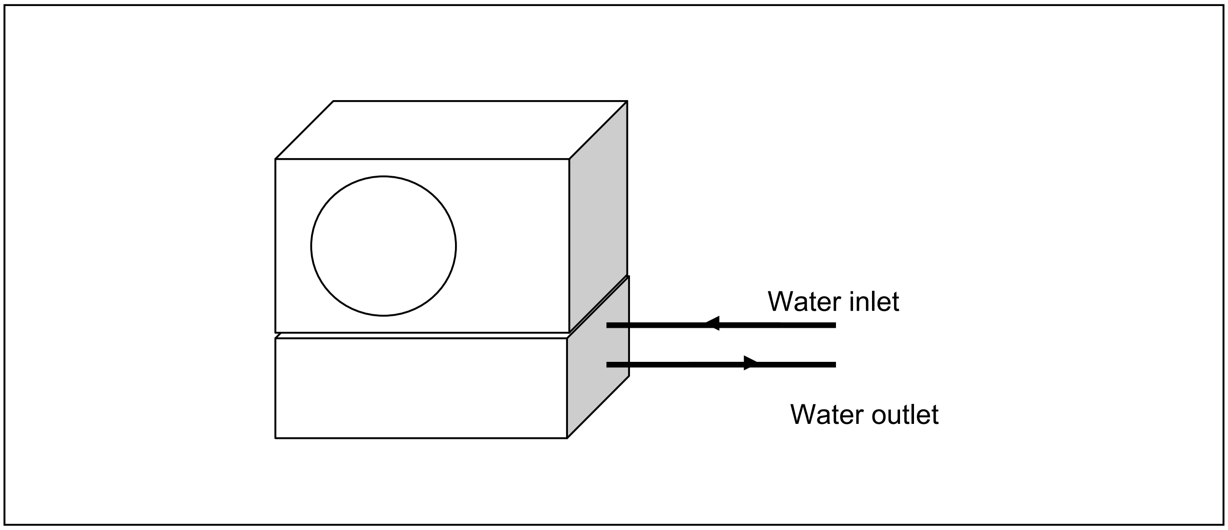
The solution to this problem is to remove the automatic air vent and plug up the hole. Make sure that all the air trapped are purged out of the system before plugging it. This can be done by continuously filling up the system with water until no air bubbles comes out of the hole.

Water Pipe Connections

All mini chiller units comes with ∅1-1/4" pipe connections.

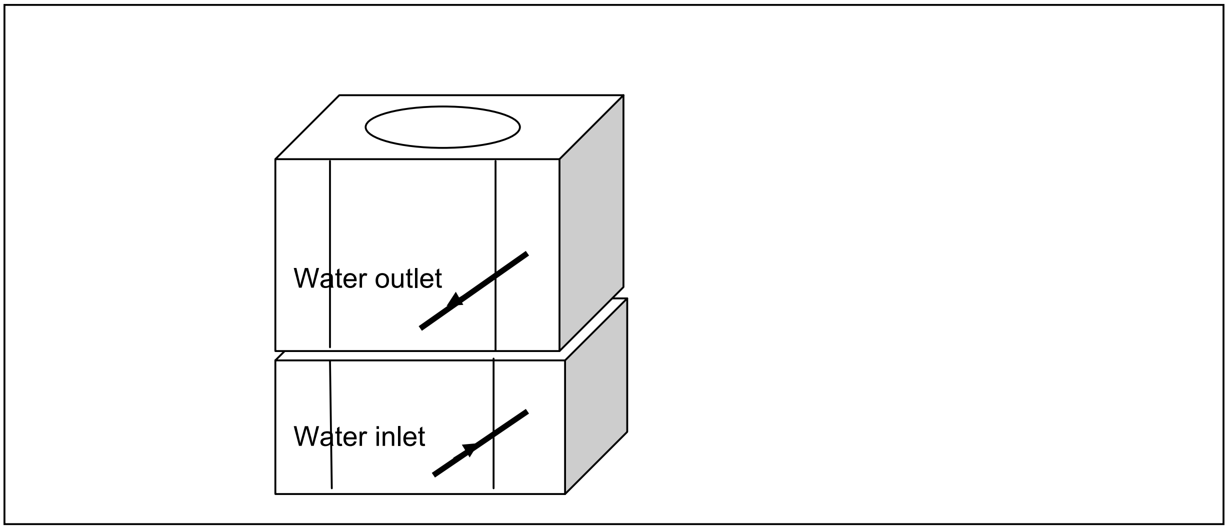
1] A-Series

The pipe connections are on the right-hand side of the unit (when facing the fan blade).



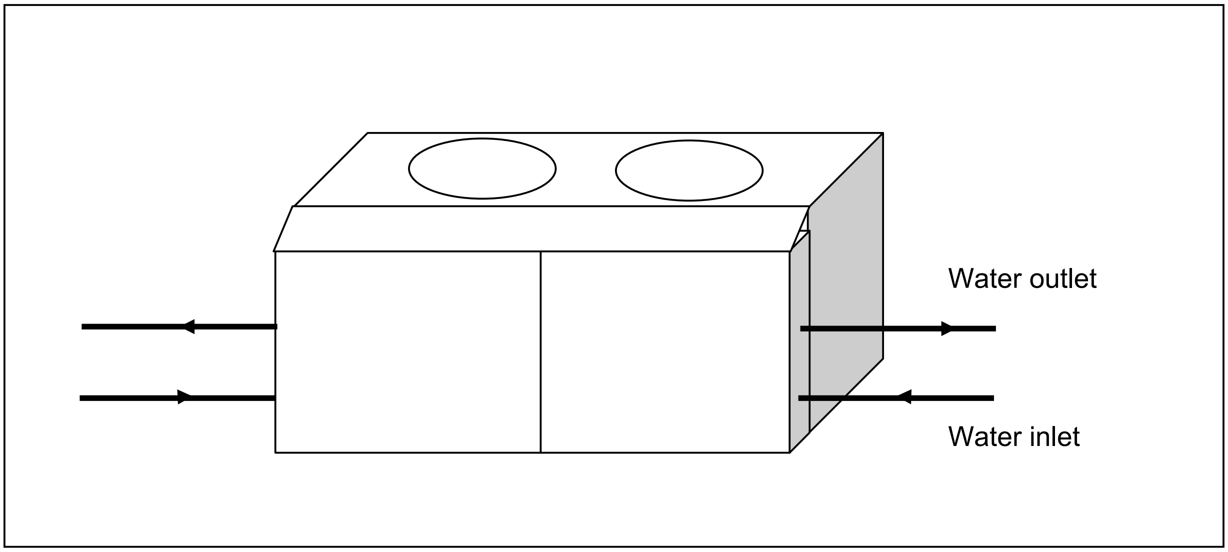
2] B-Series

The pipe connections are on the same side as the control box compartment



3] C-Series

The pipes can be connected either from the left or right side of the unit (with respect to the compartment doors).



Section 3: Water Pipe and Fittings

There are several types of pipe we can use for the water piping:

1. Black carbon steel pipe
2. Copper pipe
3. PVC pipe

Do not use galvanised iron (GI) steel pipe! This is because the zinc coating on the GI pipe will have an electrolytic reaction with the copper components of the system, e.g. the brazed plate heat exchanger and fan coil unit heat exchanger.

The zinc will be the sacrificial metal and deposit itself on the copper surfaces.

a) The pipe wall thickness will slowly eat away and cause leakages
b) The zinc deposit on the copper surfaces will retard heat transfer process. It may also reduce the gap between plates in the BPHE and slows the water flow rate.

The mini chiller water piping connections is for a pipe size of 1-1/4". For a single run installation, the recommended maximum pipe length is 150 meters, but this will depend very much on the method of installation and the fittings used. The more complex the piping network is and the more fittings there are, the higher will be the friction losses. This will limit the piping length available.

Always calculate the friction losses in the system and compare this with the capability of the water pump in the chiller unit. See Section 4

1. Black Steel Pipes

The black steel pipes are the most commonly used in chiller installations. It is relatively cheap and by far the strongest among the 3 types mentioned above.
However, these pipes are heavier and requires more extensive work to join and install.

The common pipe sizes are determined from the ASME (American Society of Mechanical Engineers) standard B36.1 OM which specifies the pipe dimensions. See Appendix 1.

Generally, steel pipes are sold in lengths of 6 meters each. The dimensions of importance which we need to know is the *nominal pipe size (NIPS)* and *schedule number* (wall thickness).
For pipes 14" (350mm) and larger, the nominal diameter is the same as the actual outside diameter.

For pipes between 3" (80mm) to 12" (300mm), the nominal diameter is close to the actual inside diameter.

However, for pipes smaller than that, the nominal value does not correspond to any actual dimension.
Steel pipes are manufactured with different wall thickness. The ASME standard has defined schedule numbers to identify these specifications. A pipe with a nominal pipe size may have several schedule numbers. See also Appendix 1

Therefore, pipes may have the same nominal diameters (outside diameters) but with different inside diameters because of the different schedule numbers.
The usual schedule numbers are 10, 20, 30, 40, 60, 80, 100, 120, 140 and 160 with the thickness increasing with the numbers.
These numbers are further classified as Standard (ST), Extra Strong (XS) and Double Extra Strong (XXS) whereby applications requiring higher pressures will need pipes with thicker walls.

However, in the HVAC industry and for our mini chiller installation, a standard schedule 40 pipe will suffice.

The steel pipes may be joined by several methods:

1. Arc welding
2. Thread (usually up to 50mm) with PTFE Teflon white tape
3. Flange with gaskets

2. Copper Pipes

Copper pipes are chosen for water piping because of their resistance to corrosion and ease of installation. The pipes are light and ductile.
However, the cost of these pipes are higher compared with steel pipes (generally by 3 - 5 times).

The sizes of these copper pipes are defined by the ASTM (American Society for Testing and Materials) standard B88 for water and drain services. See Appendix 2.
There is also another ASTM standard B280 which specifies the sizes of pipes used for refrigeration services with different wall thickness. This standard uses the outside diameter as the nominal size.
These pipes are also generally sold in lengths of 6 meters.

Generally, the B88 standard defines 4 types of copper tubes: Type K, L, M and DMV with descending wall thickness. The most commonly used types are type L and M which have higher internal working pressures. These may be of hard drawn or soft annealed temper.

The copper pipes may be joined by:
1. Brazing
2. Soldering
3. Flare joint / compression joint fittings

3. PVC Pipes

The plastic PVC (polyvinyl chloride) pipes are light, generally inexpensive and corrosion resistant. The pipes also have a very low friction factor (i.e. with smooth surface) which results in lower pumping power and smaller pipe sizes. However, these pipes are not suitable for high temperature applications as they losses strength rapidly at temperatures above ambient. The pipes also have high coefficient of expansion, i.e. at high temperatures any pipe joint made may become loose and leaks. Because of the weaker strength of the material, such pipes must be installed with shorter support spans.

As a result of the above mentioned disadvantages, it is not recommended for PVC pipes to be used for external applications, especially under direct exposure to sunshine. They may be suitable for piping water indoors, e.g. under ceiling spaces, attics, plant rooms, etc.

The PVC material is classified as a thermoplastic. Generally, there are two types:

1. U-PVC (unplasticized PVC): for general usage up to 60°C
2. C-PVC (chlorinated PVC): for higher temperature applications.

The PVC pipes and fittings used inside the mini chiller unit (factory assembled) are of **DIN 8061/8062** standard. Therefore, use back pipes and fittings with the same standard when running pipes from the chiller to the fan coil units. It is recommended that pipes with pressure rating of PN16 (16 bar working pressure) to be used. See Appendix 3.

Do not use PVC pipes manufactured to other standard specifications, e.g. BS 3505/3506 as the fittings will not match with those used in the chiller. The pipe wall thicknesses are also different.

The usual method of joining the pipes and fittings is with solvent cementing/welding. Some fittings also have threads for joining purposes (with PTFE white tape).

It is recommended that 'IPS Weld-on PVC 717' solvent cement to be used. It is gray in colour and used for heavy-body applications.

The following are some guidelines to ensure that the solvent cement joint is done properly:

a. Cut the pipe square and deburr. Clean and dry surfaces before coating the cement.
b. Apply a full, even layer of cement equal to the depth of the socket. Avoid excess and puddling.
c. Assemble while the cement is wet. If not wet, recoat parts.
d. Ensure pipe fits snugly into socket. Give a twist of 1/8 to 1/4 turn.
e. Hold for 30 seconds to prevent push out and allow for initial set. Wipe off excess.
f. Allow curing time at least 5 minutes, up to 30 minutes. Longer curing time is better for higher pressure/temperature applications.

Typical Pipe Fittings

The following are typical pipe fittings used for installing the mini chillers. Note that the pipe fitting size of the chiller itself is 1-1/4".

a) Steel Pipe

Because of the pipe fitting size, it is recommended that the connecting pipes and fittings to be joined with thread. However, where necessary, fittings for weld joining may also be used.

The following standards are applicable for these fittings:

ASME B16.9, ASME B16.11, ASME B16.28 and ASME B1.20.1

- 90º elbow

Internal thread

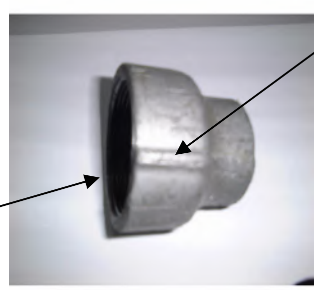
45º elbow are also available but not commonly used, unless necessary

- Tee joint

Internal thread

A tee joint can either be a flow mixing or flow diverging point, depending on the design of the pipe work.

- Reducer

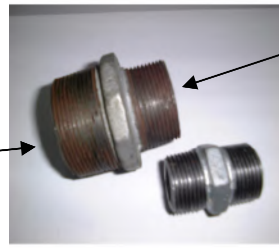


Internal thread

Some reduces/ fittings do not have these ribs: used for better gripping when tightening with pipe wrench.

- nipple

External thread

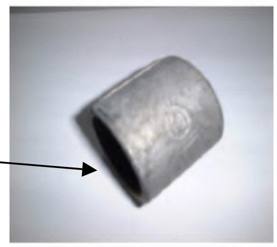


with reducing ends

Nipples are usually used for joining different types of fittings, e.g. an elbow with a reducer.

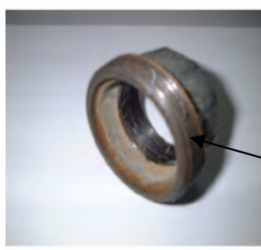
- connector

Internal thread



Used for joining two lengths of pipes together

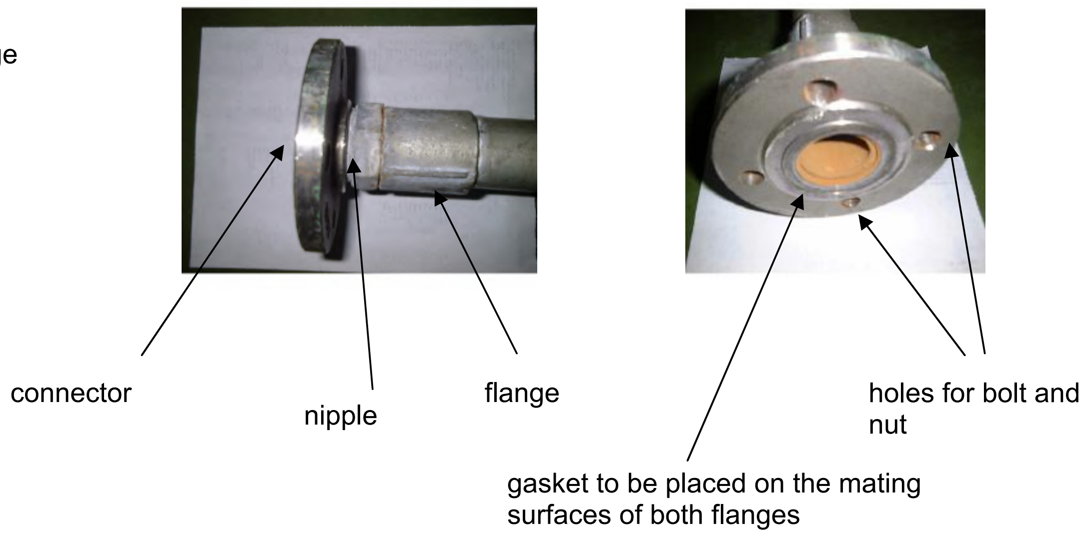
- Union/ coupling



Used for joining two lengths of pipes together

Made up of two halves, each screwed into a pipe end.
Both are then joined with a locking nut in between

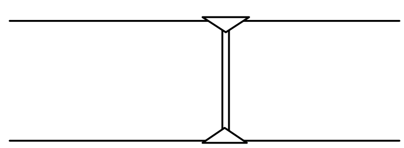
- flange



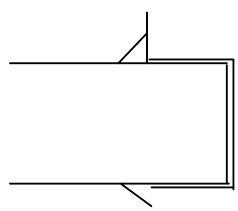
This method is not recommended for the small pipe size used for the mini chiller.

** The fittings for weld joining are very similar to those mentioned above, i.e. they do not come with the thread portion. They may be butt-welded or socket-welded.

BUTT

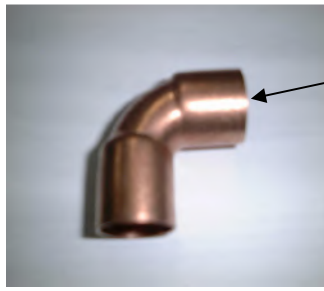


SOCKET



b) Copper Pipe
The most commonly used method of joining copper pipes is brazing with an oxy-acetylene flame and copper filler rods. For this purpose, one end of the pipe is expanded by using an expander tooling, and the end of the other pipe is inserted into the expanded end. The joint is then brazed together. *[see Appendix 4 for expansion dimensions]*
Similarly, fittings are available for such brazing joints:

- 90º elbow

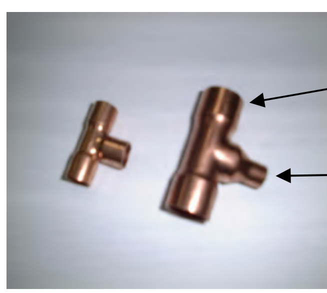


expanded end

- reducer

Usually, the pipe outer diameter will insert into the reducer inside diameter

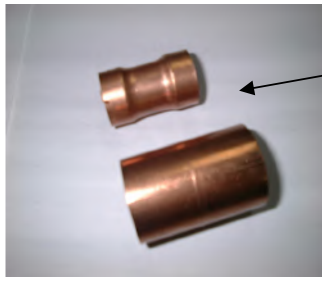
- tee joint



expanded end

some may come with reducer end

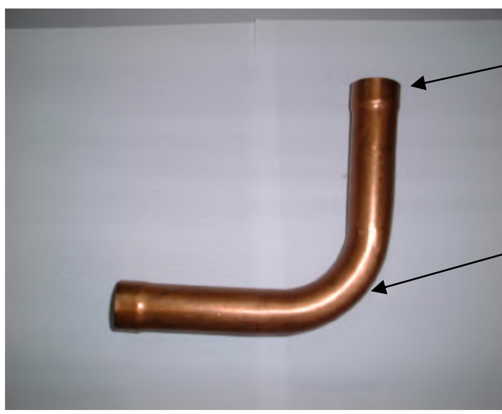
- connectors



expanded end

Sometimes, copper connectors are used instead of expanding the copper ends.
This is especially with larger pipes where expanding becomes more difficult
because of the thicker wall thickness.

Also, an alternative to using elbows is to just bend the pipes with a pipe bender to suit the installation requirement. Various bending angles can be achieved with this method. However, the larger the pipe size, the more difficult this will become.



expanded end

Pipe bend

CAUTION! Do not bend the pipes with hands. This will cause the pipe to collapse at the bending portion. Use the suitable pipe bending tool.
Manual hand benders allows a maximum size of 3/4". Pipes up to 1-3/8" can still be bended by using bending machine.

NOTE:
During brazing of copper-to-copper pipes, copper filler rods of 0% silver may be used. It is a good practice to pass nitrogen gas inside the copper pipes while brazing to prevent oxidation.

<u>Copper Pipe: Compression Fittings</u>

For some installations, the piping are connected using compression fittings. These fittings enable easy installation and dismantling. However, the cost for these fittings are higher. They are also not as strong as brazing joints. Chances of leakage are higher.

Generally, the fittings have mounting rings which are slipped onto the copper pipes. The ring is then pushed against the fitting internal surface and a locking nut is used to hold the assembly together.

- 90° elbow

Locking nut

mounting ring

- 90° elbow with threaded ends

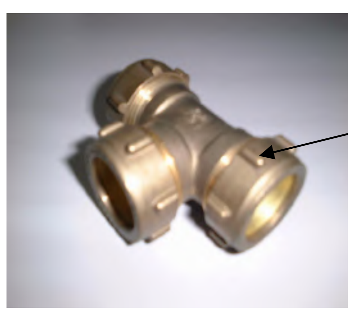
normal elbow

female thread

male thread

Such elbows are for special applications. For example, connection with steel pipe fittings, connection with a water tank.

- tee joint



ribs for gripping with a wrench

- connector

female thread

Used for connecting two pipes together.
Some have threaded ends for connection with other fittings.

- union

locking nut

threaded end

The two halves opened up

Similar to the steel type. Used for connecting two pipe together with flexibility of easy connection and dismantling.
Some have threaded ends, others with compression fitting ends.
In some installations, the copper pipes are brazed (with silver flux) onto each half of the union and then connected together with the locking nut.

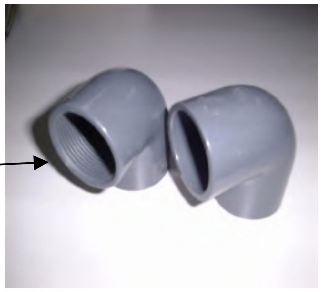
NOTE: Brazing of copper to brass requires filler rods with 34% silver.

c) PVC Pipe

It is recommended that the PVC pipe fittings used to be in accordance to the DIN 8062 standards. These fittings have thicker walls and able to withstand higher pressures and temperatures.
Generally, these fittings are the cheapest and easiest to install.

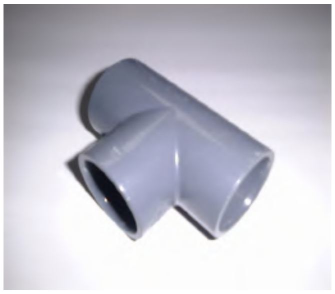
- 90° elbow

some elbows have threaded ends

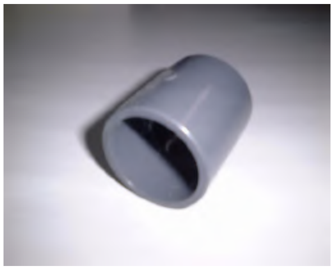


With the threaded end, it is also possible to connect with a steel pipe or steel fitting.

- tee joints

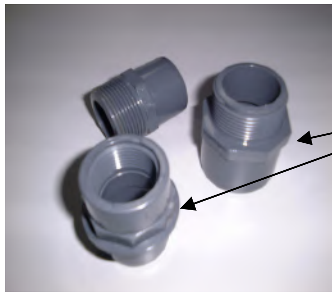


- connector



Used to connect two PVC Pipes together with solvent cement

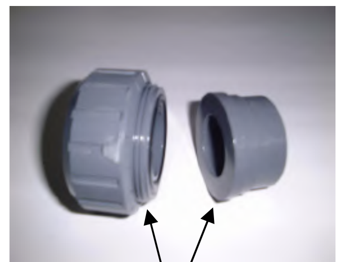
- adaptor/sockets



The sockets may have male or female threaded ends.
Such sockets are useful to adapt connection with a steel pipe or tank.

- union

locking nut



the two halves of the union

Similar to the steel and copper versions, these unions enable easy connection and dismantling of two PVC pipe ends.
The PVC pipes are joined to the two halves by using solvent cement and then they are assembled together with the locking nut.

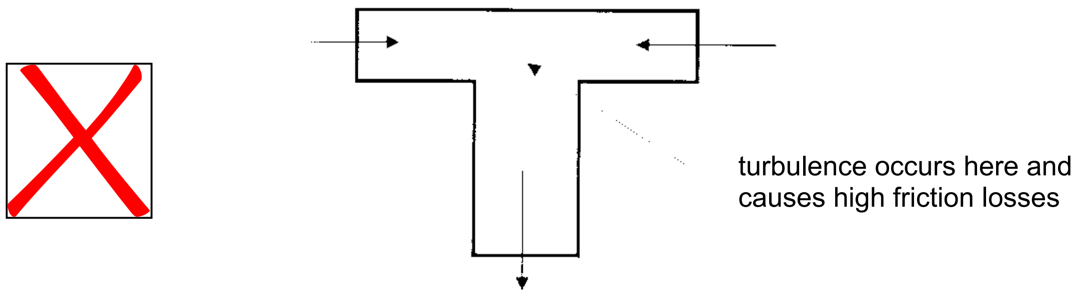
- reducer

Tee Joint Installation

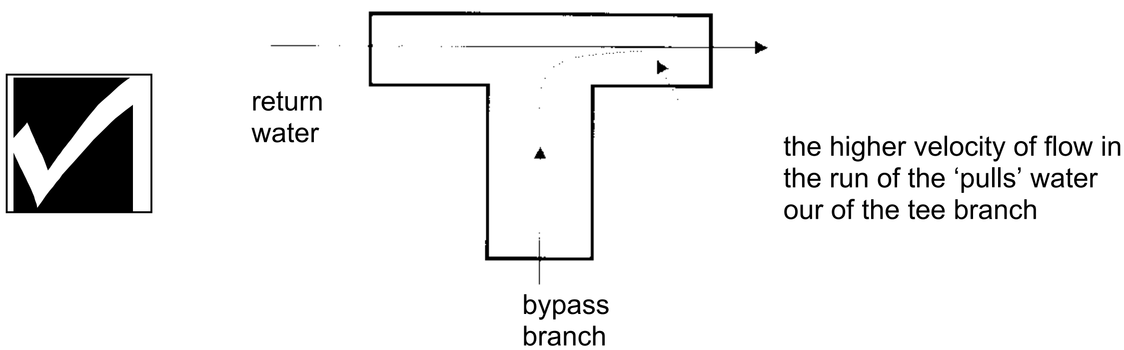
Care must be taken during installation of tee joints. Two cases are mentioned here to demonstrate the importance of understanding the design of the water flow system.

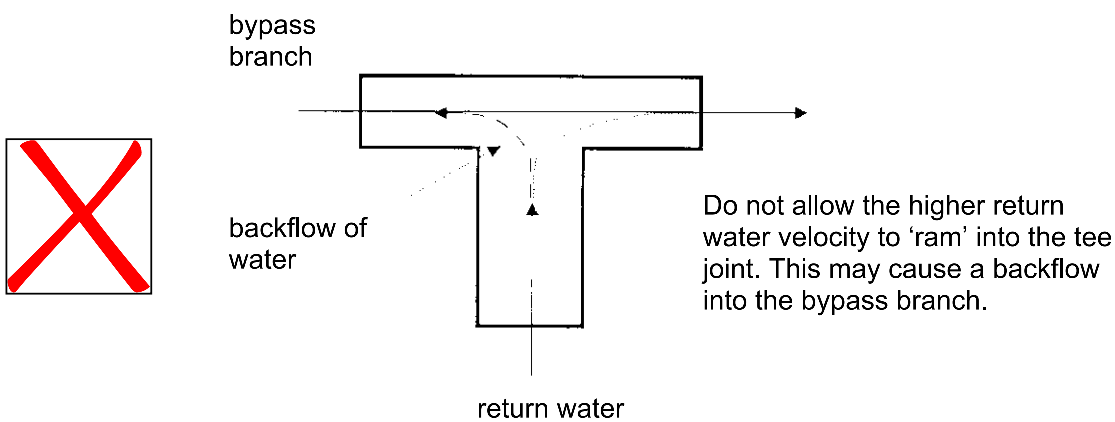
a. Avoid **"bullheading"**

Do not connect piping to the tee connection with opposing flow directions.



b. Encourage **eduction** out of a bypass tee branch.





Valves

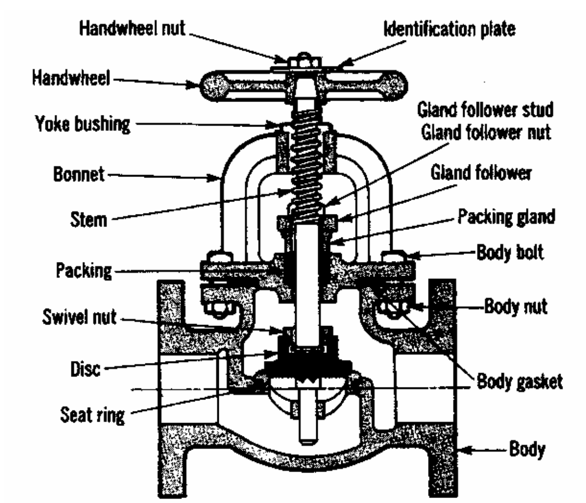
In Section 2, we have look at several piping network configurations. The diagrams shown in that section have been simplified. In actual situation, the piping will have most of the pipe fittings described earlier in this Section 3. In addition, valves are also installed along the piping lines.

Valves are used for the following purposes:

a. To isolate a component of the hydronic system from the rest of the system; thereby enabling easy maintenance and repair of that component.
b. To regulate the water flow rate through the system.
c. To divert or mix flow directions, optimizing the water temperature in the system.
d. To relieve or regulate pressure.
e. To prevent backflow.

Valves are constructed to withstand a specific range of temperature, pressure, corrosion and mechanical stress. Careful selection of the correct valve for a particular application is important to give the best service with consideration of economic requirements.

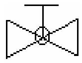
The following diagram gives the general anatomy of a valve:



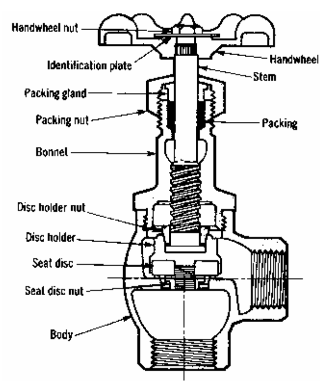
Generally, valves can be categorised as manual or automatic valves.

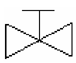
Manual Valves

The following are the types of manual valves commonly used in hydronic systems:

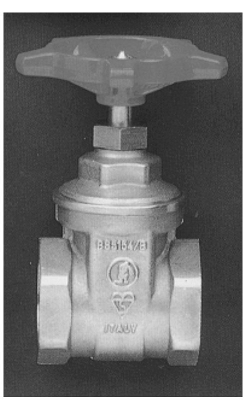
1. Globe Valve 

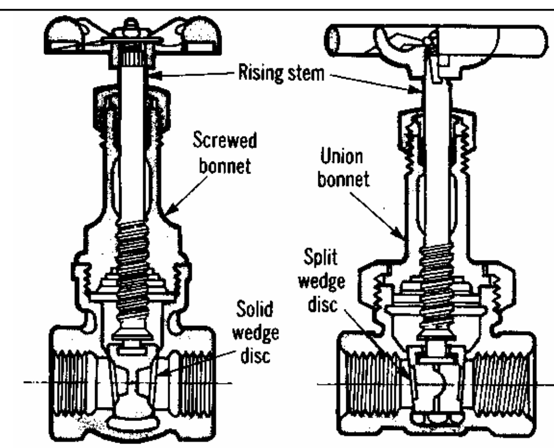
Flow is controlled by a circular disc forced against or withdrawn from an annular ring, or seat, that surrounds an opening through which flow occurs.
The movement of the disc is parallel to the flow direction.
- used for pipe diameters up to 300mm
- used for *throttling duty* where positive shutoff is required

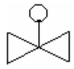


2. Gate Valve 

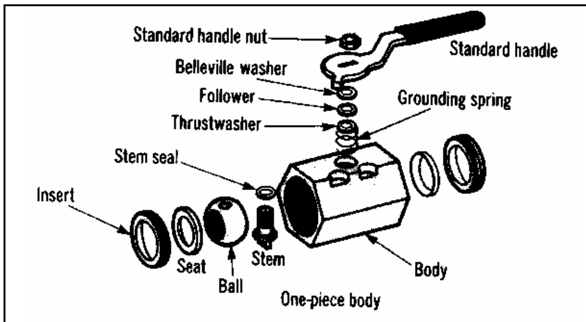
Flow is controlled by means of a wedge disc fitting against seating faces.
Gate movement is pependicular to the flow direction.
- has straight-through openings as large as the full bore of the pipe.
- this type of valves are intended to be *fully open* or *fully closed*
- **should not** be used to regulate or control flow
- useful for isolation/shut-off purposes.

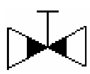




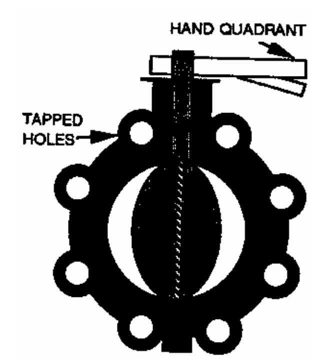
3. Ball Valve 

This valve has a precision ball seated between two circular seals or seats.
A 90° turn of the handle will change the operation from fully open to fully closed.
- may be used for throttling duty
- generally used with smaller pipe diameters (up to 75mm)



4. Butterfly Valve 

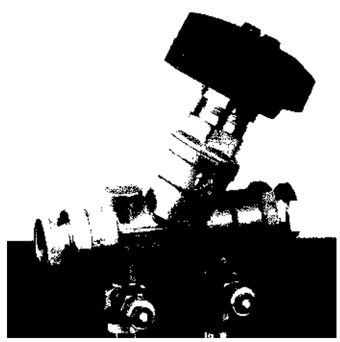
This valve has a cylindrical body with an internal rotatable disc serving as the fluid flow regulating device. This disc's axis of rotation is the valve stem and it is pependicular to the flow direction. A 90° turn will change the operation from fully open to fully closed.
- has low pressure drops
- fast operation of valve
- may be used for throttling duty

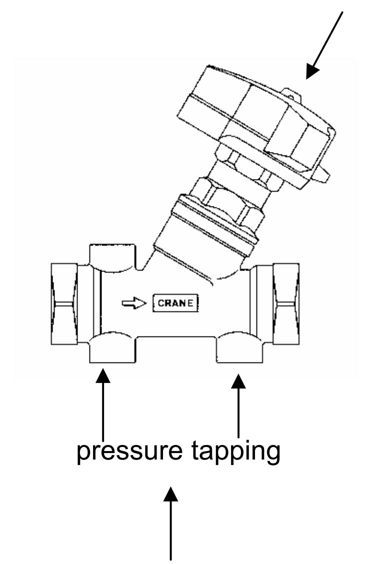


5. Balancing Valve 

This type of valve provide throttling duty to regulate water flow rate for balancing purposes. Two ports are provided in the inlet and outlet ports of the valve to permit measurement of pressure drop across the valve. By using performance charts provided, the value of flow rate through the valve can be determined. The valve handwheel will have a setting scale to determine the amount of valve opening. This is useful during field commissioning and balancing.

Generally, the internal construction is similar to a globe valve. It is more costly than the conventional throttling valves and it is only used in systems where proper and accurate balancing is required.



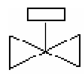


Automatic Valves

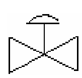
This type of valves operate in conjunction with an automatic controller or device to control the fluid flow. These controllers are also called as **actuators**. There are several types of actuators commonly used:

a. Solenoid
b. Electric motor
c. Pneumatic

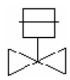
Such actuators will have gears, rack-and-pinion, cams and linkages to convert movement and allow opening and closing of the valve stem.

a. Solenoid Valve 

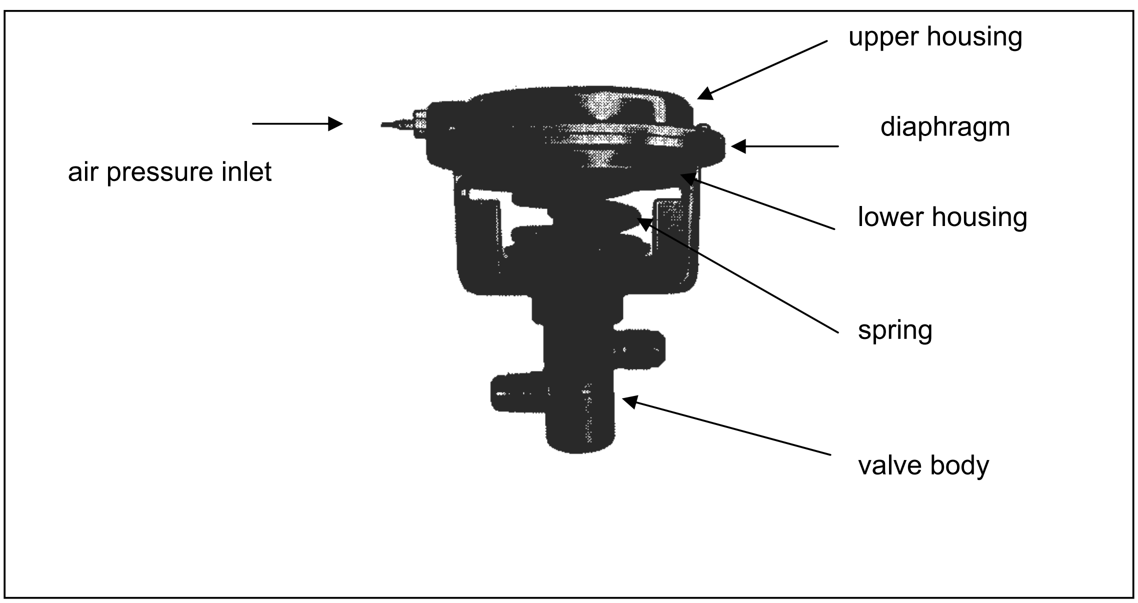
This type of valve only allows either a totally open or close position. It has a magnetic coil which will lifts or drops a plunger in the valve to open and close the flow of water. This occurs when the coil is either energized or de-energized.
Such valves are generally used for pipe sizes up to 50mm only. They are suitable for small fan coil units which require water shut-off when the fan coil is switched off.

b. Electric Motorised Valve 

The actuator has a built-in motor to produce a rotary motion. By using gears, cams or linkages, the valve stem will be opened or closed. Usually, the motor runs on DC power supply (24V).
Generally, the actuator has positioning controls whereby the valve can stroke to any position between fully close to fully open. This is accomplished with a control signal from an external feedback controller.
With this feature, it is possible to vary the water flow rate to suit any demand load of an application.
Nevertheless, the cost of such valves is high.

c. Pneumatic Valve 

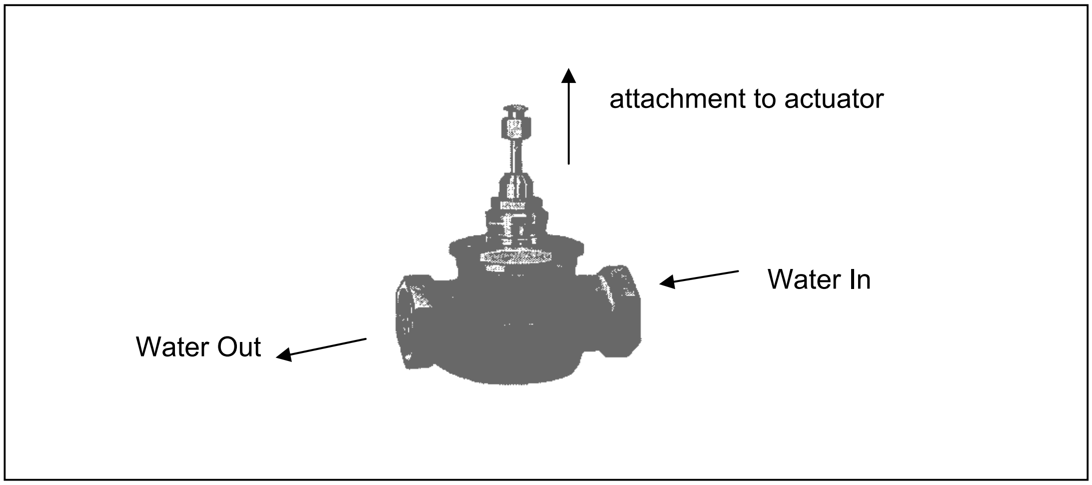
This type of valve has a flexible diaphragm clamped between an upper and lower housing. The valve stem is attached to the diaphragm. By injecting air pressure into the upper housing, the diaphragm will push the valve stem. An opposing spring force on the valve stem will also resist this movement. Therefore, by varying this air pressure, valve positioning can be achieved.
For this to work, an external pneumatic converter/positioner must be used to regulate the air pressure. A thermostat may be used together for such a purpose. This cost for this type of valves is also high.



Two Way and Three Way Valves

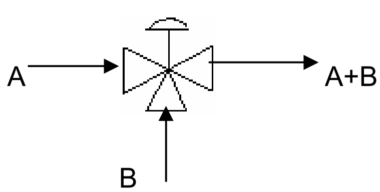
Automatic control valves used in hydronic systems may be classified as either two-way or three-way. All three types of actuators mentioned above may be used for these two types of valves.

In the **two-way valve**, water flows into the inlet port and exits from the outlet port. By means of the actuator, the flow rate may vary from full flow to zero.
There are two types available: single-seated and double-seated. For most applications, the single-seated type will suffice. In this type, there is only one valve seat and one plug-disc to clsoe against the flow. However, for applications with higher operating pressures, the double-seated types may be used.

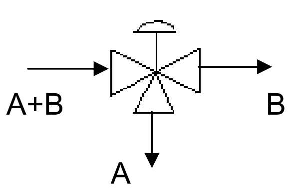


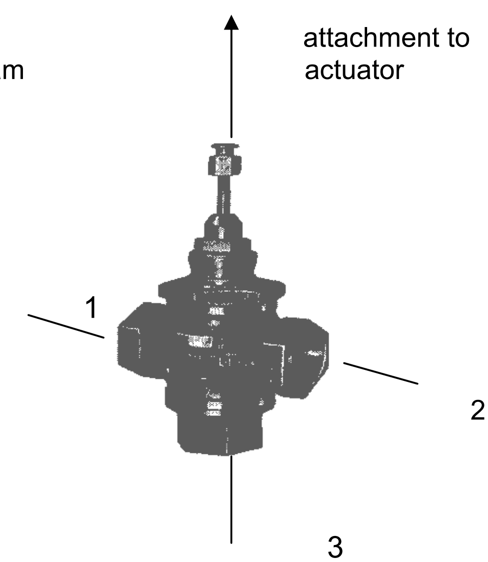
In the **three-way valve**, three ports are available. Depending on the application, these can be configured as a mixing or diverting valve.

1. **Mixing Valve**
   - two streams of water blends into a single stream

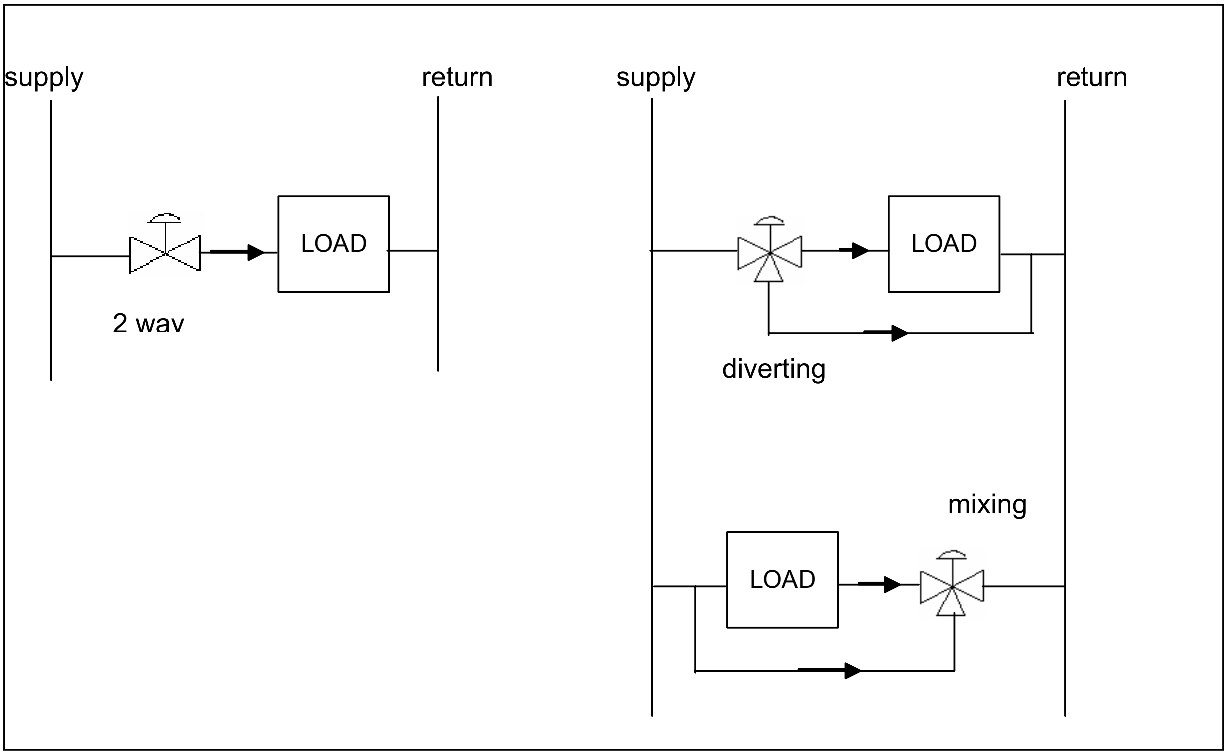


2. **Diverting Valve**
   -splits one stream into two different streams





Capacity Control With 2-Way and 3-Way Valves



The load of the fan coil unit can be calculated from the equation:

$$Q = 4180 * (\text{water flow rate, L/s}) * (\text{water temperature differential.°C}) \quad \text{Watt}$$

Therefore, the load is propotional to the water flow rate and Δt. Both the 2-way and 3-way valve will vary the flow rate to accomodate changes in the load demand.

With the 2-way valve, the system is considered as "variable flow, constant Δt".
With the 3-way valve, the system is considered as "constant flow, variable Δt".

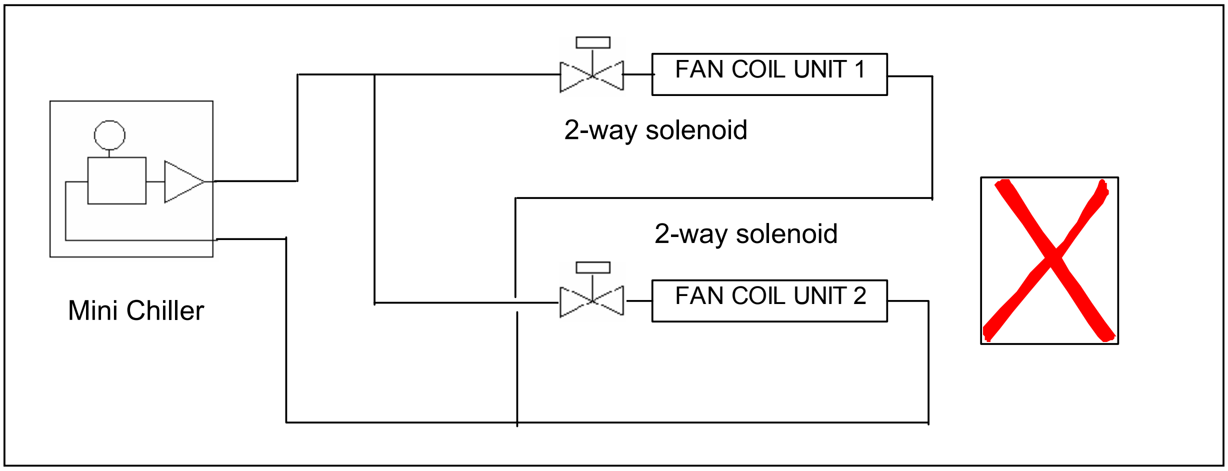
It is recommended that the 3-way valve to be configured as a diverting valve instead of a mixing valve. This is because when the fan coil unit is OFF, cold water will not enter into the heat exchanger with the valve diverting the water away to the return line. Unlike the mixing valve, even though the valve may be closed, cold water can still enter into the heat exchanger and ccumulate there. As a result, sweating on the heat exchanger and the connecting joints will occur even when the fan coil unit is not running.

However, on the other hand, 3-way diverting valves cost more than mixing valves. This is why some designs do not call for such valves, choosing instead the mixing configuration.

Application:

Both the two-way and three-way valves are suitable for shut-off and flow regulation purposes. The cost of the two-way valves are cheaper compared with the three-way valves. Thus, there is a tendency to use the two-way valves during installations.

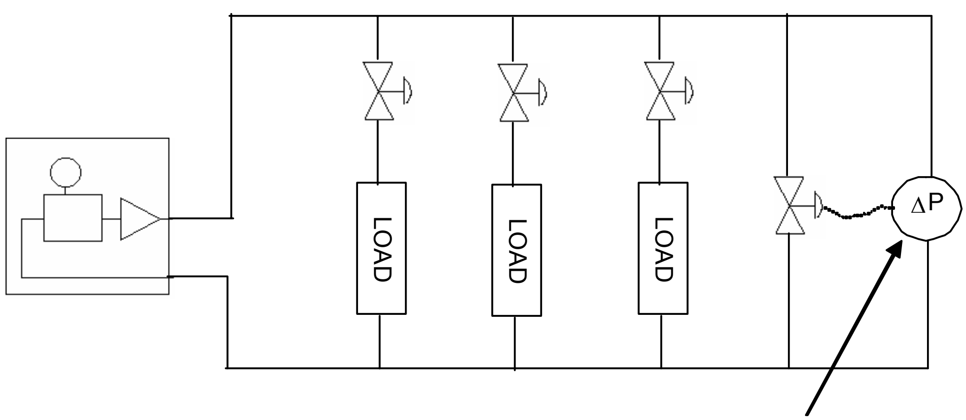
A typical two-way valve installation:



The problem with the above installation occurs when both the fan coil units are switched off. The controls of the fan coil unit will also at the same time switch off the solenoid valves, i.e. there will not be any water flow through the system when the fan coils are not in use. However, the chiller pump is still running. Therefore, the water pressure built-up in the piping may cause damage to the water pump or to the valves themselves (valve stem lifting).

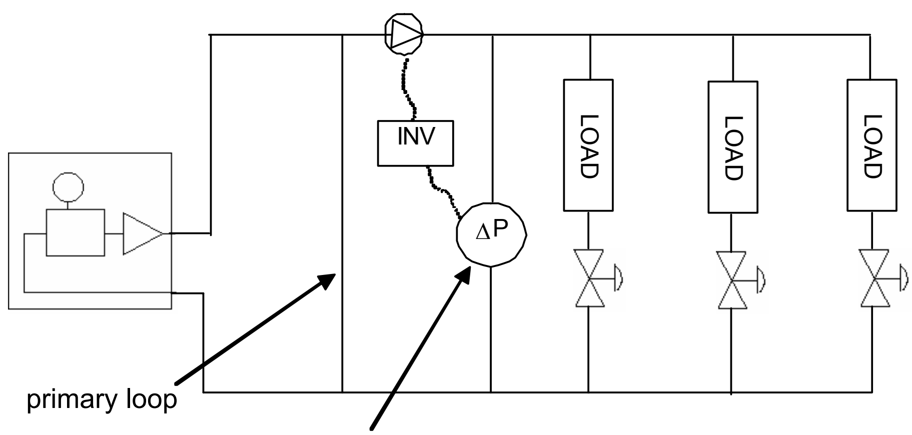
Usage of 2-way valves will require additional design considerations:

a. Add a Bypass Line to Relief Pressure



Different pressure transmitter to monitor the amount of water used. If pressure goes higher than preset value, it will open the relief valve and bypass the water

b. Use a Variable Speed Drive for the Secondary Water Pump.



When the differential pressure becomes higher, the inverter will slows down the water pump to maintain the head pressure. If no demand, the water pump will stop running.

c. Modify the Control Wiring for Chiller and Fan Coil Unit.

The above two methods will incur high cost due to the extra piping, pressure transmitter and other necessary fittings/equipment.

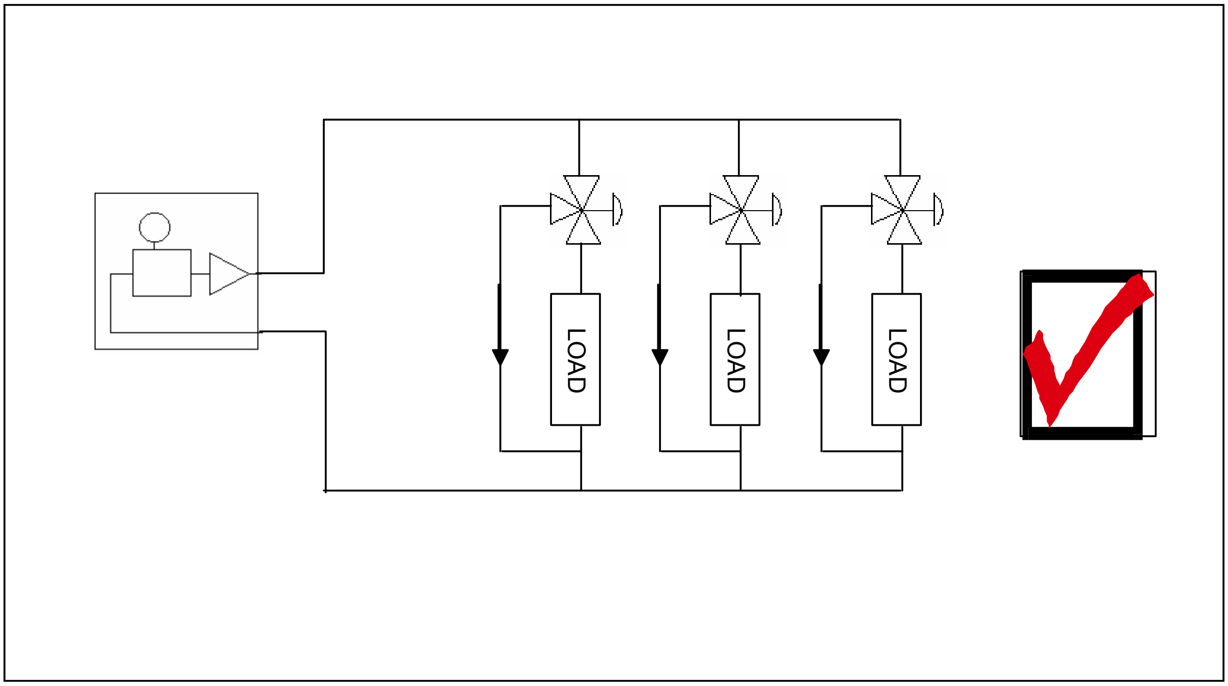
An easier method is to change the control wiring of the system. Conventionally, when the fan coil unit thermostat cuts-off, the power supply to the control 2-way valve will be off.

It is possible to run a line from the thermostat to the chiller remote switch whereby when the thermostat cuts-off, the chiller unit (and the pump) will also switch off. See Section 11 on 'Electrical Wiring Control' for more details.

However, the disadvantage with this method is that the chiller cycle on-off more frequently and the water supply temperature will fluctuate up and down.

d. In view of the difficulties mentioned above, it is recommended that 3-way diverting valves to be used in the mini chiller hydronic system.

Since the 3-way valve gives a constant flow system, there will not be any problem when there is no load demand since the water will bypass through the valve when it is in the fully closed position (with respect to the load).



However, this system has one main disadvantage. Since the supply water is by-passed around the load coil, energy is wasted. This will cause the chiller to cycle on-off more frequent as the return water temperature becomes lower.

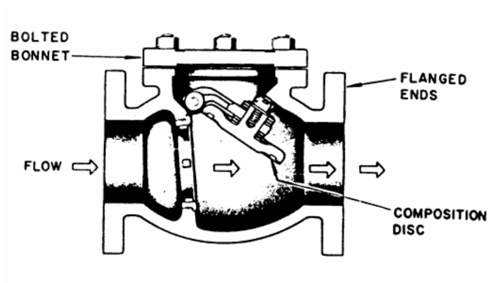
Therefore, in terms of energy efficiency, applications with 2-way valves are better.

Other Type of Valves and Fittings

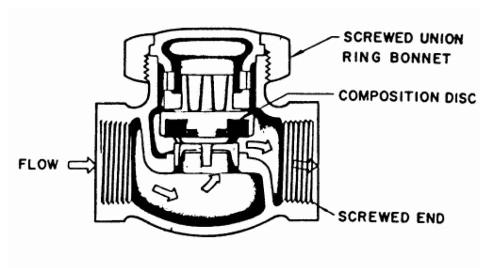
a. Check Valve 

This valve will only allow flow in one direction, i.e. to prevent back flow of water.
We have seen an example of usage in Section 2 with multiple chillers installation.

There are two basic design of these check valves:
1. swing check valve - can be installed in horizontal or vertical piping
2. lift check valve - only for horizontal piping installation



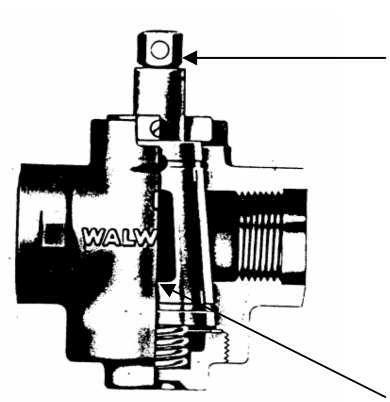
Swing check valve



Lift check valve

b. Plug Cock/Plug Valve

This type of valve is also used for throttling duty. It is less expansive compared with the globe valve or balancing valve. The setting also cannot be tampered with as easily as the globe valve.

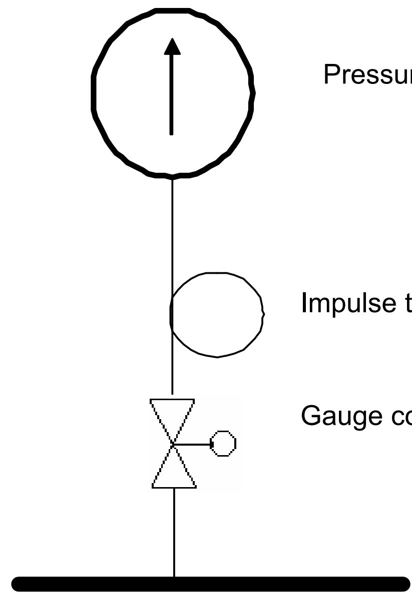


Valve stem without handwheel. Use a spanner or wrench to open and close valve.

Plug with orifice port. With a 90° turn, the port will operate from fully open to fully close.

c. Pressure Gauge Cock

Generally, this valve is a ball valve. It is used to isolate pressure gauges installed along the water pipe lines.



The gauge cock is only opened during pressure measurement. When not in use, the valve is closed to prevent prolonged pressurising to the gauge, therefore preventing damage to the gauge itself. It is also closed when changing a new gauge.

d. Safety Relief Valve *[Optional]*

The valve will open when the pressure exceeds a set value to prevent over pressuring the system which may cause damage. Normally, this is used when the system is running hot water (mini chiller in heating mode/reverse cycle) in a closed piping. The hotter the water temperature, the higher is the pressure due to expansion.

Such valves are also useful for protection against sudden pressure shocks, e.g. water hammering, and overpressuring from water fill system.
If the system is with an open piping and external tank, this valve may be exempted.

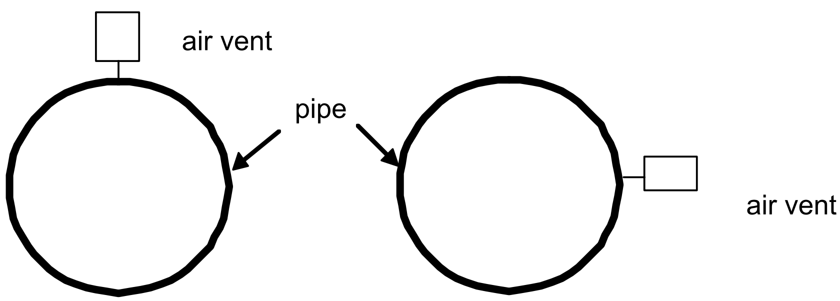
The setting of the valve should be at least 10% higher than the expected maximum operating pressure. It should be installed at the location where this pressure may be expected to occur, e.g. near any expansion tanks or pump discharge lines.
Pipe the exhaust from the relief valve to an external drain.

e. Air Vent Valve

The mini chiller unit has an automatic air vent located on top of the buffer tank. This is to release any trapped air inside the tank which may cause problem to the pumping operation. This is especially so during heating operation where oxygen and hydrogen gases are formed from the water and gets accumulated inside the tank. Air entrainment and microleaks along the joints and valves of the pump suction line will also cause air to enter the water system.

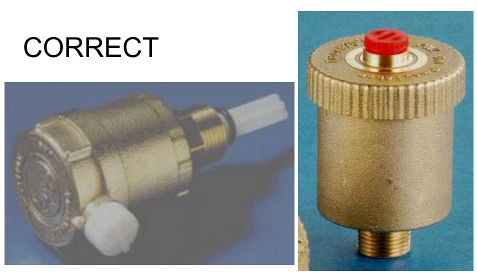
Therefore, it is a good practice to install another air vent at the highest position of the piping network to ensure that the pump performance do not deteriorates.
Such air vents are also useful during commissioning and system start-ups to release any air trapped in the piping system.

Always install the valve in a vertical position on top of a tank or pipe.

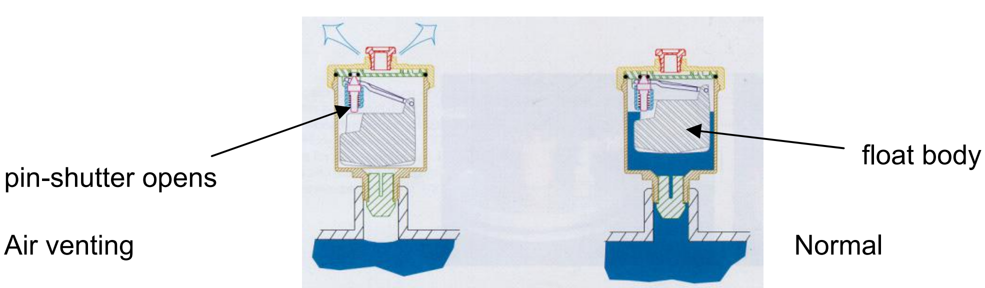


CORRECT

INCORRECT



Under normal condition, water will enter inside the valve and lifts a floating body which will raise a mechanism to close a pin-shutter. Reduction of the water level as a result of accumulated air will cause the float to drop and opens the pin-shutter thus releasing the air automatically.

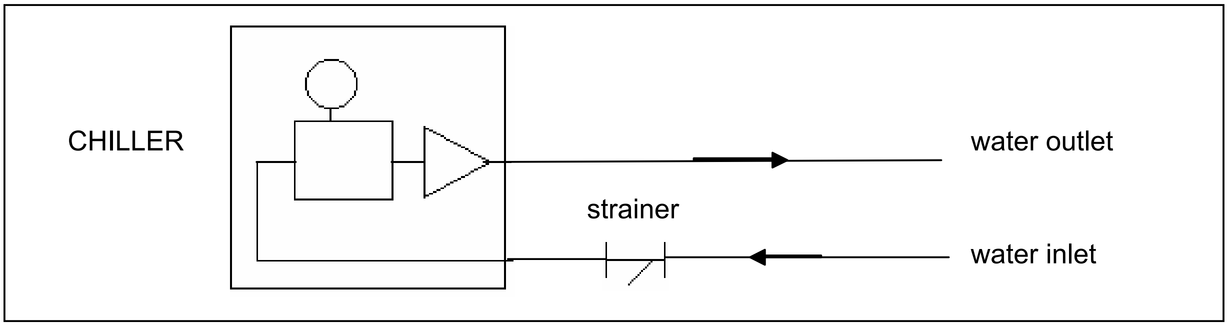


f. Strainer

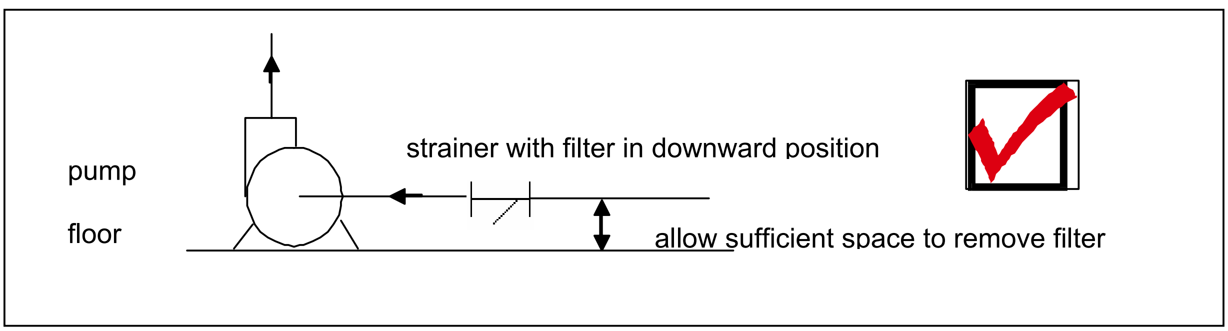
The strainer is an important element in the piping system to remove particles (e.g. sand) and dirt from the water. If not, these impurities will damage the pumping mechanism and clogged-up valves and fittings.

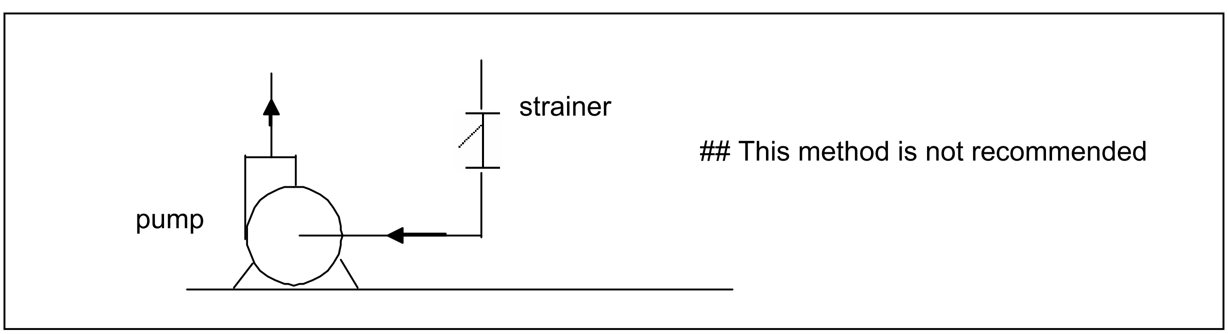
IMPORTANT!!!

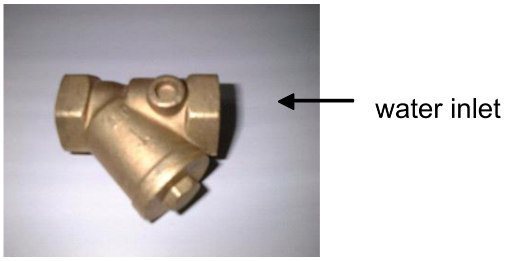
The mini chiller unit do not have a strainer built-in. Always install a strainer on the water inlet pipe into the chiller to protect the internal water pump.



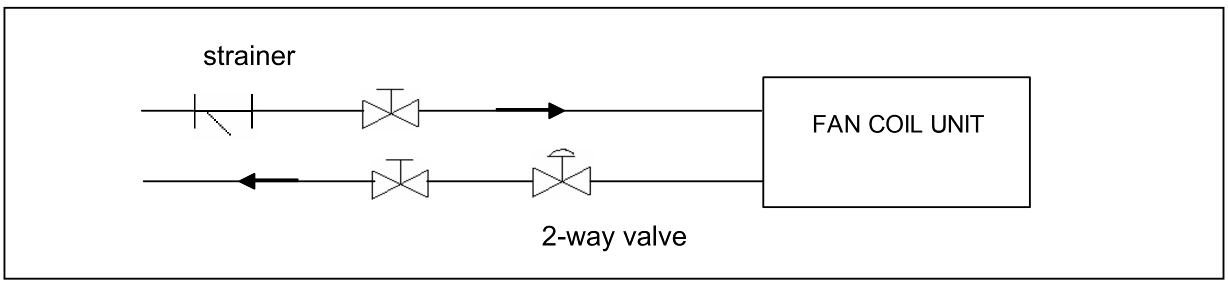
Do not install strainer on the water outlet pipe as the water velocity is higher.
Install the strainer with the filter element in a downward position. This is to facilitate easy flushing during periodic cleaning.





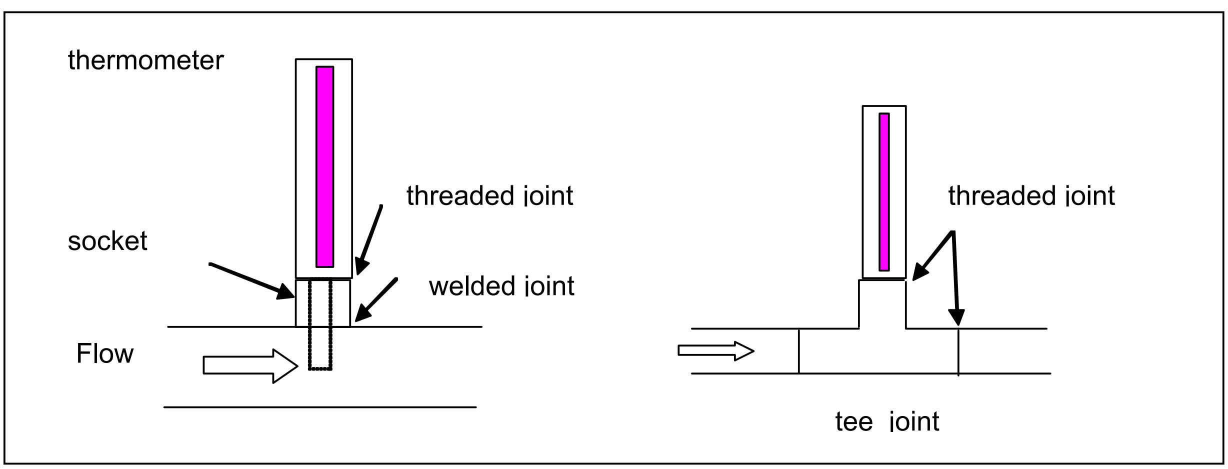


There is also a practice to install a strainer on the inlet pipe to a fan coil unit. This is done to protect the control valve, located at the outlet pipe, from clogging.



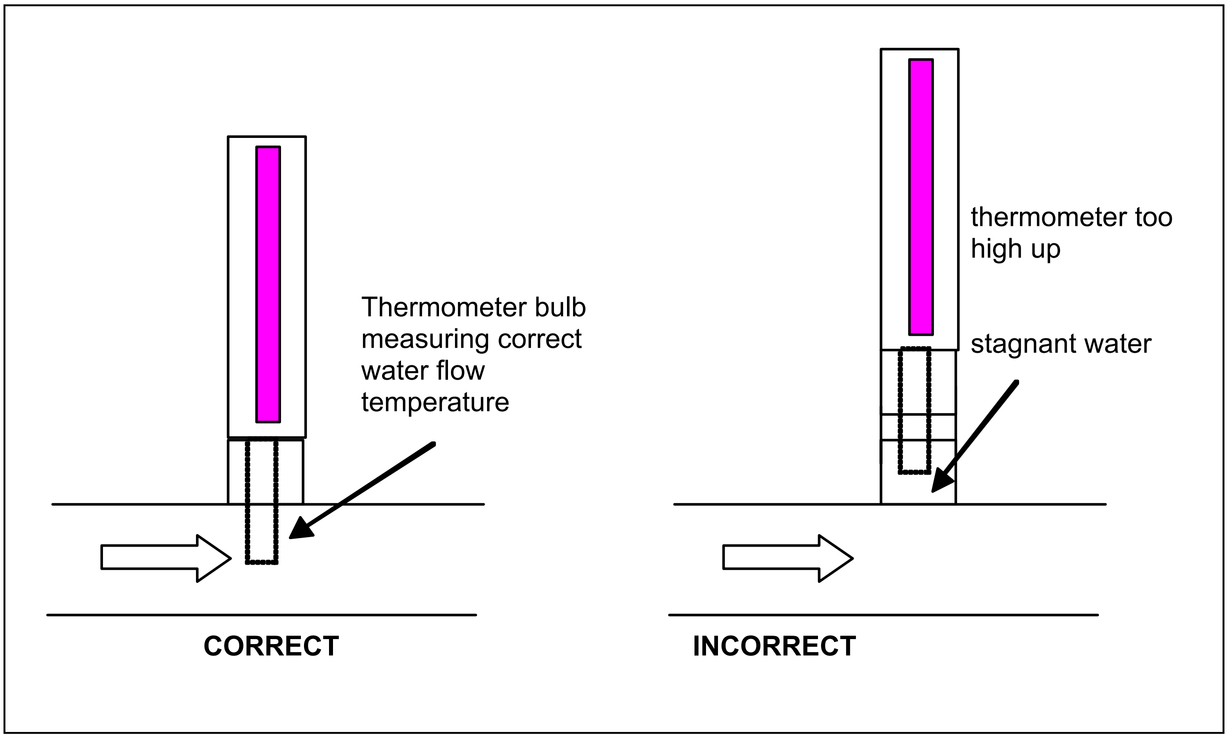
g. Thermometer

Glass thermometers are installed on the inlet and outlet pipes of either the chiller unit or fan coil units. This is to measure the water temperature differential to determine the capacity performance.
Usually, these thermometers are installed together with the pressure gauges.
Installation can be done with a socket welded onto the pipe or a tee joint connection.



Thermometers can be installed vertically, horizontally or even at an angle.

During installation, it is important to ensure that the sensing bulb is in touch with the flowing stream of water. If the thermometer is installed too "high" up the connecting socket, the bulb will measure the temperature of stagnant water in the socket.



Valve Sizing

In selecting the suitable valve to use for an application, the following items must be considered:

1. What is the fluid medium of usage.
   In chillers, the fluid is water. There are valves specially designed other fluids e.g. steam and air, which are not suitable for water.

2. What is maximum operating pressure and temperature.

3. What is the valve duty required - is it for throttling, shut-off, balancing, mixing, etc.

4. What is the pipe size to be connected
   Do not oversize or undersize a valve to suit the pipe size. Size the valve according to the flow requirements. Use reducers where applicable.

5. What is the flow rate required through the valve

6. What is the flow characteristics required - linear, equal percentage (See following pages)

7. What is the piping connection method to the valve - threaded, flanged

   Most of the above mentioned information may be obtained from the valve catalogs provided by the valve manufacturers.
   In sizing the valve, the general accepted method is by means of the **C_v (flow coefficient).**
   Different valves will have different C_v values.

Formula:

$$Q = C_v * \sqrt{(\Delta p)}$$

Definition: The C_v rating of any valve is the amount of water,Q (GPM) at standard conditions (60°F, specific graviti = 1) which will pass through the valve with a pressure drop, Δp of 1 psi with the valve in a full open position.

By using conversion factors, we can have the **flow coefficient K_v** in metric units:

$$1\ C_v = 0.857\ K_v$$

Definition: The K_v rating of any valve is the amount of water (m^3/hr) at standard conditions (20°C, specific graviti = 1) which will pass through the valve with a pressure drop of 1 kg/cm^2 with the valve in a full open position.
If the reference pressure is 1 bar, then:

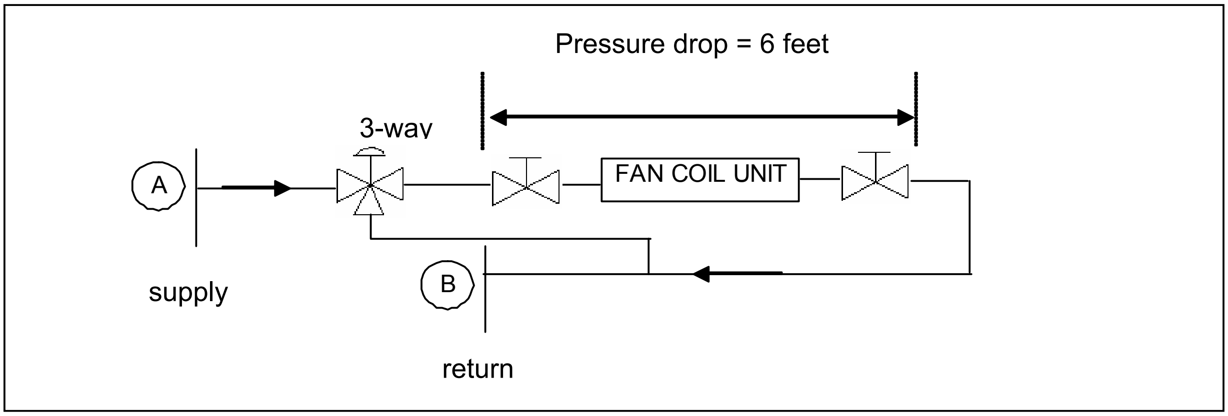
$$1\ C_v = 0.867\ K_v$$

For a given flow rate, we can select a valve with suitable C_v to give an appropriate pressure drop. These data are available in graphs provided by the manufacturer. See Appendix 5.

Selection of the valve must be done so as not to have too high a pressure drop, else the water pump head will be insufficient for the system. The values of these valve pressure drop can also be used during pump sizing. See Section 5.

For control valves (*modulating*, throttling duty, 2-way and 3-way), the pressure drop should be no less than **half** the total pressure drop in the branch. This will allow a stable control.

Example :



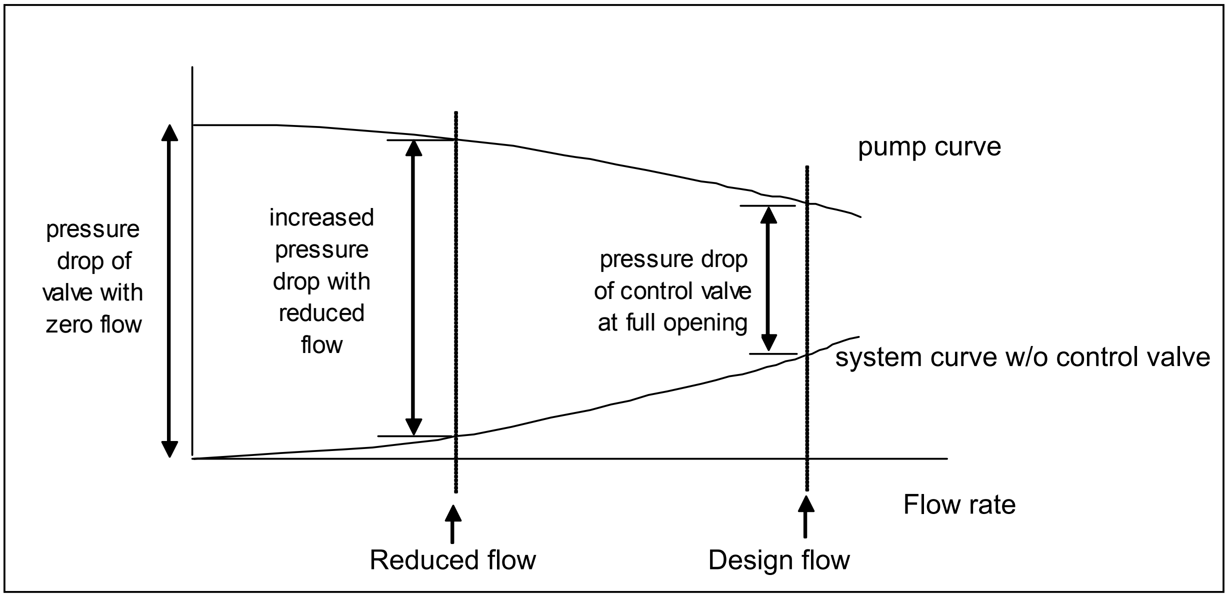
Pressure losses along piping works from A to B = 4.6 feet
Pressure drop across 2 gate valves + coil heat exchanger = 6 feet

Therefore, the control 3-way valve should have a pressure drop of at least
= 2 * (4.6 + 6)
= 21.2 feet
= 9.2 psi ** Conversion: 1 psi = 2.309 feet water

If the flow rate through the branch is 6 GPM, what valve C_v should be used?
Refering to the graph in Appendix 5, the C_v should be 2.
Therefore, a 3-way diverting valve with C_v of 2 (at full opening) should be selected for the above application.

As can be seen from the example above, the valve sizing was done with the design flow at full opening. Thus, at reduced flows, the valve will close and this will increase the pressure drop.
This can be seen from the following graph which depicts the system curve and pump curve for a single fan coil load. See Section 5 for more details on pump curves.

Head Pressure

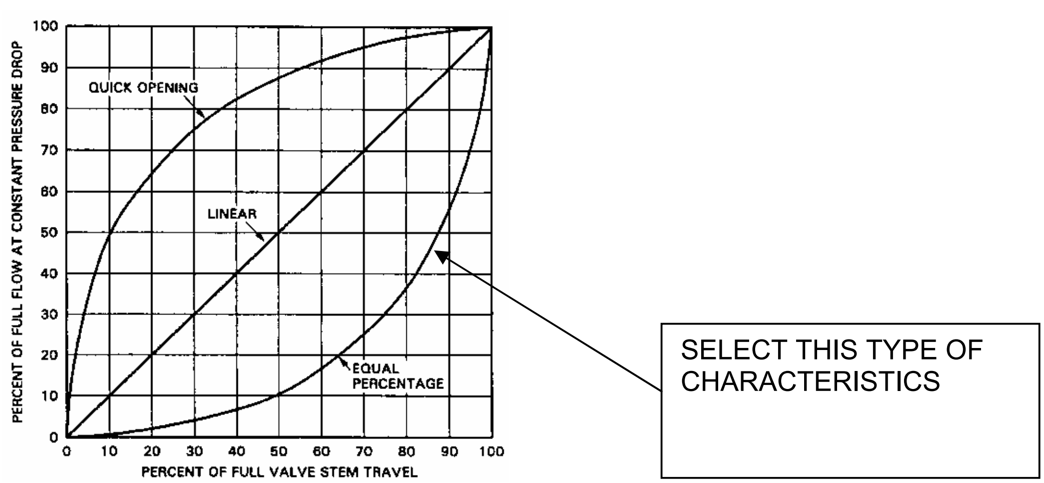


Another consideration in selecting the suitable valve is to determine the flow characteristic through the valve. Generally, there are three types:

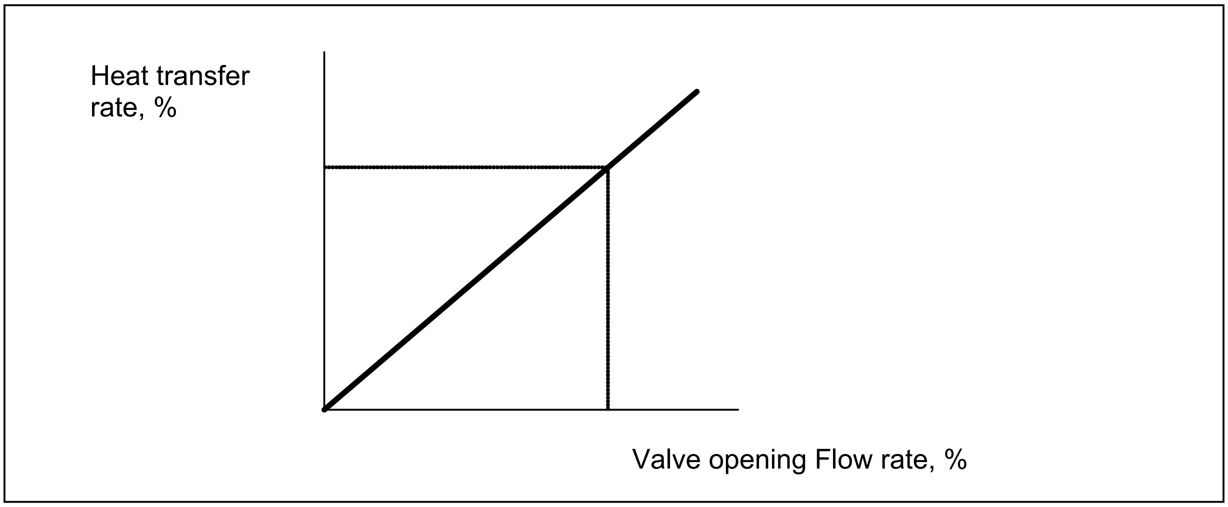
1. **Quick Opening**
   The valve shows a quick increase of flow for a small increase of opening. But as it reaches the open position, the rate at which the flow increases per movement of the opening reduces.

2. **Linear**
   This valve produces equal rate of flow increase per equal rate of opening.

3. **Equal Percentage**
   This type of valve produces an exponential flow increase as the valve opens up. The term equal percentage means that for equal amouts of valve opening, the flow increases by the same percentage.



Selection of valve with equal percentage flow characteristics will give the best performance as this will give a linear heat transfer rate with flow rate:



For automatic *on-off* valves (e.g. solenoid 2-way, 3-way), the selection is easier. Generally, use the same size as the pipe size, with a low pressure drop (e.g; 2 -5 psig: fully open). Using a smaller size (with pipe reducers and adaptors), for economic reasons, is possible, but check for excessive pressure losses which will reduce the pump performance.

Guidelines for Valve and Fitting Installation:

a. Gate valves (shut-off) are installed in the entering and leaving piping to the chiller and fan coil unit. This is to permit servicing and replacement of the equipment without draining the system. A globe valve may be used to serve as one of the shut-off valve and in addition to balance the flow rate.

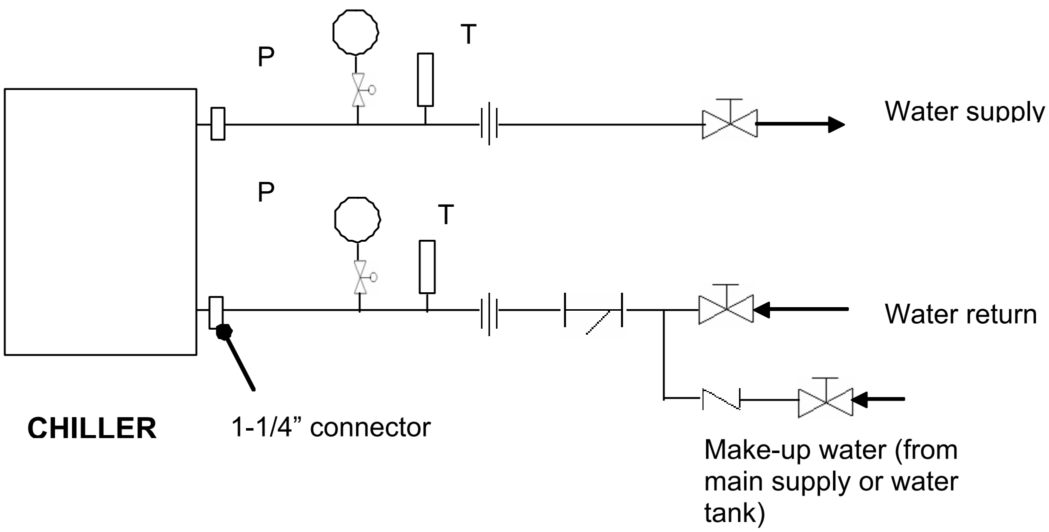
b. Valves and fittings using threaded or welded joints will require unions to permit easy removal for servicing or replacement. Unions are usually located between each gate valve and the equipment. Unions are also place before and after the control valve, and in the branch of the 3-way valve.
If flange joints are used, the need for unions is eliminated.

c. Locate the control valve in between the gate valve and the equipment to permit removal of the control valve without draining the system.

d. Strainers, thermometers and pressure gauges are located between the gate valve and the equipment.

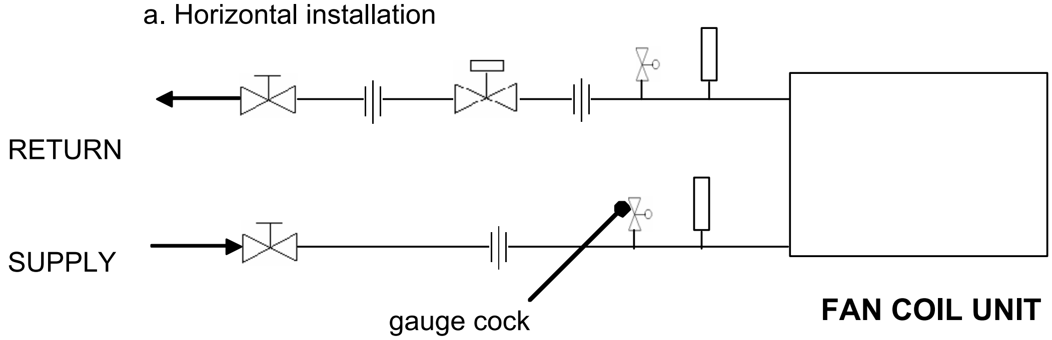
The following diagrams illustrate examples of piping layout:

- **Typical Mini Chiller Piping Installation:**

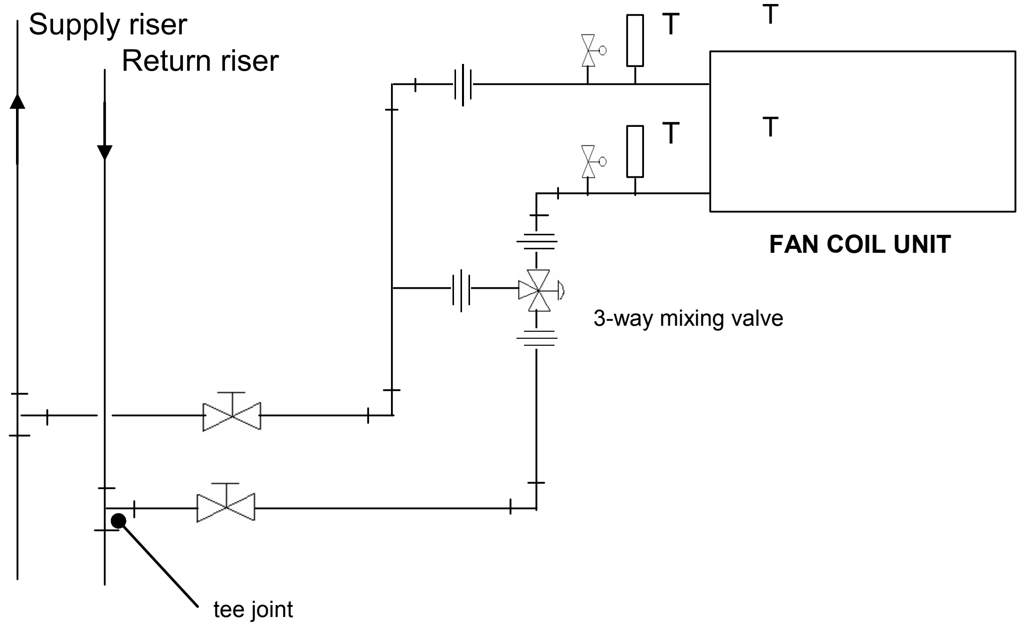


- **Typical Fan Coil Unit Installation:**

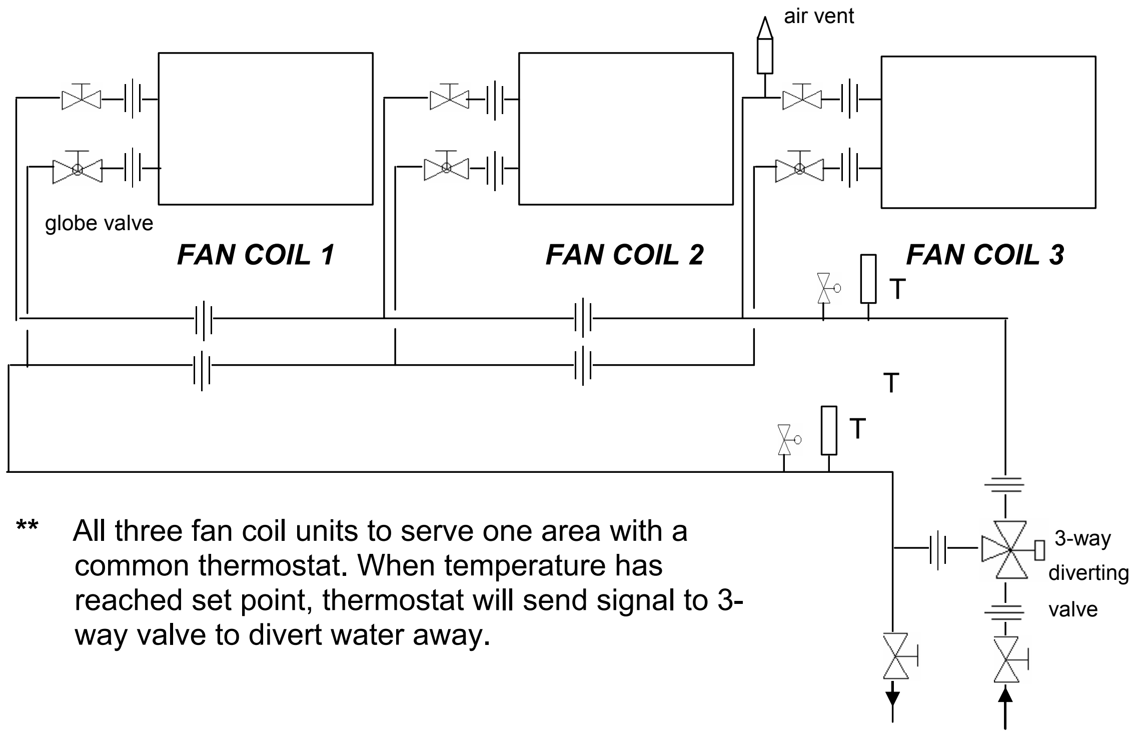
a. Horizontal installation



b. Vertical Installation

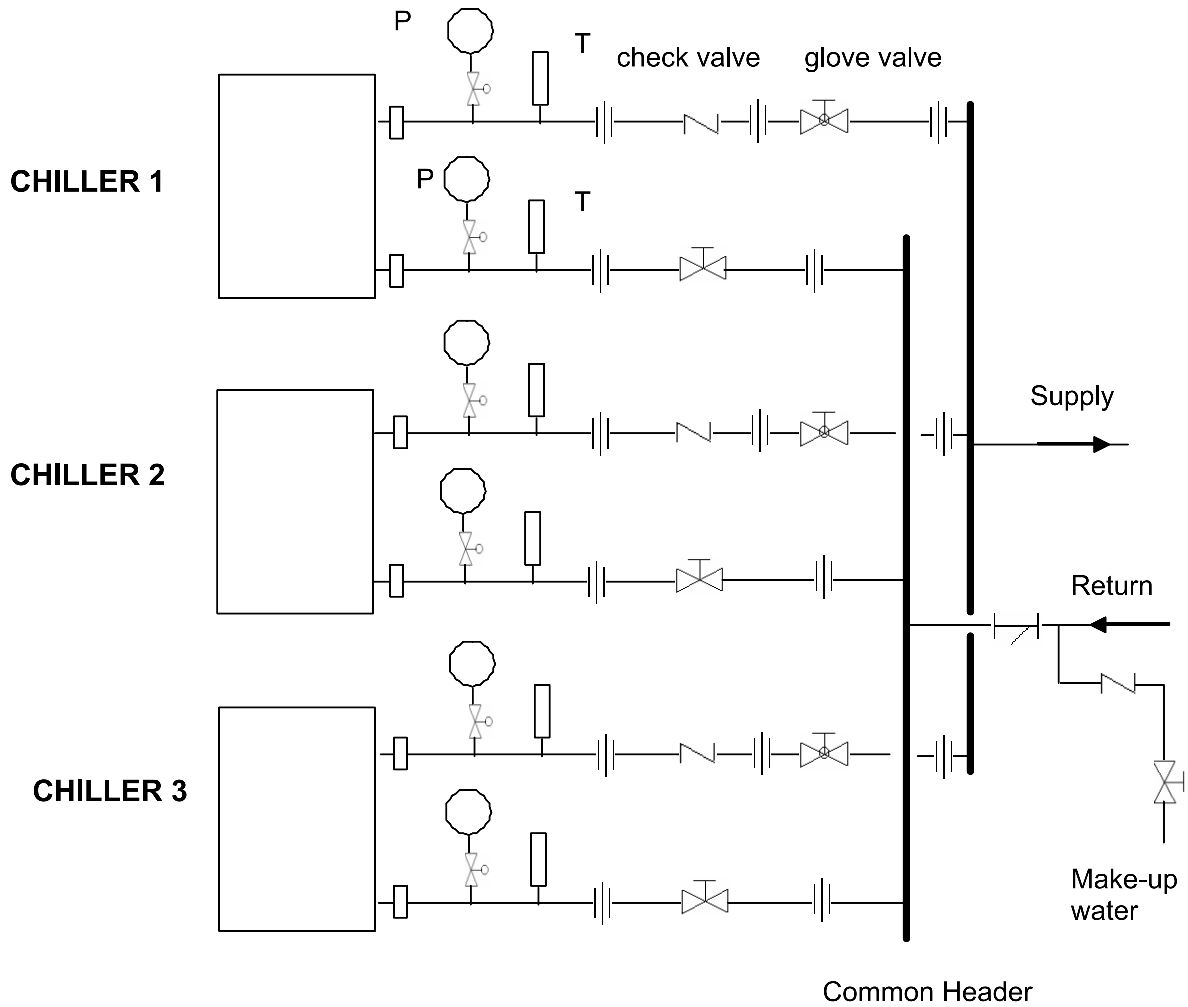


○ **Multiple Fan Coil Unit Installation**



** All three fan coil units to serve one area with a common thermostat. When temperature has reached set point, thermostat will send signal to 3-way valve to divert water away.

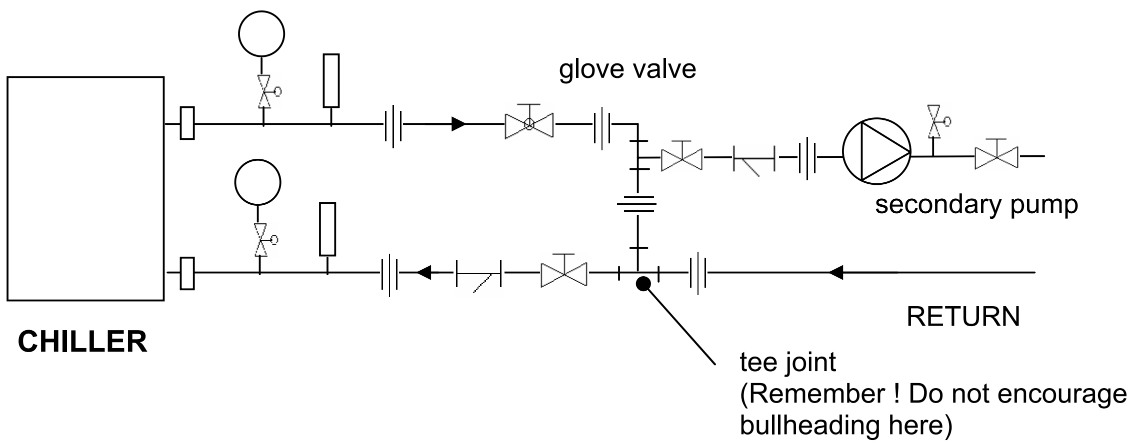
Multiple Chiller Installation



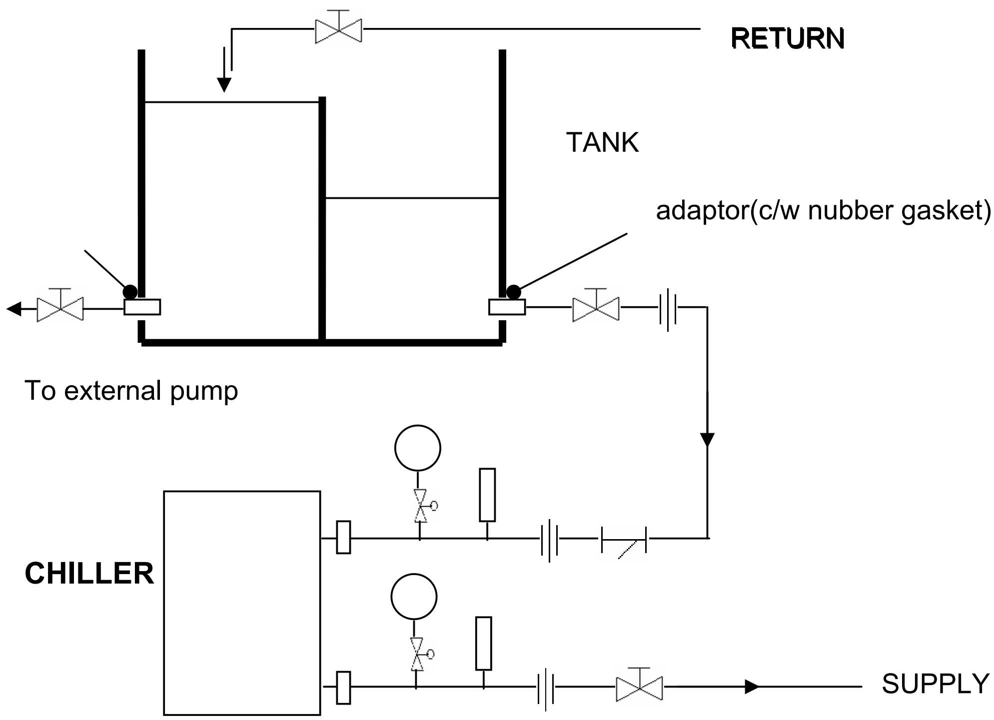
** Globe valve will be used to balance the flow rate through each chiller unit.

** Additional gate valves may be installed along the main supply and return lines to isolate the entire chiller assembly.

Primary-Secondary System



Water Tank Installation (Open System)



Section 4: Pipe and Fitting Sizing

In the previous section, we have looked at the different types of pipes which can be used in a hydronic system. We have also looked at the various types of fittings used in conjunction with the piping.
In this section, we will examine the *friction losses* which occur when water flows through the pipes and fittings.

Friction losses are dependent on the following factors:
a. Water velocity
b. Pipe internal diameter
c. Pipe length
d. Pipe internal wall roughness

Generally, friction increases when:
- Water velocity increases
- Internal diameter decreases
- Pipe length increases
- Wall roughness increases

The basic formula to calculate pipe friction losses (Hf) is the **Darcy-Weisbach formula:**

$Hf = f * (L/D) * v^2/2g$ where f = friction factor
L = pipe length
D = pipe internal diameter
v = mean velocity
g = acceleration due to gravity

The friction factor is a function of the *roughness parameter*, e, which in turn depends on the pipe material (e.g. steel, copper, PVC), and the Reynolds number, Re.

$Re = D * v \rho / * \mu$ where ρ = density
μ = dynamic viscosity

Generally, the friction losses are presented in graphical form, for various pipe material.
See attached charts for steel pipe Schedule 40,copper pipe and PVC.
Note that Carrier has developed two different type of graphs for steel pipes, i.e. for **close** and **open** system. The friction losses for the open system is higher than the close system, for the same parameters. This is to take into account the vulnerability of open systems to cause pipe fouling and scaling on the internal surfaces. A factor of approximately 1.75 is used for this purpose.

It is to be noted that the pipe friction loss charts presented are all for flows in the *turbulent regime* (Re > 10 000).

Water Flow Limitations

The factors which determine the water velocity limits are noise, erosion and installation cost. If the piping is too small, noise and erosion levels will become unfavourable even though the cost is more economical. Conversely, choosing a larger pipe will incur higher costs.

It is recommended that the following guidelines to be used for the mini chiller units:

1. The pipe friction loss used for the design of the system should be between **1 to 4 ft per 100 ft** of equivalent pipe length.

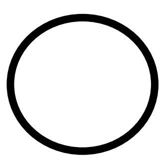
2. The velocity in the pipe should be less than 4 fps in view of the allowable noise level generated for residential and commercial buildings.
   However, the noise is not caused by the water itself, but rather by free air, sharp pressure drops, turbulence, cavitation and flashing. If precautions are taken to eliminate air and turbulences, higher velocities up to 8 fps are acceptable.

3. The minimum velocity in the pipe should be 1.5 - 2 fps to allow air entrained in the water to be carried to separation units (e.g. expansion tanks, locations of lowest pressure) for venting.

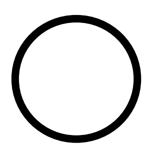
Taking into consideration (2) and (3) above, it is recommended that the water velocity in the pipe to be **2 - 8 fps.** With this, the expected service life of the pipes is more than 8000 hours/year.

Conversion factors:
1 fps = 0.305 m/s
1 ft water = 248.84 Pa
1 ft = 0.305 m

Example:
All the mini chiller units are with 1-1/4" pipe connections. Installation with 1-1/4" and 1" piping is possible, as shown in the following calculation for steel Sch 40:



Pipe size 1-1/4"
Internal diameter = 1.3799"
Cross sectional area = 0.0104 ft^2



Pipe size 1"
Internal diameter = 1.0488"
Cross sectional area = 0.006 ft^2

The following data are extracted from the mini chiller technical manual:

Model	Water flowrate		Velocity, fps	
	USGPM	ft^3/min	1-1/4"	1"
AC 40A	6.7	0.89	1.43	2.47
AC 50A	8.9	1.19	1.91	3.30
AC 58A	11.1	1.48	2.38	4.12
AC 75B	17.8	2.37	3.80	6.59
AC100B	22.2	2.97	4.75	8.24
AC125B	27.7	3.71	5.94	10.30
AC80C	17.5	2.34	3.75	6.50
AC100C	20.8	2.78	4.46	7.72
AC120C	26.7	3.57	5.72	9.92
AC150C	31.7	4.24	6.79	11.78

It is not recommended to install these units with 1" pipe size.

Equivalent Pipe Length

The concept of equivalent pipe length is very useful in calculating friction losses along the hydronic pipe system.

Defination:

The equivalent pipe length of a component in the pipe system is the length of a straight pipe which will give the same friction losses as the component itself.

For example, we have a 1" elbow which gives a pressure drop of ΔP when a flowrate of Q passes through it. If a straight 1" pipe of length *y* feet gives the same pressure drop when a flowrate of Q flows through it, then, the equivalent pipe length of that elbow is *y* feet.

It is just like thinking that the elbow has been "replaced" with the length of straight pipe.

Naturally, a straight pipe in the hydronic system do not require such usage of equivalent length.

Therefore, the total equivalent pipe length of a hydronic system

= straight pipe length + equivalent pipe length of all fittings and valves along the pipe

Generally, equivalent pipe lengths of common valves and fittings are available. See attached tables (Appendix 7).

An alternative method was published in the "*ASHRAE Handbook: Fundamentals*" for calculating the equivalent pipe length of tee joints. A graph is used to determine the number of equivalent elbows for the various flow conditions through the tee. This is then multiplied with the equivalent pipe length/pressure loss for the same size elbow. See Appendix 7.

It must be noted that the equivalent lengths given in the attached tables for the fittings are only estimates. The values are more meaningful when used for steel pipes.
Friction losses of copper and PVC fittings (e.g. elbows, tees, reducers) are quite similar to the equivalent steel type. Therefore, for estimation purposes, it is sufficient that the same equivalent lengths to be used for both copper and PVC pipes.
Nevertheless, friction loss values for different pipe material will be used in the computation of the total friction in the piping system.

If specific friction losses for any fitting is available from the manufacturer, it is advisable to use these values instead of the estimates given in the tables. This is especially applicable to valves (specific C_v) and strainers (different mesh sizes).

Internal and External Friction Losses

The friction losses of the straight pipes and fittings are considered external losses to the hydronic system. Other than that, there are also losses in the chiller unit itself, i.e. through the brazed plate heat exchanger (BPHE), internal pipework, pump fittings, flow switch, etc.
All these internal losses are as tabulated below:

Model	Friction loss, psi	Nominal water flow rate, GPM
AC 40A/AR	5.4	6.7
AC 50A/AR	6.4	8.9
AC 58A/AR	5.7	11.1
AC 75B/BR	6.0	17.8
AC 100B/BR	6.5	22.2
AC 125B/BR	6.6	27.7
AC 80C/CR	5.9	17.5
AC 100C/CR	12.5	20.8
AC 120C/CR	6.4	26.7
AC 150C/CR	9.9	31.7

In the same manner, each fan coil unit has its own internal losses through the heat exchanger.

Please refer to the respective Technical Manual for the values of these losses.

Friction Loss Calculation

It is of utmost importance that a calculation to be made to determine the total friction loss along the piping network. This is to ensure that the water pump is able to deliver the required flow rate through the system. If the friction loss is too high, the flow rate will reduce, thereby causing improper operation of the chiller. If the friction loss is too low, the piping system may be redesigned for cost savings and better efficiency.

The following guidelines should be followed during calculation:

1. It is necessary to have a drawing of the entire piping network, showing the lengths, sizes, material and fittings used. Such drawing may be in 2-dimensional or 3-dimensional (preferred).
   If the system is an open type, determine the height difference between the chiller unit and storage tank (if any).
   The straight length of a pipe is measured from center-to-center of each fitting along the pipe.

2. It is a good practice to have markings on the drawing for each branch of the pipe network. This will help in identification of which branch is being calculated.

3. The following information must be available for calculation: water flow rate (GPM) of each pipe branch, internal friction losses of the chiller unit / fan coil unit and water pump head available.
   These information can be obtained from the product catalogs or technical manuals.

4. Calculate for the branch which gives the highest friction loss. This usually corresponds to the branch which have the furthest fan coil unit from the chiller.

5. It would be better to have the actual pressure drop across any of the fittings used vs. the estimated equivalent lengths presented in the attached tables. This is especially so for the valves (with specific C_v values) and strainers (with different mesh sizes).

6. Add a safety factor of 15 - 20% to the final friction loss to account for estimation errors and actual site installation of the piping system.

7. Check the final friction loss against the pump head available. The pump head must be higher than this calculated value if the system is to work properly.

An EXCEL spreadsheet programme has been written to help in this friction loss calculation.

Several worked examples are shown for typical installations in the following pages. The EXCEL programme has been used in the computation.

Section 5: Water Pump

We have seen in Introduction that the pump is one of the fundamental component in a hydronic system. It circulates the water through all the other components in the system.
We have also seen that in the mini-chiller unit, this pump is incorporated together with the other components as one package.

In order to operate the chiller properly, it is vital to have an understanding of the pump characteristics and the factors which affect its performance.

The water pump used in the mini-chiller unit is of the ***end-suction centrifugal type***. Water enters through an inlet port at the center of an impeller and is pushed out by centrifugal forces of the impeller to a discharge volute around the impeller. As a result, a water pressure head is developed at the discharge port.
To rotate the impeller, the pump assembly is coupled with an induction motor. Therefore, torque developed by the electric motor serves as the input power to the pump and gets converted as output in the form of the water head pressure.

Factors which describes the performance of a pump:
a) Volumetric Flowrate
b) Head Pressure
c) Input Power
d) Efficiency
e) NPSH (nett positive suction head)

Various pump designs are available to meet different requirements. Some of the common parameters which pump manufacturers use for their design are:

1. Impeller Diameter
   Generally, the larger impeller will give higher flowrate and higher head pressure.

2. Number of Impellers
   These multiple stages will increase the flowrate and head pressure as compared to a single stage impeller.

3. Impeller Speed
   Most pumps are of the single speed design. However, variable speed pumps are also available which requires the usage of a speed controller (e.g.inverter unit). Generally, the faster the impeller rotational speed, the higher the flowrate and head pressure.

4. Material of Impeller and Pump Body
   This will depend on the usage of the pump. Stainless steel and cast iron are two common materials used for the impeller and body. Applications which requires clean and hygienic pumping medium will require usage of stainless steel, e.g. for domestic water supply and food industries. Cast iron are sufficient for sewerage systems.

5. Pump Configuration/Type
   There are various other types of pumps to suit the pumping needs, e.g. in-line centrifugal pumps, submersible pumps, dosing pumps, etc.

Proper selection of the pump is crucial to meet the pumping requirements. Other factors like the operating temperature and pressure of the medium must also be considered in the selection. Refer to the corresponding pump specifications and catalogs for detailed information of the pumps.

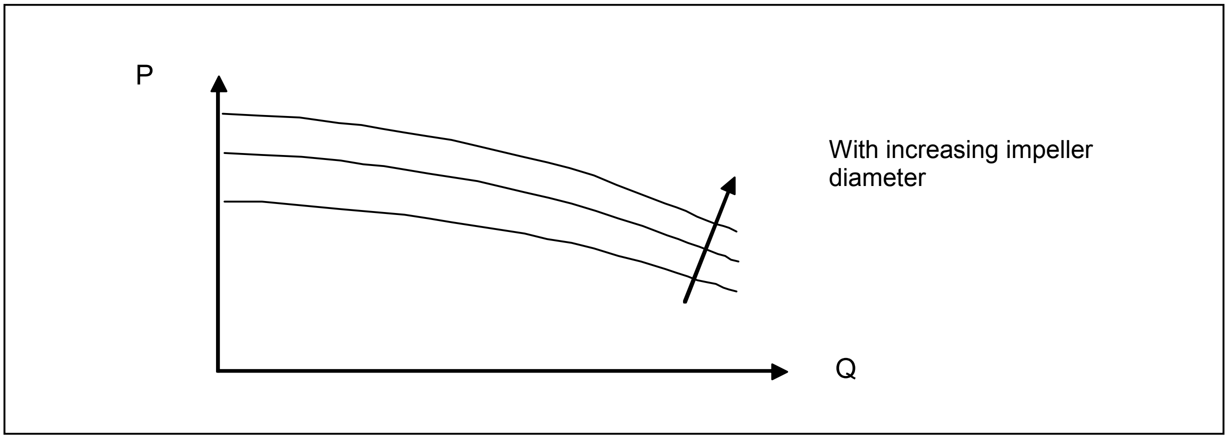
The multistage end-suction pump used in the mini-chillers are from GRUNDFOS.
The models involved are:

Mini-Chiller	**Model**
AC 40A/AR	CH2-30
AC 50A/AR	CH2-30
AC 58A/AR	CH2-30
AC 75B/BR	CH4-40
AC 100B/BR	CH4-40
AC 125B/BR	CH4-40
AC 80C/CR	CH4-40
AC 100C/CR	CH4-40
AC 120C/CR	CH8-40
AC 150C/CR	CH8-40

The impeller and all movable parts in contact with the water are made of stainless steel.
The pump suction and discharge chambers are made of cast iron.
Please refer to the attached Technical Product Information for more detailed information. (Appendix 8)

Pump Performance

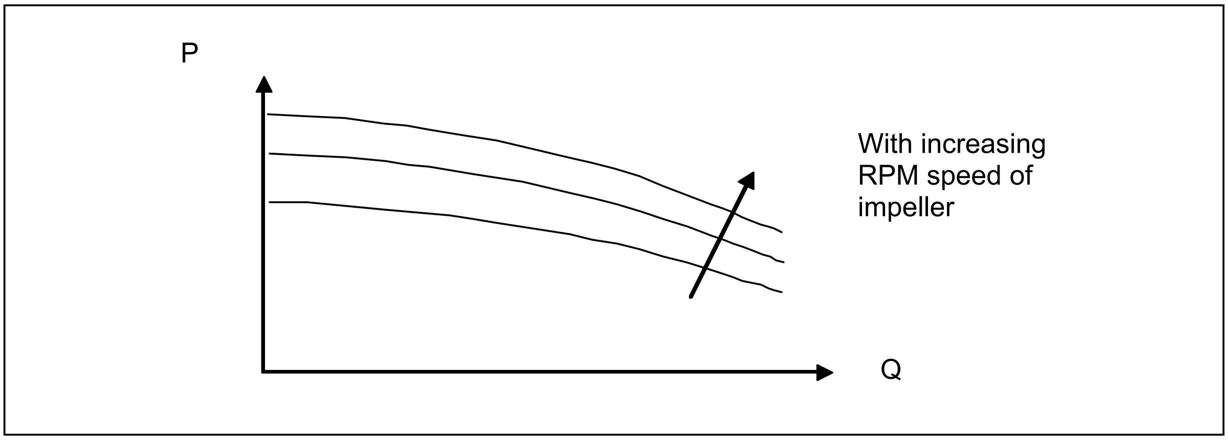
One of the most useful performance chart of a pump is the P-Q curve, which describes the relationship between the head pressure (P) vs. the volumetric flowrate (Q). The shape of the curve is as follows:



This curve shows that when the head pressure increases, the flow rate reduces (and vice-versa). By calculating the system pressure drop, we can thus determine the flow rate when the pump is running. Hence, we can check whether the system pipe design is suitable for a particular pump application.
This pump head pressure can also be measured at the pump discharge port by using a pressure gauge.

The above curve is for a single fixed speed pump. If the pump were to operate under different power supply frequencies (e.g. from 50 Hz to 60 Hz), another set of curves must be used.

For variable speed pumps, the P-Q curves will look as follows:



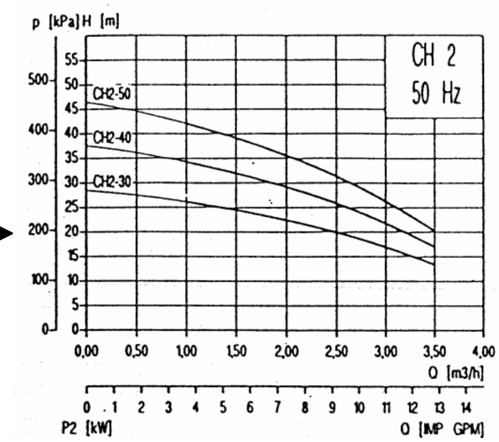
Let us now examine the sample calculation of the friction loss shown in Application Example No. 1 (Section 4).

The flowrate in that example is 11 USGPM = 2.497 m^3/hr at a total friction loss of 14.67m. For the mini chiller model AC 58A, the pump used is CH2-30.

The performance curve of the pump shows that at the design flowrate, the pump is able to deliver a head pressure of 20 m. This is more than sufficient to cater for the total system friction loss. Therefore, the pump is OK.

2.497 m^3 /hr

20 m

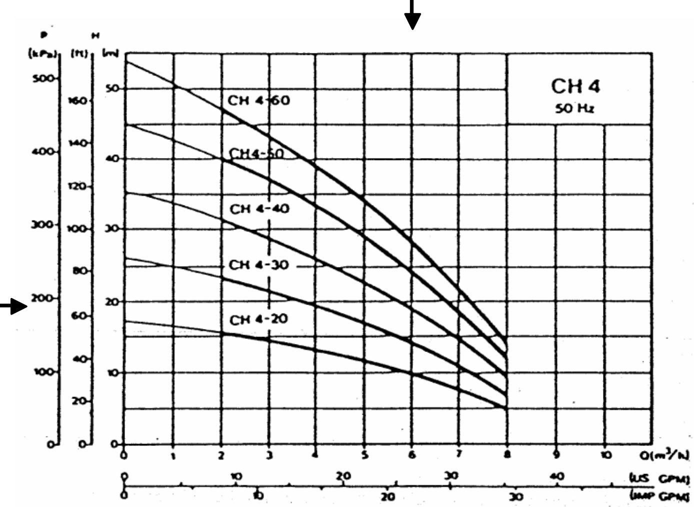


Similarly, in Application Example No. 2, we have a flowrate of 27 usgpm with a requirement of total friction loss of 26.4m. Entering now into the pump performance curve of CH4-40, we find that at this flowrate, the pump can only deliver a head pressure of 19 m.

This is not enough for the system. Therefore, it is necessary to redesign the piping network to have a lower friction loss in order for the pump to deliver the required flowrate.

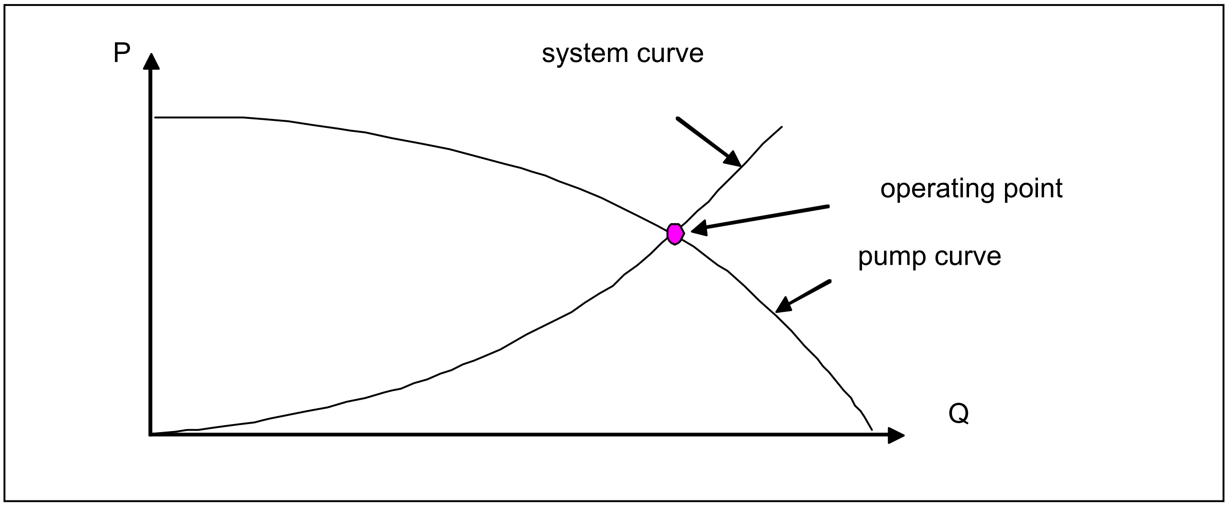
27 USGPM

19 m



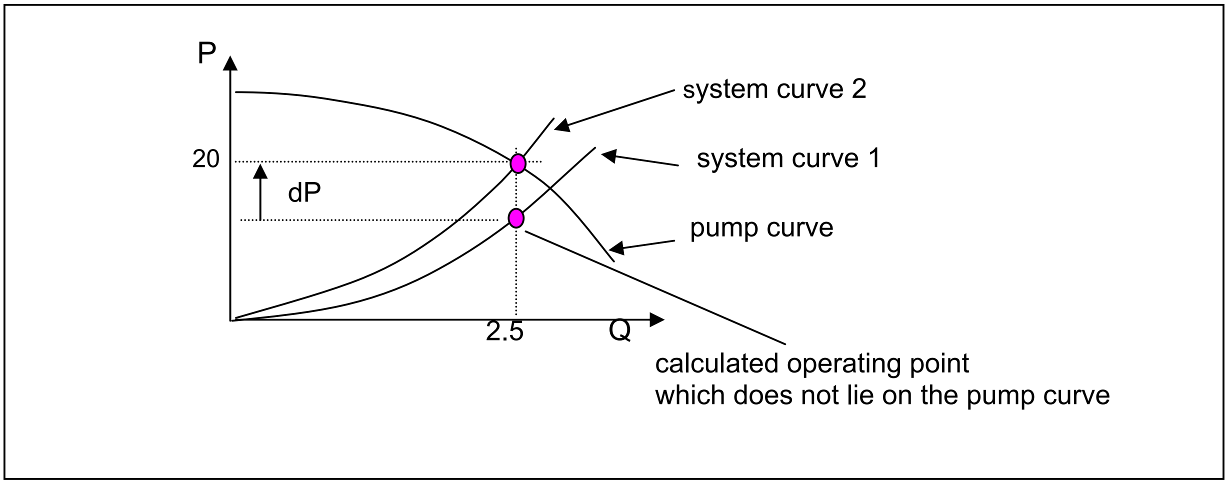
System Curve

The system curve of a hydronic system is a plot of the pressure loss vs. the flowrate of the piping system itself. This curve describes the performance of the piping network itself. By plotting this curve onto the pump P-Q curve, we have the following:



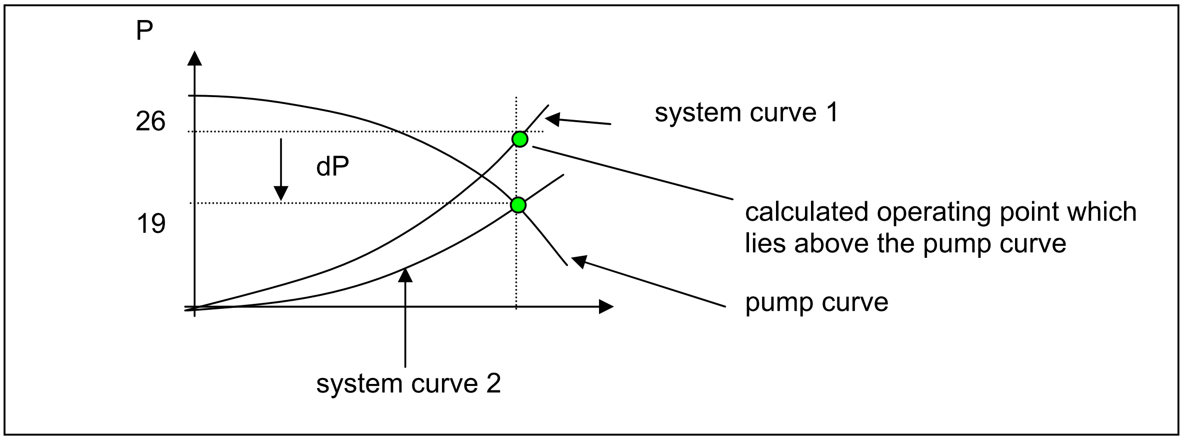
Note that the characteristics of the system curve is the opposite of the pump curve, whereby water will have a higher pressure loss in the piping system when the flowrate is higher.
The intersection of these two lines will give the operating point of the system.

What we have done in the Application Example No. 1 and 2 is to calculate the desired design operating point of the mini chiller with that particular piping network. In the first example, we have found that the pump has a much higher capacity compared with the requirement (System Curve 1)



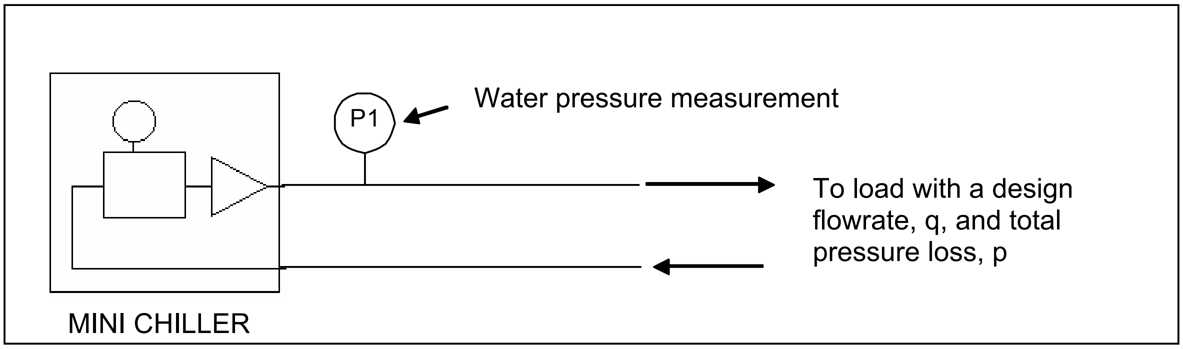
In order to "balance" back the pump operation, we need to increase the piping friction loss by dP (e.g. by adjusting the globe valve) so as to obtain System Curve 2. If this is not done, the pump will deliver a much higher flowrate compared with the design value.

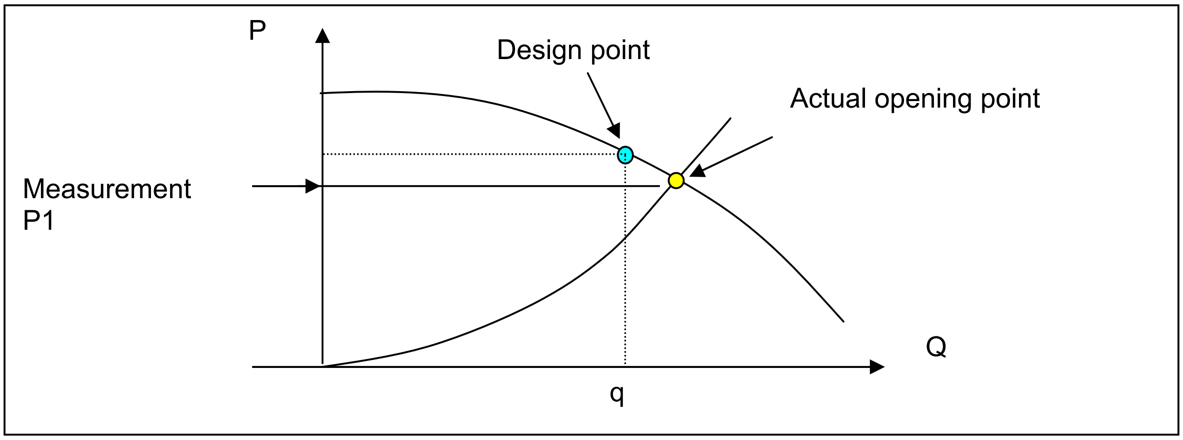
In the second example, we find that the water pump is insufficient to cater for the system curve.



In order to use the mini chiller, it is necessary for the piping network to have a characteristic of System Curve 2. The only way to do so is to redesign the piping system to give a lower friction loss.

Alternatively, we can use the pump P-Q curve during commissioning of the hydronic system. To do so, we need to measure the water pressure at the discharge port. This value is *quite close* to the actual head pressure developed by the pump. By plotting this pressure on the P-Q curve, we can then determine the approximate flowrate flowing through the system and compare it with the design requirement. Appropriate action can then be taken to ensure sufficient and correct amount of flowrate.

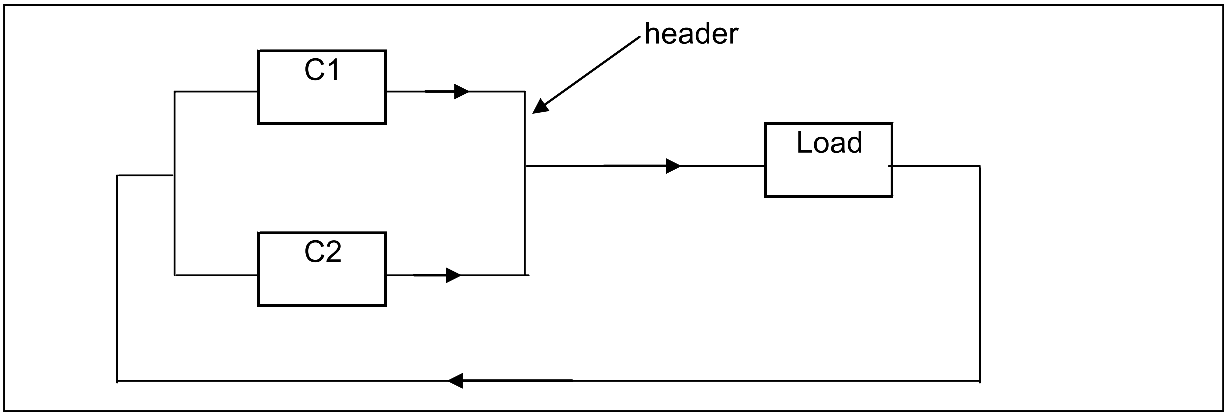




Parallel and Series Pump Operation

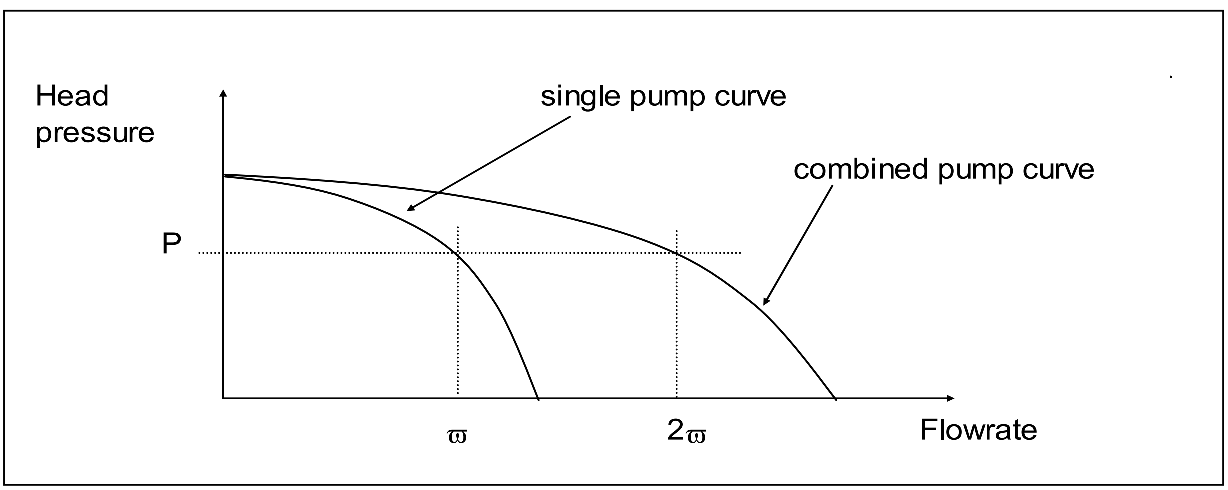
We have seen examples of the mini-chillers operating in parallel, e.g. where they are connected together via a common supply and return header pipe. Such installations are common when the single chiller do not have sufficient cooling capacity. In the **parallel** operation, the water pumps will work together to deliver a higher water flowrate (which is equivalent to the summation of each individual pump flowrate) at the operating head pressure.

Example: Two mini-chillers of the same model are connected together to a load as shown schematically (simplified) below:



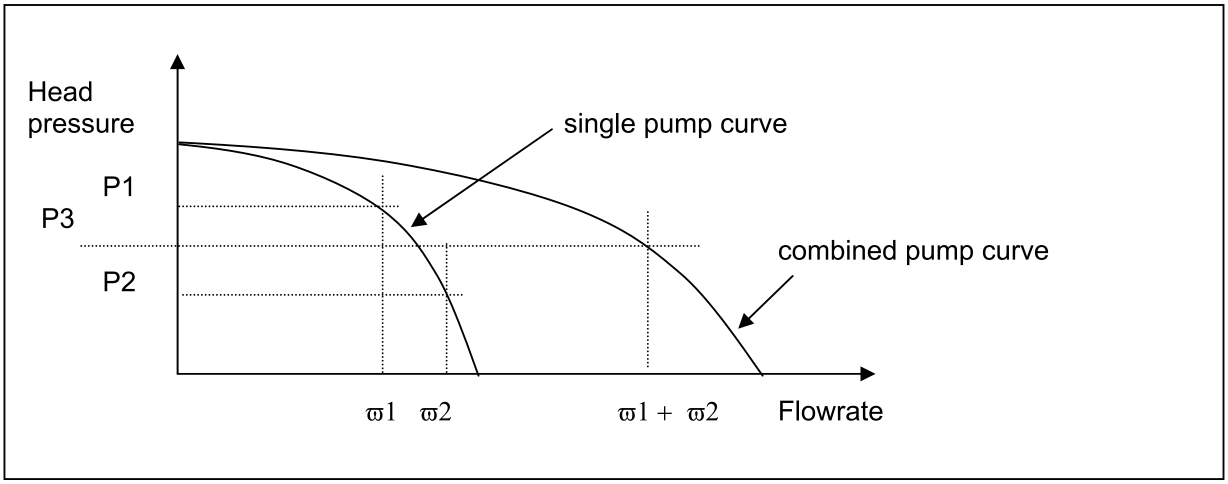
The pump in each chiller is delivering a flow of ϖ GPM. Assume that the friction loss in each branch of the header pipe is the same. Therefore, the flow in the load will be 2ϖ GPM .

If the total pipe friction loss is P ft, we can have the following pump curves:



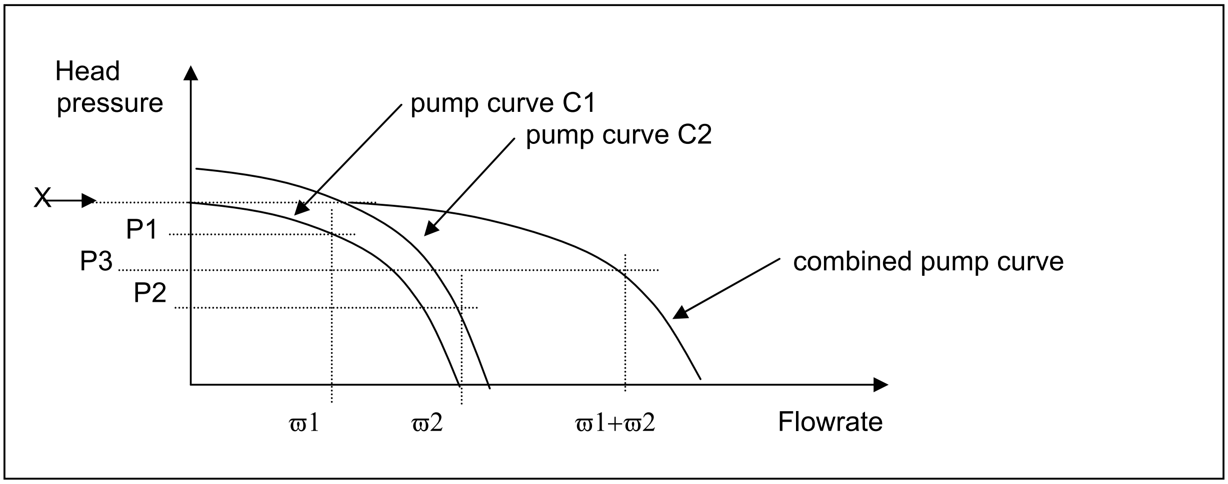
Now, if the friction loss in each branch is different, this will cause the flowrate in each branch to be different also, say ϖ1 and ϖ2.
Therefore, the total flow to the load will become ϖ1 + ϖ2.

Thus, the pump curves will become:



The two pumps will experience different head pressures P1 and P2.
Therefore, the pressure after the header will be P3 when the two flows combine together.

What happens when the two chillers C1 and C2 are of different model, i.e. pumps of different characteristics?
In such instances, we will still add the two curves together, and we will have the pump curves as follows:



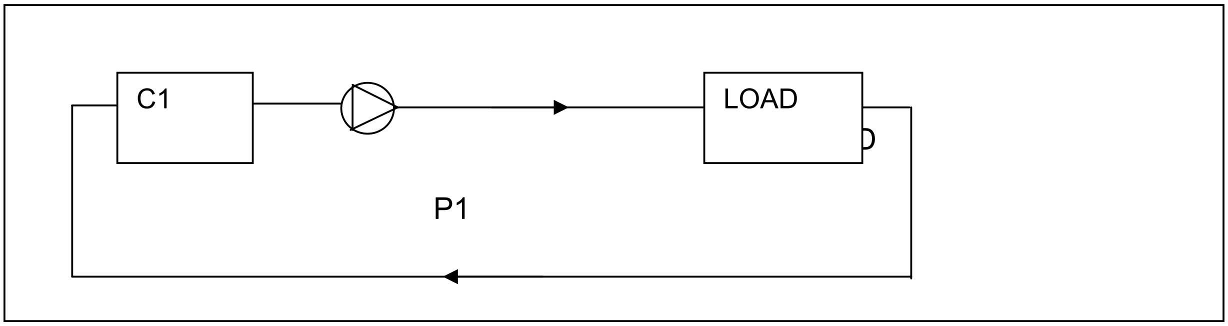
Of course, both the pumps will be operating under different head pressures P1 and P2, and then combines together to give a pressure of P3 at the header.

One caution point we need to take care with parallel pumping of different pump capacities is to ensure the operating head pressure does not cause the pump of lower capacity to operate at shut-off conditions and cause over-heating, i.e. at point X.

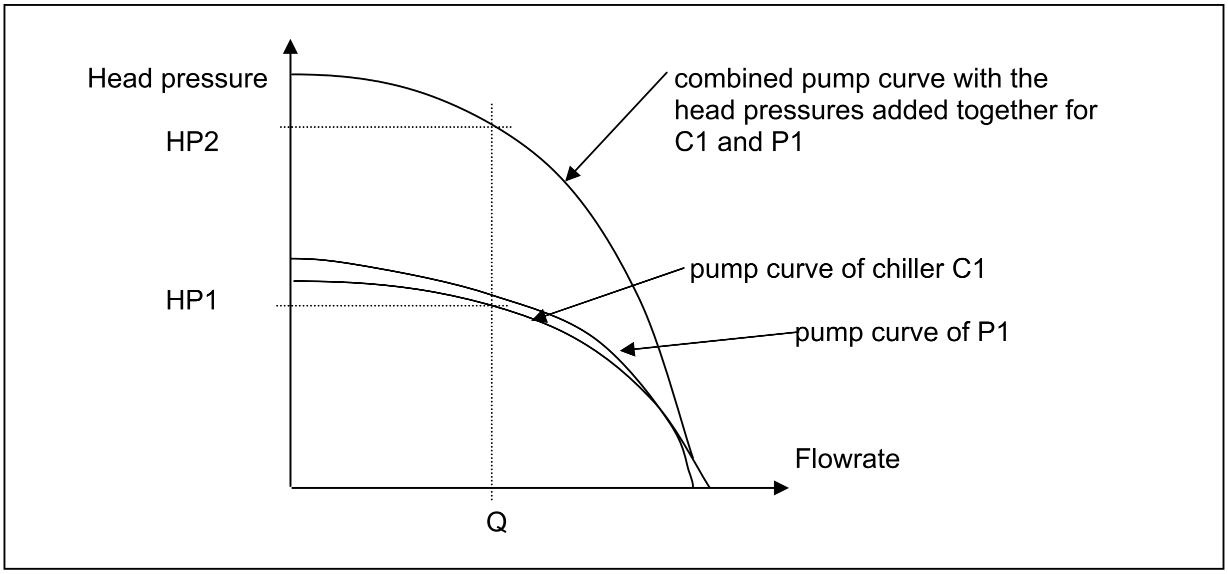
Therefore, it is very important to have a thorough understanding of the operating condition when operating parallel pumps. Always check with the pump curves.

Pumps may also operate together in **series**. This is done to increase the head pressure for a particular flowrate. However, it is not recommended for the mini chiller units to be installed in series. This will cause problems in controlling the water temperature and may cause damage to the heat exchangers and pumps.
Should the need arises, install the pump along the water discharge line to boost the head pressure.

Example: The head pressure of the pump in chiller C1 is not sufficient to overcome the total friction loss to the the load. Therefore, an additional pump P1 is installed to increase the head pressure at the same water flowrate, Q, from HP1 to HP2.



The pump curve will look as follows:



Cavitation

The phenomenon of cavitation occurs when the absolute pressure at the pump suction approaches the vapour pressure of water at the operating temperature. If the suction pressure becomes lower than the vapour pressure, vapour pockets (in the form of bubbles) will form along the pump impeller blade passages. This means that there is a change of phase from liquid to gas.

When these bubbles moves to the pressure side of the impeller, they collapse and **implode** on the blade surfaces. Such implosion causes erosion on the surface and create a pressure wave (or hammering noise) which can cause a noisy operation.
Such phenomenon is more critical with hot water because at higher temperatures, the vapour pressure increases and the tendency of achieving this pressure is easier.

Therefore, it is important that a calculation of the pump inlet suction pressure to be made of the designed system and check it with the pump performance limits.
The amount of this suction head pressure in excess of the vapour pressure required to prevent formation of the vapour bubbles is known as the Net Positive Suction Head Required (NPSHR). This NPSHR is a characteristic of a pump and is available from the manufacturer pump curves.

Note: The NPSHR can also be defined as the frictional resistance from the pump inlet to the first impeller.

In order to prevent cavitation, the actual system net positive suction head must be equal to or greater than the NPSHR value. This actual head pressure is also called as the Net Positive Suction Head Available (NPSHA).

$$NPSHR \leq NPSHA$$

How can we calculate NPSHA?

There are two ways to do this:

1. For open systems, use the following equation:

   $NPSHA = P_a + P_s - P_{vp} - P_f$

   where P_a is the atmospheric pressure
   P_s is the static head of water level above the pump impeller
   P_{vp} is the vapour pressure of water at the operating temperature
   P_f is the friction loss of the suction pipe, fittings and valves.

   Generally, if the water tank is elevated compared with the mini-chiller unit, there will be no problem with cavitation, unless the friction loss along the suction line is very high. See following example.

2. For close systems, use the following equation:

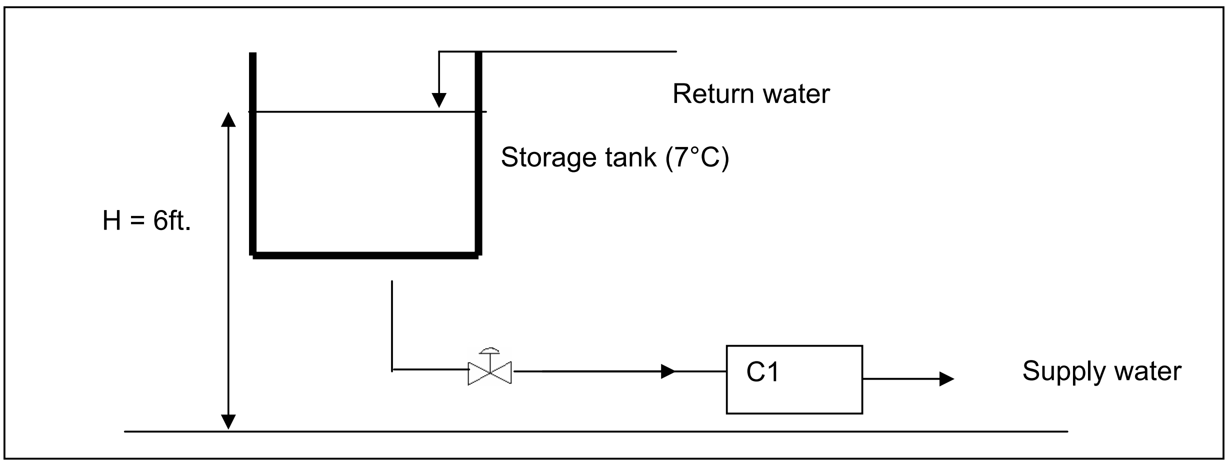
$$NPSHA = P_a + P_s + (v^2/2g) - P_{vp}$$

where P_a is the atmospheric pressure
P_s is the pressure at the pump inlet
v is the velocity of water at the pump inlet
g is the accelaration due to graviti (32.17 ft/sec^2 or 9.81 m/sec^2)
P_{vp} is the vapour pressure of water at the operating temperature
[Note: The term $v^2/2g$ is the velocity head of water at the pump inlet]

For both equations 1 and 2, it is recommended that an additional of 2 m (6.56 ft) to be deducted from the NPSHA as a safety factor to cater for the actual pipe installation.

Example 1:

A mini chiller (C1) is installed with a storage tank in the following configuration:



The chiller operate at the following parameters: Flowrate = 8 USGPM (1.82 m^3/hr); the total suction line friction losses = 2 ft; the internal friction loss from the chiller inlet pipe to the pump inlet = 1.6 ft.
The water tank is elevated at a height of 6 ft.
The chiller has a water pump of model CH2-30.

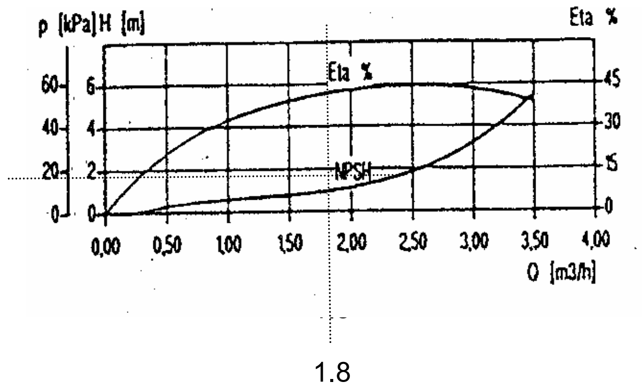
At 7°C, the water vapour pressure is 0.34 ft wg.
The atmospheric pressure at the site of installation is 34.0 ft wg.

By using equation 1, we calculate:

$$NPSHA = 34 + 6 - 0.34 - (2+1.6) = 36 \text{ ft.}$$

By taking a safety factor of 6.56 ft, we get NPSHA = 29.44 ft.

From the performance curve of CH2-30, at a flowrate of 1.82 m^3/hr, we have a NPSHR = 1 m = 3.28 ft



Since NPSHA > NPSHR, there will be no cavitation problems.

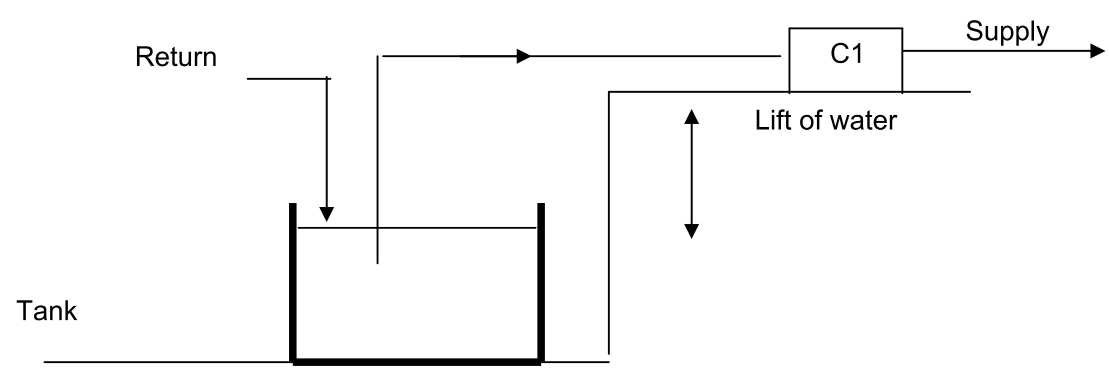
We can see that the elevated tank will not give any cavitation problem as the water column height will be sufficient to keep the inlet pressure higher than the vapour pressure.

However, if the mini-chiller is located above the tank, i.e. the pump is used to lift up water from the tank, then care must be taken to check for cavitation.
Suppose the tank is lower than the pump inlet, then the value of P_s in equation 1 will be negative. Rearranging the equation 1:

$$P_s = P_a - P_{vp} - P_f - NPSHA$$

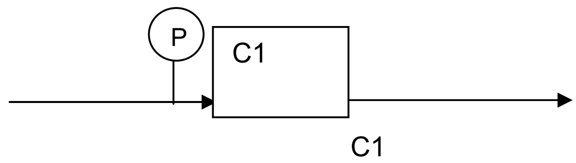
Therefore in the above example, for the same flowrate of 1.8 m^3/hr and a NPSHR of 3.28 ft, we can calculate what the maximum height is which the pump in the chiller unit can lift up without giving cavitation problems, i.e.

$$P_s|max = 34 - 0.34 - (2+1.6) - 3.28 = 26.8 \text{ ft. (or 20.24 ft with safety factor)}$$



Example 2:

A mini chiller installed in a close piping system has the following operating parameters:



- 20 USGPM = 2.674ft^3/min
  = 4.54m^3/hr

Pipe size is 1-1/4" SCH 40 steel pipe
The pressure measurement at the inlet pipe is 1 psig (= 2.3 ft wg.)
The chiller has a pump, model CH4-40.
The water temperature is 12°C.
The atmospheric pressure at the site of installation is 32.3 ft wg.

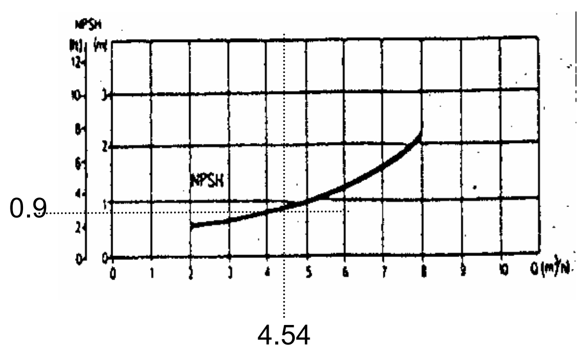
From the steel pipe data table (Section 3), the cross sectional area of the 1-1/4" pipe is 965 mm^2 = 0.0104 ft^2.
Therefore, the water velocity at the inlet pipe = 2.674/0.0104 = 257.12 ft/min.
= 4.28 ft/sec.

At 12°C (53.6°F), the vapour pressure of water is 0.48 ft wg.

Entering equation 2:

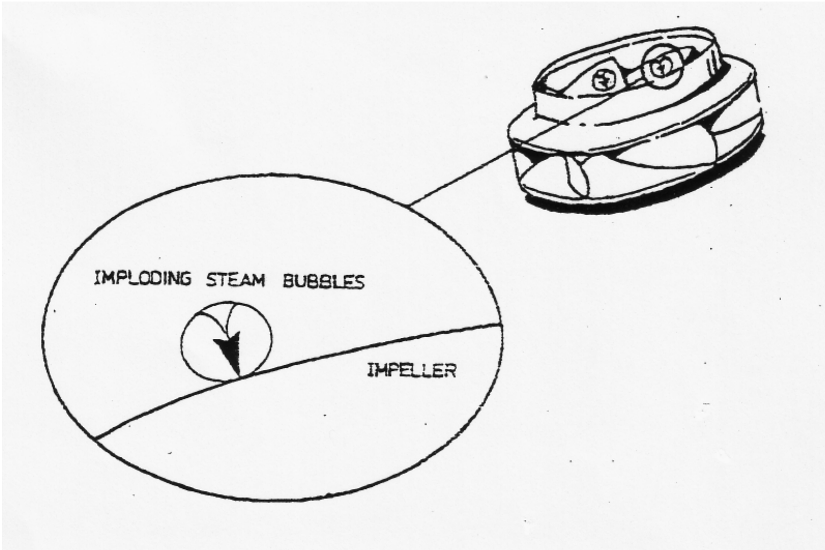
$$NPSHA = 32.2 + 2.3 + (4.28^2/2*32.17) - 0.48 = 33.7 \text{ ft.}$$

From the pump curve, we find that NPSHR = 0.9 m = 2.95 ft.



Again, we find that there is no problem of cavitation in this example since NPSHR < NPSHA.

Diagram of an imploding bubble which causes cavitation on the pump impeller:



Air Lock

Air lock is the phenomenon when air gets sucked into the pumping chamber and prevents water from discharging out of the pump volute. This normally occurs during refilling of water into the chiller unit during maintenance service. This can also occur when there are air leaks along the suction pipe causing air entrainment. In open systems, vortexing of the water can also cause air to be drawn into the pump.
See Appendix 10.

When this happens, we need to release the air from the pump. This can be done by opening the air bleed hole on the pump housing. While the pump is running, slowly open this hole and allow the air to release out. Do this until water comes out of the hole and then close it back.

Section 6: Water Storage Tank and Expansion Tank

It has been mentioned in the *Introduction* that there is a water buffer storage tank inside the mini chiller unit [for series A and series B versions]. The capacity of the tank is:

Model	**Capacity/litres**
AC 40A	32
AC 50A	
AC 58A	
AC 75B	150
AC100B	
AC125B	

The function of having this tank is to create a volume of water large enough to prevent short cycling of the compressor, i.e. to prevent the compressor from switching ON/OFF too frequently. This will usually happen during low load conditions, e.g. during night time, when the indoor fan coil units may switch off by the action of the room thermostat. As a result, only one or two fan coil units will be running while the larger capacity chiller unit continues to operate.

What is the effect of having the compressor switching ON/OFF too frequently? The main problem is overheating of the compressor motor winding. The winding will not get sufficient cooling from the refrigerant flow, and also there may be insufficient oil return which causes insufficient lubrication.

Therefore, it is vital that a proper calculation of the total system water volume to be made to determine if the chiller can operate safely.

The formula to calculate the minimum water volume is as follows:

$$V_{min} = \frac{860 * kW * \text{Compressor OFF time}}{\Delta T * 60 * \text{No. of load steps (or No. of compressors)}}$$

Units:
V_{min} litre
OFF time minutes
ΔT deg. C

Conversion:
1 kW = 3412 Btu/hr

Example:

A mini chiller (series A) has a cooling capacity of 40,000 Btu/hr (11.72 kW). The mini chiller controller has been programmed to operate with a minimum compressor run time of 3 minutes and an off time of 4 minutes (i.e. a minimum cyle of 7 minutes.)

The series A chillers only have 1 compressor.
Therefore, the minimum volume required for a temperature differential of 5 deg. C is:

$$V_{min} = \frac{860 * 11.72 * 4}{5 * 60 * 1} = 134 \text{ litres}$$

With an internal buffer tank of 32 litres, the remaining volume of (134 - 32) = 102 litre must be from the external piping and fan coil units.

Therefore, it is important for a calculation check to be made for this total water volume to ensure a proper operation. Too short a piping (e.g. back-to-back installations) may cause the compressor to cycle ON/OFF too frequently during low loading conditions.

It is recommended that the compressor do not switch ON/OFF for more than 8 cycles per hour.

The above recommendations are applicable for close piping systems. In the case of open systems, whereby there is an external tank, there should be no problem of having the compressor short cycling as the additional volume of water in the external tank will take a much longer time to pull down the temperature.

With the series-C chillers, no buffer tank is required. This is because of the chiller control algorithm used to control the two compressors in the chiller (i.e. two capacity load steps).
By having a sequential ON/OFF of the compressors (i.e. first ON, first OFF) and anti-short cycling timer in the controller, the compressors are prevented to ON/OFF too frequent beyond the specified cycles.

Thus, it is not necessary to perform similar minimum water volume calculations for these chillers.

How to calculate the water volume in the piping system?

We need to determine the volume in the piping system which contributes to the total volume required by the system.

The following volumes per unit length can be used for this calculation. These figures are taken from the pipe data tabulated in Appendix 1, 2 and 3:

Pipe Size	Water volumn, litres/m
Steel, Schedule 40 (ST)	
NPS 1/2"	0.196
3/4"	0.344
1"	0.558
1-1/4"	0.965
1-1/2"	1.313
2"	2.165
2-1/2"	3.089
Copper, Type L	
OD 1/2"	0.094
5/8"	0.151
3/4"	0.225
7/8"	0.312
1-1/8"	0.532
1-3/8"	0.811
1-5/8"	1.148
2-1/8"	1.997
2-5/8"	3.079
PVC, DIN 8062	
OD 20mm	0.227
25mm	0.353
32mm	0.581
40mm	0.908
50mm	1.425

The volume is then calculated by multiplying the above figures with the corresponding length used in the system.
The volumes of all the different sizes used in the network is then added up to give the total system volume.

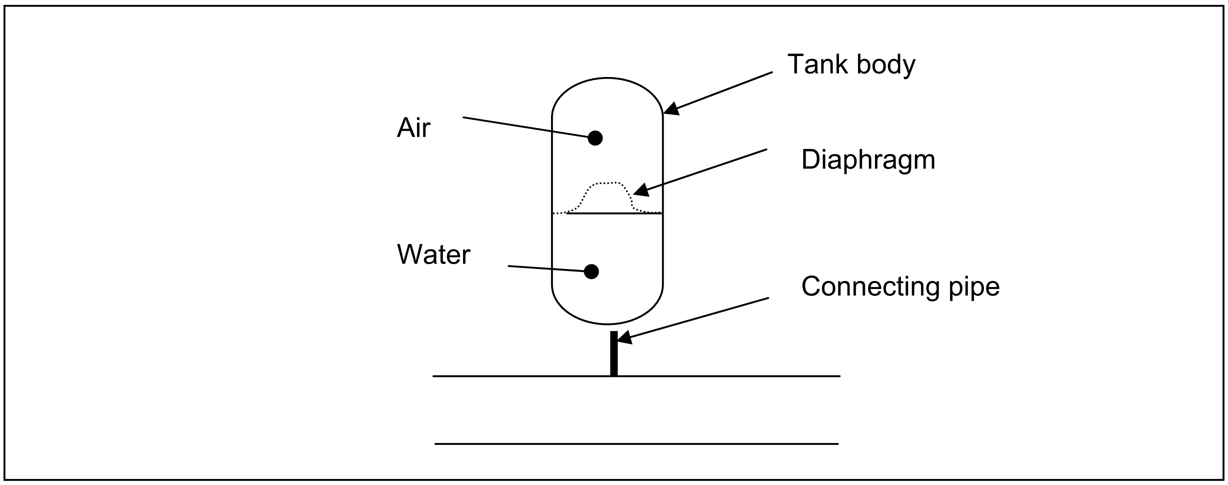
Expansion Tank

In the mini-chiller unit, the expansion tank is located on the storage tank. However, this tank is only available in the larger units, i.e. AC 75B, AC 100B, AC 125B.
For the smaller units, i.e. AC 40A, AC 50A and AC 58A, the expansion tank must be located externally.
Generally, the expansion tank provides a space into which the water can expand or from which it can contract as the water undergoes volumetric changes with respect to changes in temperature. Therefore, it is **recommended** for such an expansion tank to be installed externally for the smaller mini-chillers when running cooling only cycle, but it is **compulsory** to do so for the heat pump units with both cooling and heating cycles. Failure to do so will cause serious damage to the hydraulic components in the unit and also may cause cracking of the piping network. This is due to the expansion of the hot water in the pipes.

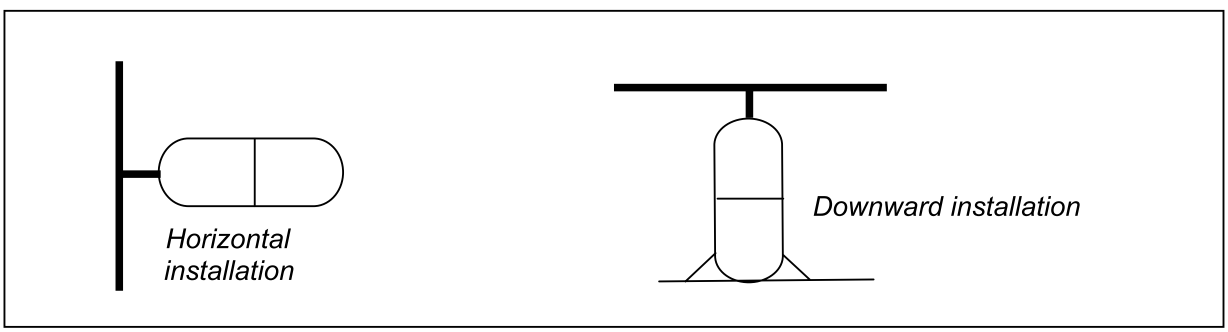
To allow for this expansion or contraction, the tank provides an interface point between the water and a compressible gas (e.g. air or nitrogen). There are 3 types of expansion tank available:

a. A closed tank which contains a captured volume of air and water
b. An open tank, i.e. with the water surface open to the atmosphere
c. A diaphragm tank, in which a flexible membrane is inserted between the air the water

The expansion tank which is used in the mini chiller units is of type (c). This type is recommended as the diaphragm will prevent the air dissolving into the water.



The tank is usually installed vertically, either upwards or downwards. However, due to space considerations, it is also possible to install it horizontally.



The expansion tank in the larger mini-chiller unit is connected to the top of the water storage tank and it has a capacity of 8 litres, with a charged pressure of 1.5 bar.

To calculate the size of a diaphragm expansion tank, use the following formula:

$$V_t = V_s \left[\frac{[(v_2/v_1) - 1] - 3\alpha\Delta t}{1 - (P_1/P_2)} \right]$$

where
V_t is the tank volume
V_s is the water volume in the system
v_1 is the specific volume of water at lower temperature
v_2 is the specific volume of water at higher temperature
α is the linear coefficient of thermal expansion for the body
= $11.7 * 10^{-6}$ m/(m.K) for steel
= $17.1 * 10^{-6}$ m/(m.K) for copper
Δt is higher temperature (t_2) - lower temperature (t_1)
P_1 is the pressure at lower temperature
P_2 is the pressure at higher temperature

To size the tank for the heating cycle of the mini-chiller unit, use the lower temperature (t_1) as the design chilled water temperature (e.g. 7°C) and the higher temperature (t_2) as design hot water temperature (e.g. 40°C).

Using the largest AC 58A as an example, we calculate as follows:

Water volume required = (50,000 Btu/hr / 10,000) * 25 litres
= 125 litres

At 7°C, the specific volume can be read from the water properties table (App. 11)
$v_1 = 0.001\ m^3/kg$
At 40°C, the specific volume $v_2 = 0.001008\ m^3/kg$
Use the pressure P_2 equivalent to the pressure relief valve setting, e.g. 300 kPa.
Use the pressure P_1 as the positive pressure at the point of installation, e.g. 80 kPa.

Therefore,

$$V_t = 125 \left[\frac{(0.001008/0.001) - 1] - (3*11.7*10^{-6})(40-7)}{1-(80/300)} \right]$$

= 1.17 litres
(1.4 litres, taking into account a 20% safety factor)

Thus, using a 2 litres expansion tank will suffice for the above operation

Reworking the example by using the lower temperature as 0°C and the higher temperature as 80°C, we will get:

$$V_t = 125 \left[\frac{(0.001028/0.001) - 1] - (3*11.7*10^{-6})(80-0)}{1 - (80/300)} \right]$$

= 4.29 litres
(5.1 litres with 20% safety factor)

Thus, a 6 litres tank is needed.
Therefore, the higher the water temperature, the larger the volume of the tank that is required.

Note: If the tank is located at a location with lower pressure, it can be seen that the volume required will be smaller. Therefore, the expansion tank should be located at the position with the a low pressure, e.g. on the water return suction line or at the highest point of a vertical pipe system.

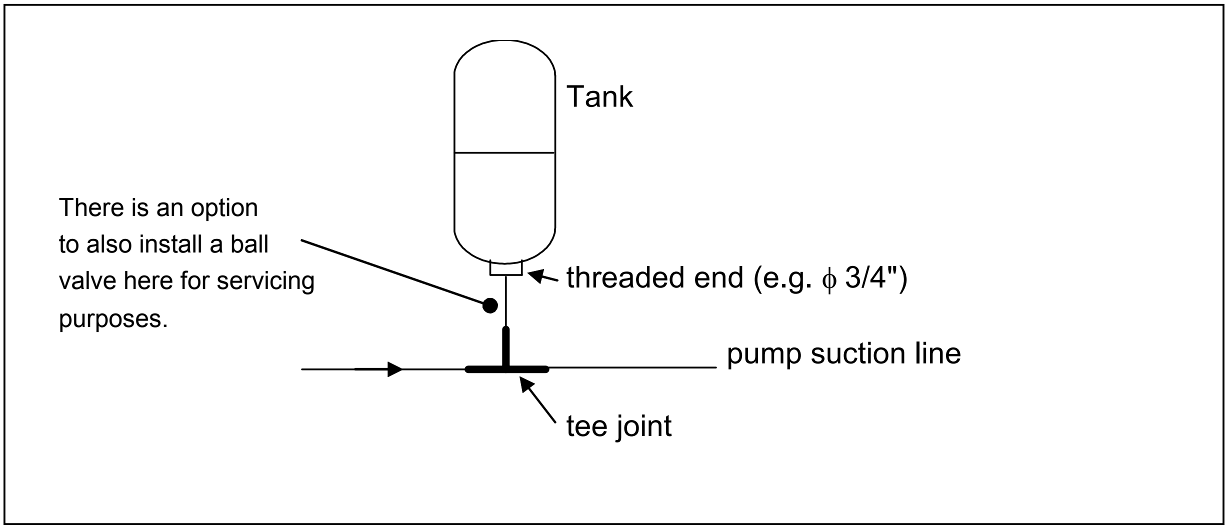
To calculate the expansion tank size for cooling only systems, use the lower temperature as the design chilled water temperature and the higher temperature as the ambient temperature (e.g. 35°C).
Generally, the size of the expansion tank for chilled water system is much smaller compared with the hot water applications.

Using a larger expansion tank than the calculate requirement is OK. The larger volume will not affect the system, rather it will help to cater for a larger water volume than the value used in the calculation.

An expansion tank is not required for an open piping system as the reservoir tank itself will allow for the expansion.
There should only be ONE expansion tank in the close piping system.

Installation of External Expansion Tank

To install the expansion tank to the water pipe, make a tee-joint at the point of installation.
Most tanks have threaded ends for connection purposes.



Section 7: Insulation Material

In this section, we will look at the insulation material needed to be used for the chilled water piping installed with the mini chiller unit.

The purpose of using the insulation material around the pipe is:

a) To prevent heat gain to or heat loss from the water in the pipes.
b) To prevent water condensation along the pipes due to the chilled water flowing in the pipes
c) To prevent injury due to the hot water flowing in the pipes

The type of insulation material used will depend on the pipe material used in the installation. For black steel pipes, it is common to either use closed cell elastomeric insulation (e.g. "Armaflex") or polyurethane foam with external aluminium cladding. For copper pipes, the closed cell elastomeric insulation is used. Similarly, PVC pipes may use the same type of insulation as the copper pipes.

It is important that the thickness of the insulation material used for the pipes are sufficient to fulfill the above mentioned requirements. Hence, it is recommended that a calculation check to be made to determine the insulation performance. To do this, the following items must be known:

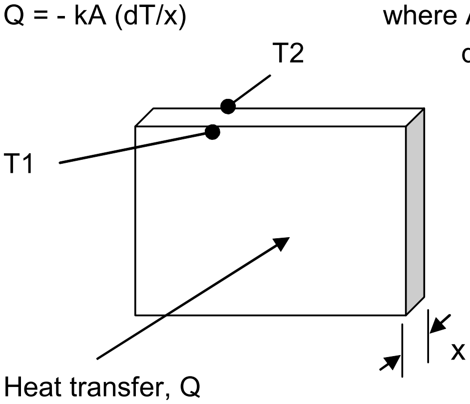
1. Insulation material thermal conductivity coefficient (k)
2. Pipe Size
3. Air condition (dry bulb temperature and humidity / or wet bulb temperature) at the site of pipe installation - use the most extreme conditions that exists at the site
4. Convective heat transfer coefficient (h)

The k-value of the insulation material describes how much heat is being conducted through the insulation. A good insulation will have a low k-value. The amount of heat conducted can be calculated as follows:

a. Through a slab of thickness, x

$Q = - kA (dT/x)$ where A is the surface area of the slab

dT is the temperature difference between the the two slab surfaces, i.e. (T1 - T2) with T1 > T2

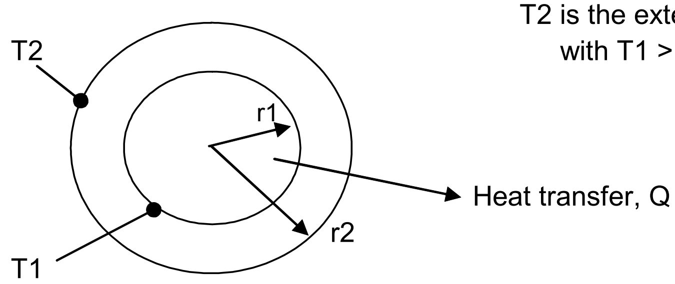


** This equation is also called as <u>Fourier's Law</u>

b. Through a Hollow Cylinder With Internal Radius, r1 and External Radius, r2

$$Q = \frac{2\pi kL\,(T1 - T2)}{\ln(r2/r1)}$$

where L is the length of the cylinder
T1 is the internal surface temperature
T2 is the external surface temperature
with T1 > T2



The piping insulation can be considered as a hollow cyclinder and the above formula may be used in calculating the insulation thickness.
When the heat flux has conducted through the thickness of the pipe insulation, the heat will then dissipate at the external surface by means of convection.
The heat transfer rate by convection (Qc) from a surface with temperature T can be expressed as:

$$Qc = hA(T - Ta)$$

where Ta is the ambient air temperature
A is the surface area

By equating the conductive and convective heat transfer equations, it can be shown:

$$r1 * \ln(r2/r1) = \frac{k\,(T1 - T2)}{h\,(T2 - Ta)}$$

Therefore, with the known k-value and h-value, together with the pipe size (r1) and operating temperature T1, we can calculate the external radius, r2, to obtain a specified external surface temperature, T2.

a) We can thus calculate the minimum required insulation thickness to ensure a safe external surface temperature to protect from the hot water pipe temperature.

b) We can also calculate the minimum required insulated thickness to prevent condensation by ensuring the external surface temperature is not lower than the ***dew point temperature*** of the air surrounding the piping.
Refer to Appendix 12 for a psychometric chart to determine the dew point temperature for different temperatures and humidity levels.

k-values of Insulation Material

The following values can be used for the common insulation materials used:

	k-value (W/m.K)
Closed cell elastomeric insulation	0.034 - 0.0374
Polyurethane	0.021 - 0.026
Fibre glass	0.03 - 0.033
Polystyrene	0.028 - 0.03

For other types of insulation material, refer to the manufacturer's catalogs and specifications for the k-values.

If polyurethane is used with an external metal cladding (e.g. aluminium or galvanized), there will be two k-values involved in the computation equation. However, since the cladding is a good thermal conductor, it is possible to ignore this thin metal (usually 0.3 - 0.5 mm thick) in the calculation of the polyurethane thickness required.
Nevertheless, if necessary, the following equation can be used:

$$r3[kb*\ln(r1/r2) + ka*\ln(r1/r2)] = \frac{(ka*kb)\ (T3 - T1)}{h\ \ (T3 - Ta)}$$

where ka and kb are the k-values for the two different material
r3 and T3 are the radius and surface temperature of the external cladding

The k-value for aluminium (kb) is 212 W/m.K

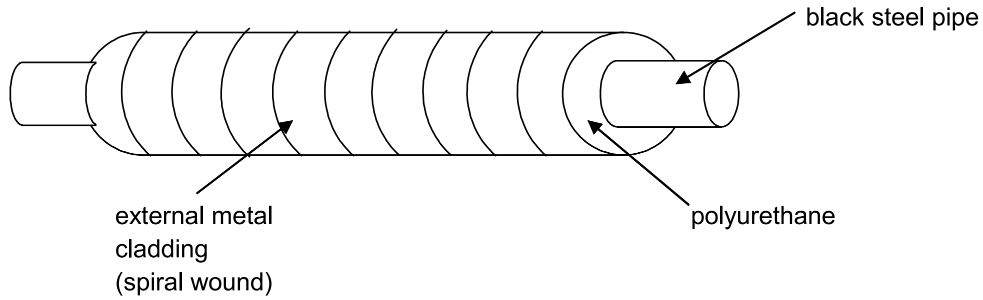
h-values

The following convective heat transfer coefficients can be used for different surface conditions (assuming free convection):

	h-value (W/m.K)
Matt surfaces, black or grey	9 - 10
Metallic surfaces, not polished	7 - 8
Metallic surfaces, polished	5 - 6

Pre-Insulated Pipes

These are black steel pipes which have been injected with polyurethane foam together with an external spirally wound metal cladding (aluminium or galvanised iron). Because these pipes have been pre-fabricated, they are widely used in the installation of chillers. The insulation forms a rigid and strong bond with the pipe surface.



Pipes can be joined together with arc welding.

Advantages:

a. Due to the strong bond of the polyurethane, there are no air leakages through the insulation and cause internal condensation.
b. The metal cladding gives a good finishing to the installation. Paint can be applied easily over the metal, providing protection against corrosion and giving colour codes to the different pipes used.

Disadvantages:

a. High cost.
b. Joints with fittings and between pipes require additional insulation moulding. This is done by making a mould with thin metal sheets (aluminium or GI) around the fitting or pipe joint. A mixture of polyurethane chemical and foaming agent is then poured into the mould and allowed to fill the mould.

Pre-fabricated pipe sectional polyurethane can also be used for this purpose, e.g. for elbows and straight pipe joints. An external metal cladding can then be rivetted around these sections.

As a result of this, the installation of such insulation is more extensive and requires skill.

Sectional Polyurethane

As an alternative to the pre-insulated pipes, pre-fabricated sectional polyurethane can be attached onto the bare black steel pipes with an external metal cladding rivetted around the pipe.

Various shapes and sizes are available to fit the piping network.

It is important that a layer of grease to be applied on the internal surface of the polyurethane sections before placing it around the pipe. These sections are then secured tightly around the pipe by tying with metal wire.
The layer of grease is to ensure that the sections stick firmly onto the pipe surface and to seal any air gaps, especially at sections' joining surfaces, thus preventing condensation.

Even though this method is cheaper compared with the preinsulated pipe, one major problem is condensation because it is difficult to ensure a complete air-tight installation along the entire pipe length due to the number of sections used.

Closed Cell Elastomeric Insulation

This type of insulation, made from nitrile rubber, is usually used with copper pipes. Some common names for this type of insulation are Armaflex, Insuflex and Superlon. Tubular form of this insulation are usually used for the copper pipes. However, sheet form are also used to insulate storage tanks, ductwork and steel pipes.

This insulation is soft, flexible and easy to install. It can be formed to suit various shapes and sizes.
For the tubular form, the insulation can either be slipped-on or snapped-on. Adhesive is then used to stick together all the joining surfaces. It is not needed to stick the insulation onto the pipe itself. Rather, the correct size of the insulation must be used to match the pipe external diameter. Using too large a size will cause air pockets in between the insulation and pipe which will create condensation. A smaller size will not allow the pipe to slip-on or cause incomplete wrap-around during snap-on. See Appendix 13.

For the sheet form, adhesive can be used to just stick the insulation onto the surface.
Joining edges and corners can also be sticked in the same manner.

This type of insulation is of the closed cell structure. As compared with the open cell insulation, the closed cell give better thermal insulation performance and lower water moisture permeability. Absorption of water into the insulation will cause degradation of the thermal conductivity properties over time. Hence, it is not desired for the insulation to retain water.

Example of Selection:

The mini chiller has a piping network of diameter 1-1/4". The pipes are to be insulated with Armaflex. The pipes run through a ceiling space with a temperature of 38°C and 85% RH.
Determine the minimum insulation thickness required to prevent condensation if the chilled water temperature is at:

a. 7°C
b. 2 °C

The Armaflex insulation has a k-value of 0.0374 W/m.K. The tubular insulation has a black surface, thereby use a h-value of 9 W/m.K. By entering into the sizing Excel spreadsheet programme, we calculate:

1. For a 7°C water temperature, the insulation must be at least 1 inch thick.

2. For a 2°C water temperature, the thickness required is 1.1 inch.

It is recommended that the next size up to be selected to provide some safety factor for the selection.

If a pre-insulated pipe is used instead, what is the thickness required?
Ignoring the effect of the external cladding, and entering again into the programme with a k-value of 0.025 W/m.K, we have the minimum thickness:

1. For 7°C water: 0.7 inch

2. For 2°C water: 0.8 inch

Note that polyurethane is a better thermal insulator compared with the Armaflex, therefore the thickness is lower.

Piping Insulation Thickness Calculation: To Prevent Condensation

Air Condition:

DB/ ºC	38	Dew Point	
RH/ %	85	DP/ ºC	35.07

Pipe specification:

Pipe dia. 1.25

Radius, r1 15.879 mm

Pipe surface temperature / ºC 2

Insulation material:

Material: Pre-insulated polyurethane pipe
Thermal conductivity, k 0.025W/mK

Surface convective heat transfer Coefficient, h 9 $W/m^2 K$

Insulation selection:

Calculated insulation size
r2 37.004mm

Insulation thickness **(Minimum)** **21.1mm** 0.8in

USE THE NEXT SIZE THICKNESS AVAILABLE OR THICKER – FOR SAFETY FACTOR

Piping Insulation Thickness Calculation: To Prevent Condensation

Air Condition:

DB/ ºC	38	Dew Point	
RH/ %	85	DP/ ºC	35.07

Pipe specification:

Pipe dia. 1.25

Radius, r1 15.879 mm

Pipe surface temperature / ºC 7

Insulation material:

Material: Pre-insulated polyurethane pipe
Thermal conductivity, k 0.025W/mK

Surface convective heat transfer Coefficient, h 9 $W/m^2 K$

Insulation selection:

Calculated insulation size
r2 37.004mm

Insulation thickness **18.5 mm**
(Minimum) 0.7in

USE THE NEXT SIZE THICKNESS AVAILABLE OR THICKER – FOR SAFETY FACTOR

Piping Insulation Thickness Calculation: To Prevent Condensation

Air Condition:

DB/ ºC	38	Dew Point	
RH/ %	85	DP/ ºC	35.07

Pipe specification:

Pipe dia. 1.25

Radius, r1 15.879 mm

Pipe surface temperature / ºC 7

Insulation material:

Material: ARMAFLEX
Thermal conductivity, k 0.0374W/mK

Surface convective heat transfer Coefficient, h 9 W/m^2 K

Insulation selection:

Calculated insulation size
r2 41.440mm

Insulation thickness **(Minimum)** **25.6 mm** 1.0 in

USE THE NEXT SIZE THICKNESS AVAILABLE OR THICKER – FOR SAFETY FACTOR

Piping Insulation Thickness Calculation: To Prevent Condensation

Air Condition:

DB/ ºC	38	Dew Point	
RH/ %	85	DP/ ºC	35.07

Pipe specification:

Pipe dia. 1.25 in

Radius, r1 15.879 mm

Pipe surface temperature / ºC 2

Insulation material:

Material: ARMAFLEX
Thermal conductivity, k 0.0374W/mK

Surface convective heat transfer Coefficient, h 9 $W/m^2 K$

Insulation selection:

Calculated insulation size
r2 44.980mm

Insulation thickness **(Minimum)** **29.1 mm** 1.1 in

USE THE NEXT SIZE THICKNESS AVAILABLE OR THICKER – FOR SAFETY FACTOR

Example no. 2

For **heating applications**, it is desired to check the insulation thickness required to ensure an external insulation temperature of not more than 37°C. The hot water temperature was found operating at a maximum temperature of 50°C. The pipe size is 1" and the insulation material used is fibreglass encased in a metal cladding. The k-value of the insulation material is 0.035 W/m.K. The air temperature around the pipes is 34°C.

By entering the data into the Excel spreadsheet programme, we can determine that the insulation thickness required is at least 0.5 inch.

It should be noted that the closer the external surface temperature is to the ambient air temperature, the thicker will the insulation be. It is not possible to have the external surface temperature colder than the air ambient temperature, else convection will not occur.

Piping Insulation Thickness Calculation: Hot Pipe Insulation Thickness

Air Condition:

DB/ ºC	34
RH/ %	

Pipe specification:

Pipe dia. | 1 | in

Radius, r1 12.703 mm

Pipe surface temperature / ºC	50	
Insulation surface temp. / ºC	37	OK

Insulation material:

Material: Fiberglass
Thermal conductivity, k 0.0374W/mK

Surface convective heat transfer Coefficient, h 9 W/m^2 K

Insulation selection:

Calculated insulation size
r2 24.956mm

Insulation thickness **12.3 mm**
(Minimum) 0.5 in

USE THE NEXT SIZE THICKNESS AVAILABLE OR THICKER – FOR SAFETY FACTOR

Insulation thickness selection can also be made with the manufacturer's recommendations.
Please refer to the relevant catalogs or technical manuals. Usually, manufacturers will publish selection tables to suit various temperature applications. Some also have graphical methods for this purpose. Computer selection programmes are also available.
See Appendix 14 for an example of a nomograph used by Armaflex.

Whatever method is used, it is a good practice to use a thicker insulation size to cater for any unforseen circumstances. However, this must be balanced with economic consideration as thicker material will cost more.

Section 8: Pipe Support

Depending on the complexity of the piping network, various pipe supports are needed to hold and support the piping along its route. Such supports will include hangers, saddles, trays, brackets, anchors, etc.

These supports must be strong enough to withstand all static and dynamic load conditions, which include:

a. The weight of the pipe, fittings, valves, water and insulation material
b. Wind, ice and seismic forces (where applicable)
c. Vibrations and water hammering
d. Forces imposed by thermal expansion and contraction of the pipe bends and loops

Generally, the pipes from the mini chiller unit are run along the ceiling space, along wall surfaces, through floor slabs, through walls and also along the floor level. The following diagrams give suggestions on how various pipe supports are used for the different type of applications.

Other than that, the number of supports must be sufficient along the pipe length to prevent the pipe from sagging. The spacing between supports will depend very much on the pipe material and the pipe size.

"Softer" pipes, e.g. PVC and copper, will require shorter support spans.
Refer to the attached table for suggestion of this support/hanger spacing.

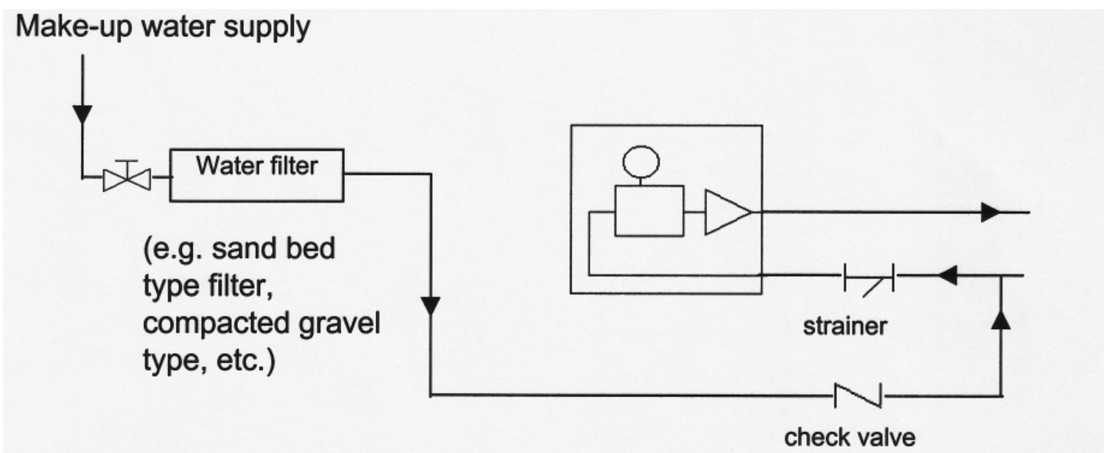
Section 9: Water Side Treatment

The brazed plate heat exchanger (BPHE) which is used in the mini chiller unit consists of several stainless steel plates brazed together to form two distinct flow channels in between each successive plates. Water flows in one channel and refrigerant in the other, usually in a counter flow direction.

Because the spacing in between the plates is small, it is vital that these flow channels (especially the water side) are not blocked by debris, fouling or scaling. Such impurities will restrict the flow rate and reduces the chiller performance. Furthermore, the heat transfer efficiency will be retarded.

Generally, debris in the water (e.g. sand, gravel, metal pieces) will be removed by the strainer installed along the water suction pipe. This will depend on the filter mesh size used in the strainer itself. A filter mesh size of 16 - 20 is recommended for this purpose. Nevertheless, it is also a good practice to install another water filter along the make-up water supply pipe for the same purpose.

It is important that these filter elements to be serviced periodically to remove any trapped particles and debris inside them. Flushing of the pipes periodically with water is also a good maintenance practice.



Usually, such coarse debris are found during initial start-up and commissioning of the mini chillers. These debris are left-overs during the installation of the water piping. Therefore, it is recommended that a thorough flushing with clean water to be done in the water piping before the chiller is started. Check and clean the strainer element also before start-up. Fouling refers to the tendency of the water to form a film on the heat transfer surfaces. There are two types of fouling:

a. Organic surface fouling
b. Inorganic suface fouling

The organic fouling includes microbiological growth or slime on the surfaces of the heat exchanger plates and pipes. Algae may also formed on these surfaces. This type of fouling is more significant in open systems whereby oxygen dissolved in the water through the open storage tank will encourage the microbiological growth.

Scaling is a type of inorganic fouling. It is caused by deposit of inorganic salts (e.g. calcium sulfate, calcium carbonate) in the water onto the heat exchanger plate surfaces and pipes. Such phenomenon occurs when the water temperature gets higher, usually > 50°C. This is because the solubility of the salts becomes lower when the temperature becomes higher. When coupled with low water velocities (laminar flow) and uneven flow distributions (e.g. at areas of water stagnation in the heat exchanger), a thin hard layer of scaling will form on the surfaces.

Generally, scaling is not a problem with chilled water systems.

Symptoms:

1. A heat exchanger which has been choked with coarse debris will normally exhibit a sudden increase in pressure drop. This is due to the sudden block of water flow by the debris.

2. Both the organic and inorganic surface fouling will show a gradual increase of pressure drop and a gradual drop in the heat exchanger performance.

Remedy

For both the above symptoms, it is necessary to remove all these fouling material in order to have an optimum chiller performance. We have mentioned earlier that the coarse debris is relatively easy to remove by cleaning the filter elements and flushing out with water. Nevertheless, sometimes some of the larger debris may be stuck in between the plates.

If such blockages are too severe, it may be necessary to change a new BPHE altogether. For both the surface fouling, a chemical cleaning is needed to remove them.

a. Organic fouling

Use an alkaline cleaning agent like caustic soda or sodium hydroxide ($NaOH$) at a 5% concentration. Mix with clean water and then pump in the solution into the heat exchanger and piping system. An external circulator pump may be used for this purpose.
Refer to the chemical manufacturer recommendations for directions of usage. Additional surface active substances may need to be added into the mixture for better cleaning performance.
After cleaning, flush the whole system with clean water to remove

b. Inorganic fouling

The most commonly used cleaning agent for scaling problems is acid.

Mineral acids have a strong ability to dissolve the scales. But these can also corrode the steel and copper material in the system. Such acids include sulfuric acid, hydrochloric acid and nitric acid. However, these acids will also attack/corrode the stainless steel, gaskets and copper parts.

Organic acids are weaker than the mineral acids in the corrosive properties but still able to dissolve the scales. This make them ideal when used to clean the BPHE.
Such acids include phosphoric acid, formic acid and acetic acid. Usually, this acid is used in combination with other chemicals to enhance the cleaning capabilities.

Whatever type of acids used, care must be taken in handling the chemical. A concentration 2 to 5% should be mixed and circulated into the system. An additional inhibitor chemical may be added, if necessary, to diminish the corrosive action onto metals.
Refer to the chemical manufacturer recommendations on the required dosage to use. Upon completion, flush with lots of clean water to remove any excess acids. Depending on the directions of usage, some may require neutralization and passivation after cleaning.
Example of Cleaning chemicals:

a. AlfaCaus : sodium hydroxide for cleaning of organic fouling

b. AlfaPhos : phosphoric acid (organic acid)

c. AlfaCarbon : formic acid (organic acid)

d. Kaloxi : citric acid, phosphoric acid

e. P3-T 288

f. Nitric acid (1 %) + P3-stabicipNA (inhibitor)

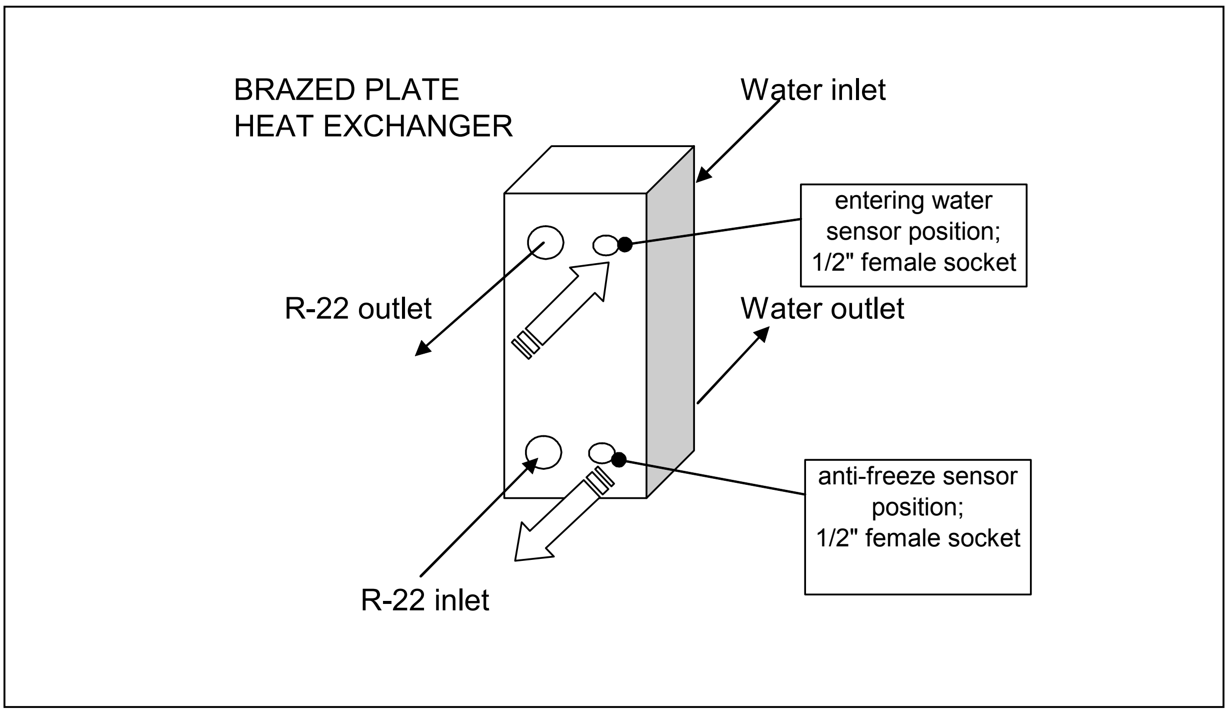
Recommendations for Cleaning

It is recommended that the cleaning chemical to be pumped directly into the BPHE, which will also recirculate into the piping network.

Flush out all water from the piping system.

Remove the entering water sensor and anti-freeze sensor from the BPHE. Connect the supply and discharge tubing/hose from the cleaning chemical pump to the BPHE (via 1/2" female sockets).

Do not run the water pump in the mini chiller unit. Run the cleaning pump for 10 to 15 minutes unless otherwise instructed by the chemical manufacturer. Refer to cleaning instructions provided by the manufacturers.



Drain away the cleaning chemical. If necessary, a neutralizing agent (e.g. sodium hydroxide) can then be pumped in a similar manner. Refer to the chemical manufacturer's instructions. After cleaning, flush out with clean water through the BPHE . Refill the buffer tank in the unit and run the water pump to recirculate through the piping system. Drain and refill until all the cleaning chemicals are flushed out. It is also possible to allow the pump to push out water through the entering water sensor socket.

Periodic maintenance

It is a good practice to have a periodic maintenance for the mini chiller, especially on the water side.
Check the water quality regularly. Drain out some water from the buffer tank and observe for excessive impurities and rust. For open systems, this can be done from the reservoir tank.

If the water is dirty (e.g. dark brown in colour), drain away the water and refill with clean water.

It is recommended that the water to be replaced at least once a year to prevent fouling on the BPHE. If the water quality is poor, this should be done more regularly. Close monitoring will be required.

Glycol Solutions

As mentioned earlier, the mini chiller has two water sensors at the BPHE:

a) Water Entering Temperature Sensor

This has an adjustable range of 10 to 15°C. Adjustment is by turning a varistor on the electronic controller board. Refer to the Technical Manual for more details on this adjustment. However, if required, this can further be adjusted down to 3°C, i.e. with a leaving water temperature of approximately -2°C. Such requirements are usually needed for process cooling whereby sub-zero water temperatures are used for cooling of machines and equipment. It is recommended to consult trained technicians or service personnel to perform this adjustment.

b) Anti-Freeze Sensor

This sensor will protect the water temperature from becoming too low and freezes up. Formation of ice in the BPHE will cause it to crack due to expansion. Therefore, the factory setting for this sensor is 2°C. However, if required, this can be further adjusted to a minimum of -4°C, i.e. when used in special process cooling applications. Again, consult trained technicians to do this adjustment.

Because of the danger of the water becoming ice, special precautions must be taken:

1. For sub-zero applications, the water must mix with anti-freeze glycol solution. There are two commonly used types: ethylene glycol and propylene glycol. In some instances, brine (sodium chloride) is used.

   Whatever type is used, the quantity mixed with the water must be sufficient to reduce the water freezing point to cater for the operating water temperature in the process cooling. It is recommended the freezing point is at least 3°C below the operating temperature. For example, if a temperature of -2°C is required, we need to ensure that the water freezing temperature is at least -5°C to prevent ice formation. Looking at the property table of ethylene glycol, the mixture should have about 13% glycol by volume in order to have the required freezing point. See Appendix 15.

   If propelyne glycol is used, the percentage should be about 14.5% by volume.
   The minimum operating temperature of ethylene glycol is -23°C and of propylene glycol is -18°C. The lower water freezing temperature is required, the higher concentration of glycol must be used. However, the viscosity of the mixture will increase, thus increasing pumping power requirements and reducing heat transfer efficiency. High concentrations of glycol will also increase costs and adversely affect the physical properties of the fluid.

2. Make sure that the water pump is ON all the time the chiller is in use. This will ensure no stagnation of water in the BPHE which reduces the risk of ice formation.

Aqueous solutions of glycol are corrossive to metals and therefore it must be used with an inhibitor. This corrossion inhibitor forms a surface barrier that protects the metal from attack. The inhibited glycol solution are generally stable and relatively non-corrossive to most standard materials. The exception is galvinised steel because the zinc coating will react with the inhibitor part found in most formulated inhibited glycol sold commercially.

Performance effects of glycol solutions:

a. Higher concentrations of glycol will retard heat transfer coefficient in the BPHE. For example, a 30% glycol concentration may cause a drop of capacity by about 20%. Refer to the attached graph depicting this drop of performance (Appendix 16).

b. As the concentration increases, the viscosity of the solution also increases. Therefore, the friction losses of the piping system will also increase. A correction factor must be used to evaluate this increase. See Appendix 16.

c. Similarly, the viscosity increase will also affect the water pump performance. The flow rate and efficiency will reduce with higher concentrations. Thus, the head pressure developed will also drop. See also Appendix 16.

Due consideration of these effects must be given when designing and selecting the chiller unit for such a system. Failure to do so may result in insufficient capacity and water flow rate.

Guidelines:

1. Before applying the glycol solutions, thoroughly clean and flush the system. Reaction with sludge, rust, deposits and oil may retard the inhibitor function. This is especially so after using cleaning agents in the BPHE. Complete removal of the cleaning agent is necessary before charging in the glycol.

2. Calculate the total water volume in the system and determine the amount of glycol needed. The solution can be mixed outside the system in drums or barrels and then pumped into the system.
   Use clean and soft water (low in chloride and sulfate ions) for the mixing. Distilled water, deionized water or condensate water may be used for this purpose.

3. The system must not be connected to an automatic make-up water pipeline. This may cause dilution of the concentration and increases the water freezing point.
   The inhibitor portion in the solution may also deplete over time due to reaction with contaminants in the system.
   Therefore, it is vital that a maintenance programme is in place to determine the glycol concentration in the system. This can be measured by using refractometer (which measures the refractive index of the solution), gas chromatography or density bottle (though not so accurate).

4. Do not mix different inhibited glycol formulations together.

Section 10: Heating Operation

In most of our discussion in the previous sections, emphasis has been given to the cooling operation whereby the mini chiller produces chilled water. The heat pump version of the mini chiller (designated with "R" at the end of the model name, e.g. AC 50AR, AC 125BR, AC 80CR can operate both under the cooling mode and heating mode, i.e. it can produce either chilled water or hot water. The heating cycle is run during the cold, winter months. Operation of the heating cycle is accomplished by reversing the refrigerant flow in the circuit with a 4-way valve. By doing so, the BPHE becomes the condenser which rejects the heat absorbed from the ambient air into the water. The mini chiller has been designed with a rated water entering and leaving temperatures of **40°C and 45°C** respectively in the heating cycle.
(Compare rating for the cooling cycle at 12°C and 7°C for entering and leaving temperatures)
The maximum allowable entering water temperature is 50°C, i.e. corresponding to a leaving temperature of 55°C.

The mini chiller has also been designed to operate the heating cycle with an ambient temperature range of -5°C to 15°C.

Because of the higher water temperature, several precautions must be taken into consideration when using this system:

Application considerations:

1. In multiple chiller installation, all the chillers must either run in the cooling mode or heating mode. We cannot have a few units running cooling cycle while the rest running heating cycle because this may damage the compressor as a result of overloading.

2. In the same manner, in multiple fan coil units installation with a single mini chiller, the wiring of the system must be in such a way to have all the fan coil units either in cooling mode or heating mode.

3. Do not use PVC pipes for such heating systems. PVC is OK for chilled water but long term usage with hot water will soften and weaken the material. Most of these pipes will exhibit sagging in between supports after some time.
   It is recommended that black steel or copper pipes to be used instead.

4. Any gaskets, sealants or insulation material used in the piping system must able to withstand temperatures of at least 60°C without degradation of their physical properties.

5. Recheck again the pipe insulation thickness which has been sized for the cooling cycle to prevent condensation. In the heating cycle, the insulation thickness must be sufficient to have a safe handling surface temperature (e.g. 30 to 35°C).

6. As a result of the reverse cycle, the finned tube heat exchanger coil will now act as an evaporator in the heating cycle. Therefore, moisture removal will occur at this coil and the water will flow down to the ground. Care must be taken for proper drainage of this water. Do not allow this condensate water to drip onto live wire parts. Do not allow this water to form puddles and submerge wire cables.

7. As mentioned in Section 9, scaling of the BPHE becomes more prevalent with hot water systems (temperature >50°C). A more regular monitoring of the pressure drop across the BPHE is required to check for fouling. A better periodic maintenance programme may be necessary.

8. Check the pump specifications whether it can operate at the required operating temperature. The GRUNDFOS CH pumps have a maximum fluid temperature of 90°C. It is also a good practice to counter-check again the NPSHA for the pump with the higher water temperature. This is because the vapour pressure of water will increase and will reduce the NPSHA. Refer to Section 5.
   Therefore, the risk of cavitation occuring in the pump is higher with hot water systems. Adjustments to the system may be necessary for a safe operation.

9. The hot water will cause expansion of the pipes. The linear thermal expansion for carbon steel and copper changes as follows:

Temperature.°C	**Linear thermal expansion, mm/m**	
	Carbon steel	**Copper**
0	0.2	0.31
10	0.32	0.47
49	0.76	1.14
Increase with respect to 0°C	2.8 times	2.7 times

Therefore, it is important that the piping installed with the supports must have sufficient flexibility to allow for the expansion. A general practice is to never anchor a straight pipe run at both ends. Pipe bends and loops are excellent to absorb such "shape changes" due to expansion and contraction. Rubber expansion joints can also be installed along the piping for the same purpose.

During operation of the heating cycle, check for any piping deformation. Check also for failure of any pipe supports and leakage due to cracking.

10. Perhaps the most important function that occurs during the heating cycle is the defrost function. Operation of heating cycle under sub-zero ambient temperatures will cause the evaportor condensate to ice-up on the fin surfaces. The ice/frost will retard heat transfer and reduces the chiller performance. Therefore, the electronic controller in the mini chiller will initiate a defrost cycle to melt off the ice by momentarily switching the system back to a cooling cycle. During this time, the finned tube heat exchanger will become the condenser and gets heated up to melt off the ice. Once completed, the chiller will again revert back to heating cycle.

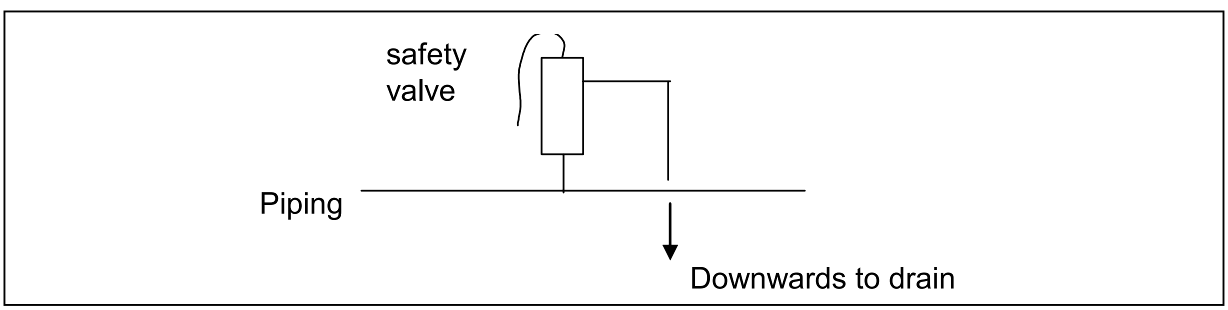
    During the defrost cycle, there will be a lot of water dripping down from the unit. Always ensure proper drainage of this water. See Clause 6 of this section.

    When running this defrost cycle initially, there may be instances whereby the controller will trip the chiller. Check the nature of fault from the controller LED display (e.g. "HP" or "LP"). Refer to theTrouble Shooting table in the Technical Manual for remedial actions. It may be necessary to consult trained service personnel to perform some minor adjustments to optimise this defrost cycle.

11. It is an <u>option</u> whether to install or not a safety pressure relief valve into the pipe system It is recommended for safety purposes, but this will increase the cost of installation.
    Such valves are useful to protect against overheating of water when the other safety protection features in the chiller unit (i.e. water temperature sensor, compressor overload protector, high pressure switch) have failed.
    A reasonable setting of pressure should be selected to ensure a smooth operation under the highest operating temperature without any nuisance trips. An example is 300 kPa.

    Note: Other than overheating, the safety relief valve will also protect the system from
    a) overpressurising from make-up water system and
    b) shocks from water hammer.

    The safety relief valve must exhaust to a suitable drain. Install the drain pipe downwards from the valve into a drain. Horizontal drain pipes can cause injury due to the spitting of hot water.



    The safety valve is usually installed at the highest point of the pipe system and/or near the waterwaer make-up connection.

12. Before purging or releasing hot water from the chiller unit, allow sufficient time for the water to cool down first. Water temperature of 40 to 50°C can cause injury to the body. Remember also that the hot water will be under a higher pressure and sudden opening of drain valves may cause spitting out of hot water.

External boiler installation

In some instances, the heating capacity of the mini chiller unit is not sufficient for an application. Therefore, to supplement the heating capacity, two methods can be used:

1. Electric heater

   1-phase or 3-phase electric heaters can be installed into the fan coil units or into the duct work itself to generate the extra heating capacity required. However, proper installation of the heaters must be done to prevent risk of fire. Due to the high amperage of the heaters, suitable cable size must be used. The heaters must interlock with the fan coil blowers whereby the heaters will not switch on as long as the blower is off. This is to prevent overheating. Thermostats must also be installed near the heaters to cut-off the heaters when the temperature gets too hot.

   Generally, heaters are easy and convenient to use. However, the operating cost of the electricity used is high.

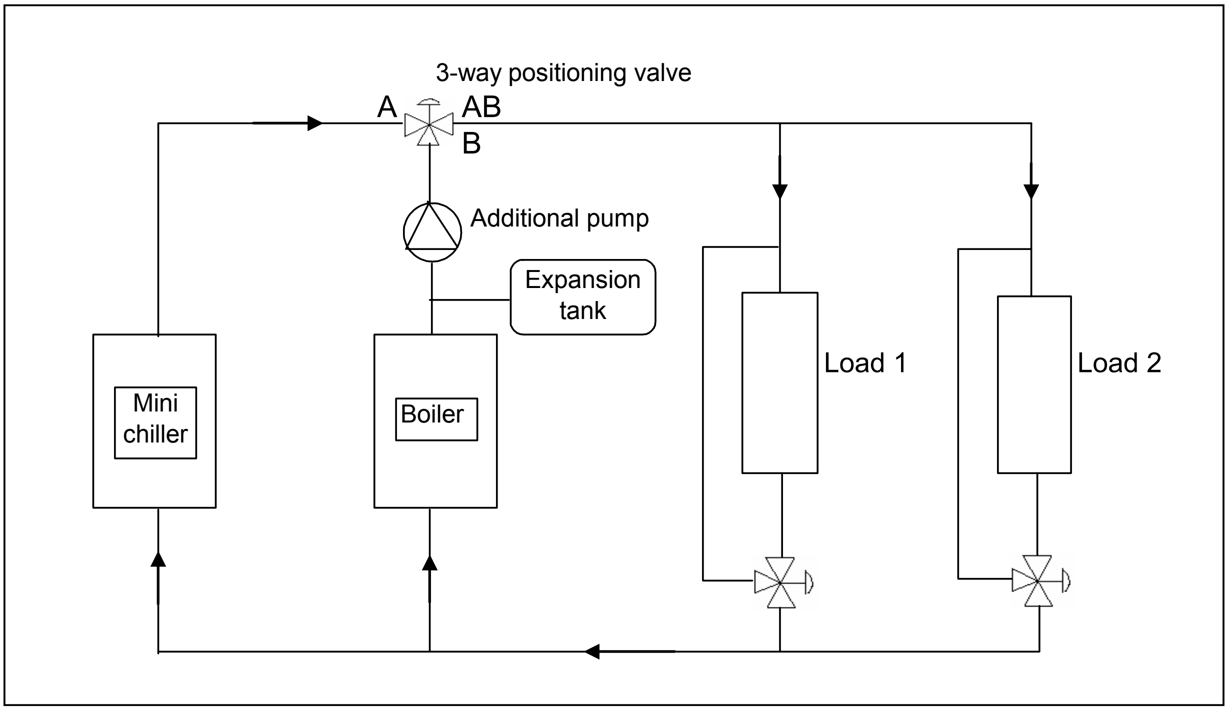
2. Hot water boiler (diesel fired, fuel oil fired or gas fired)

   Boilers can handle larger heating loads with a lower operating cost when compared with heaters. With proper installation and maintenance, boilers can be made to run with high efficiencies. Nevertheless, the operation of the boiler is more complex. Safety requirements are higher. The safe operation of boilers is beyond the scope of this manual. Please refer to the boiler manufacturers for more details and information.

   There are several methods available to run the piping between the boiler and the mini chiller unit, together with the fan coil units. This will depend on the design requirements of a particular system. Only 2 common methods will be discussed here:

   a. 2-pipe system

      In this method, the boiler is connected with a cooling only mini chiller unit via a 3-way positioning valve which is then piped to the fan coil units.
      All the fan coil units must required either cooling or heating loading. It is not possible to have some fan coils in cooling and some in heating.
      However, the boiler will take up all the heating load which cannot be supplied by the mini chiller unit.



When the 3-way positioning valve is at A-AB, chilled water will flow into the loads. When the 3-way positioning valve is at B-AB, hot water will flow into the loads.

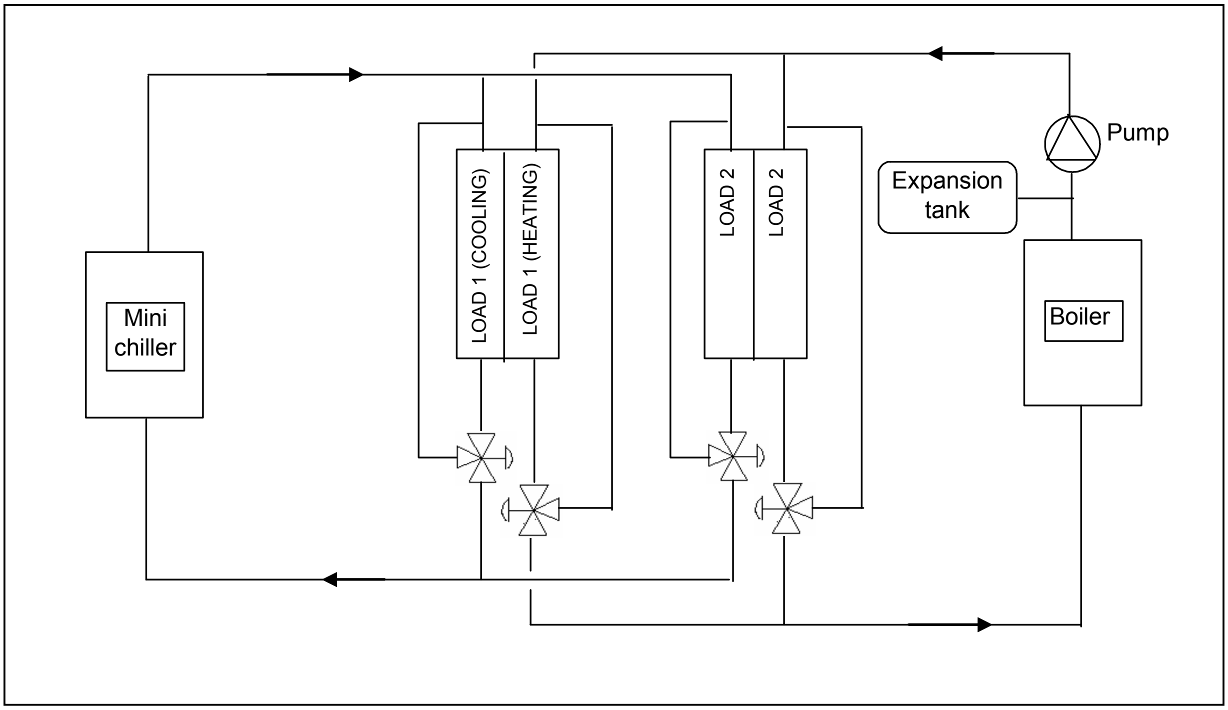
Since the pump is in the mini chiller unit, an additional pump is required to circulate the hot water from the boiler. An expansion tank is also required for the boiler as the expansion tank in the mini chiller is effectively "isolated" from the hot water system. See Section 6 on method of sizing this tank.

The changeover from cooling to heating (and vice-versa) must be done in such a way so as not to expose the chiller unit to damaging hot water and not to expose the boiler to damaging cold water. Such changeover of modes will require some time to allow the water temperature to rise or drop within the safe operating limits of the boiler or chiller. Therefore, rapid load swings are not possible with this method.

b. 4-pipe system

This is the preferred method for such installations. The mini chillers will pumped the chilled water in a separate circuit from the hot water boiler circuit. The heat exchanger in the fan coil units will have two independent circuits to accomodate this.

Therefore, both the chilled water and hot water flow can be regulated and controlled independently, as both the flow streams are effectively isolated from each other.
It is also possible that the mini chiller to be of the heat pump version so that the heating capacity of the chiller can be supplemented by the boiler. Therefore, it is possible to reduce the size of the boiler itself, thus saving cost.



A water pump and expansion tank is also required for the hot water system. By this configuration, we can have the cooling coil in the fan coil unit for humidity control of the air and the heating coil to **reheat** the air. Nevertheless, this method is more expansive as the pipe network is more extensive.

Section 11: Electrical Wiring Control

The mini chiller unit has a PCB (printed circuit board) electronic controller to operate the unit. The function of the controller is:

a) to sequentially ON/OFF the compressor, fan motor and pump according to the water temperature settings and operation mode settings.
b) to protect the chiller from operating beyond the maximum pressure and temperature limits specified.
c) to initiate and terminate the defrost cycle (heating mode only).

A power supply connection is required to operate the chiller unit. Generally, all the models will equired a 3-phase AC power supply (e.g. 415VAC/50Hz)# . The PCB will use this power and convert it to a 12V DC supply to operate the electronic components on the board. By using relays and switches on the board, the PCB will thus perform the above mentioned functions. See the Technical Manual for detailed wiring diagram of the PCB and internal wiring of the chiller.

To connect the power supply cord, open the knockout hole on the chiller unit near the control box. Insert the power cord into the hole and connect them to the terminal blocks provided in the control box (R,S,T,N and Earth).

The following recommended power cable wire sizes are reproduced here from the IOM:

Model	AC40A	AC50A	AC58A	AC75B	AC100B	AC125B
	AC40AR	AC50AR	AC58AR	AC75BR	AC100BR	AC125BR
				AC 80C/R	AC100C/R	AC120C/R
Wire size, mm^2	4	4	4	6	10	16

Other than that, several interconnecting cables must be pulled between the mini chiller and the indoor fan coil units. For all models, it is recommended the size of these interconnecting cables to be of size 1.5 mm^2.

How these interconnecting cables are wired-up will depend on how the system has been designed to operate. See following pages.

Guidelines for wiring installation:

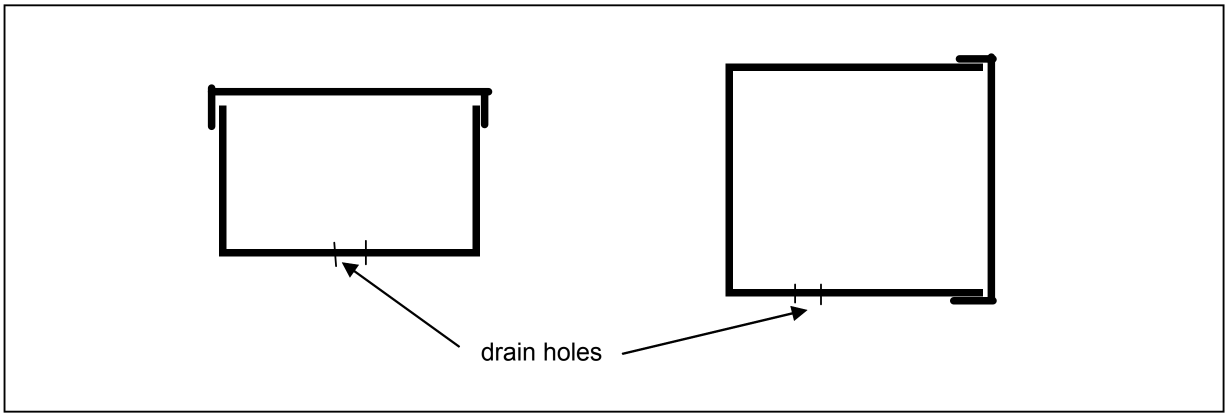
1. Use ring type cable lugs for all termination of cables at terminal blocks. It is not recommended to use fork type cable lugs.

Note #: Refer to the unit nameplate for the required power supply.

2. All external wires must be placed inside a trunking or conduit pipe for protection purposes. Ensure sufficient support for the trunking or conduit so that there is no sagging. It is recommended to use galvanised steel trunking and conduit pipe for external use. Do not use PVC wire conduits because these will become brittle after long exposure to sunlight.

3. Do not allow water (e.g. condensate water) to drip onto the wires. This could lead to electrical shocks.

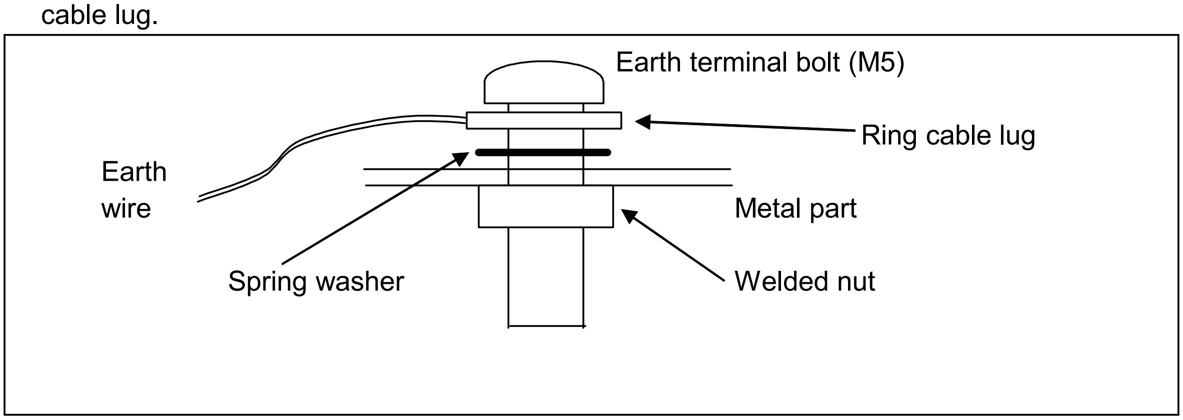
   Do not allow rain water to accumulate inside an exposed wire trunking. It is a good practice to drill some drain holes at the bottom of the trunking to drain out any water.



4. Do not run the wires beneath the chiller unit. Condensate from the heat exchanger or during the defrost cycle may drip down onto the wires.

5. Do not run the wires through a location which may accumulate water, especially after rain.

6. It is vital that the chiller unit has proper Earthing. Make sure that the Earth wire is present and connected. In some models, the Earth wire is connected to a terminal block. In others, an Earthing nut terminal is provided on control box metal part. The wire must be screwed on tightly with sufficient force so that the spring washer beneath the screw will securely hold the cable lug.



Wiring configuration [for series A and series B mini chillers]

For the AC 40/50/58- A/AR series, the PCB is located in the bottom compartment of the chiller unit. There is an interconnecting power cable between this bottom compartment and the upper condensing unit (factory provided). The incoming power cable can either be connected to the upper section or to the bottom compartment. The interconnecting cable to the indoor fan coil units will be done via the bottom compartment. In the control box of the bottom compartment, terminal blocks are provided for the cable termination.

For the AC 75/100/125- B/BR series, there is only one control box which houses the PCB.
This is located in the upper condensing unit. The incoming power supply cable and interconnecting cable will enter into this box. Terminal blocks are also provided for cable termination.

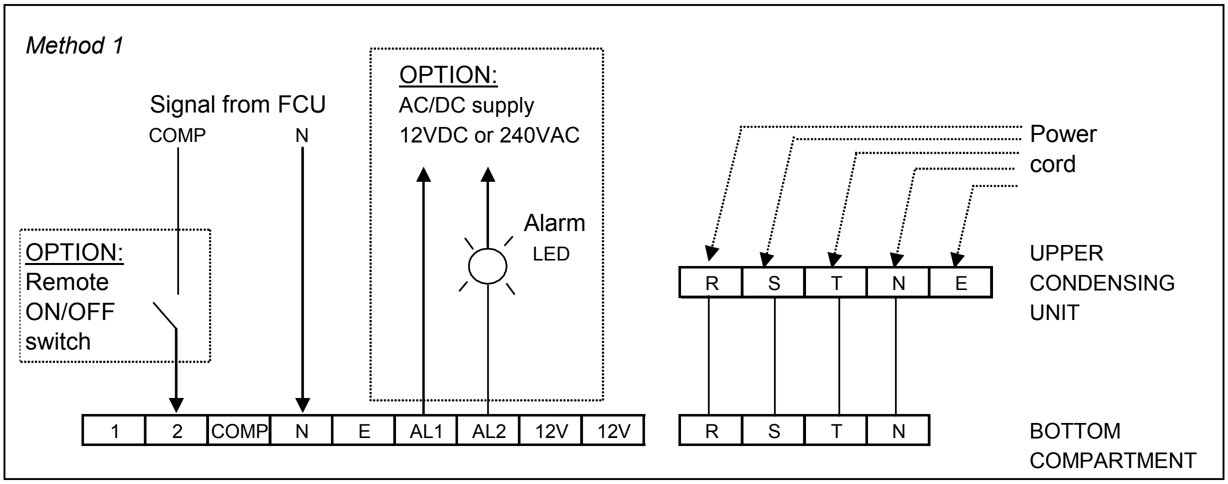
The following pages will describe some examples of the wiring configuration between the mini chiller and fan coil units.
Please note the following items for these examples:

a. The option Alarm LED from terminal AL1 and AL2 is meant to be installed into the switchboard. It acts as a visual indication if an abnormal operation has occured. The PCB will give out a signal to light up the LED when any of the protection devices trip.

b. The option Remote Switch may be located at a convenient place for easy access to the user. It may be placed inside the switchboard. It can also be an emergency switch to stop the chiller unit.

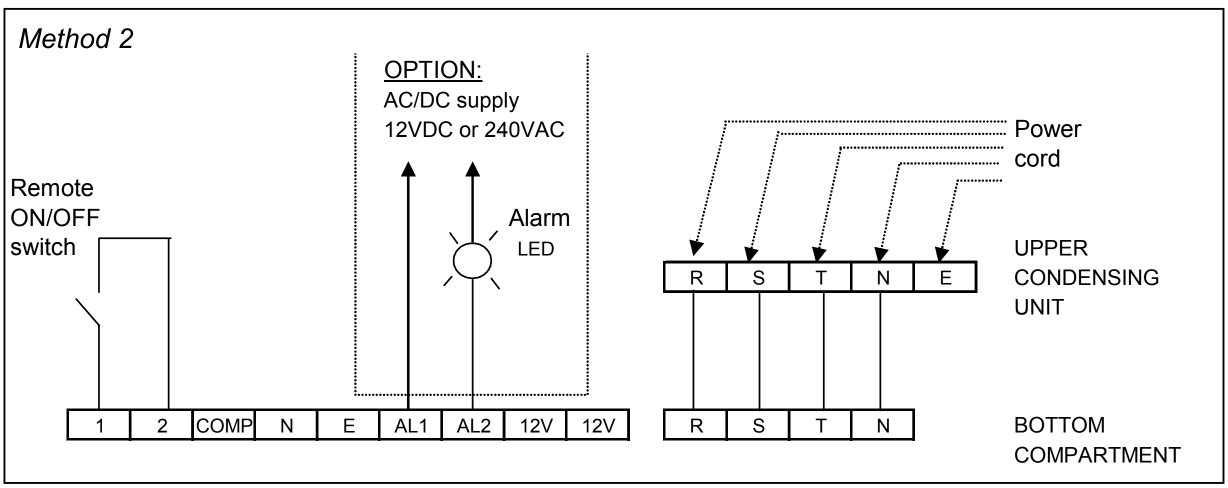
c. The power supply for the fan coil units are separated from the mini chiller.

AC 040A/050A/058A



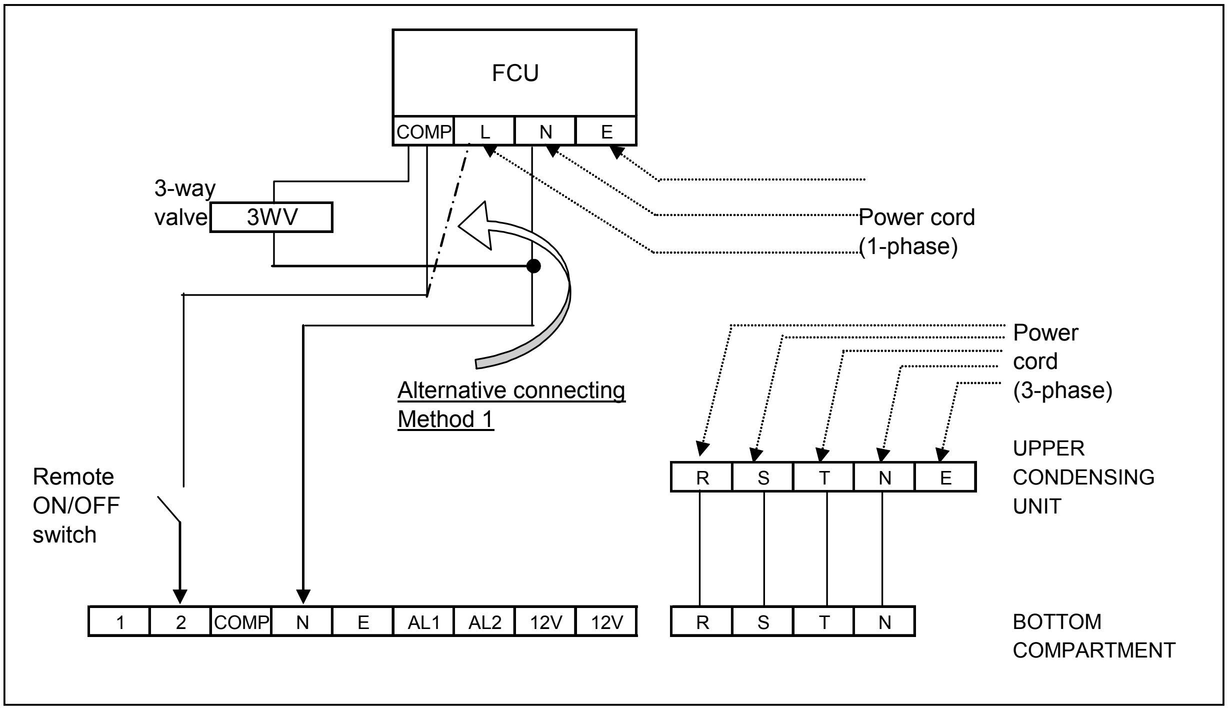
The mini chiller is switched ON or OFF by the command of the fan coil unit. The signal COMP from the fan coil unit will supply the power to the PCB in the chiller. The demand for cooling, as detected by the FCU thermostat, will thus cycle the chiller ON/OFF. However, as a result, the water pump will also follow this ON/OFF cycle. This is not recommended for low water temperature settings whereby the pump must be ON all the time to prevent water freezing in the BPHE.

An alternative to this is to use the "L" terminal from the fan coil unit to connect to "2" (instead of COMP). By so doing, the chiller (and pump) will keep on running as long as the fan coil unit is ON.

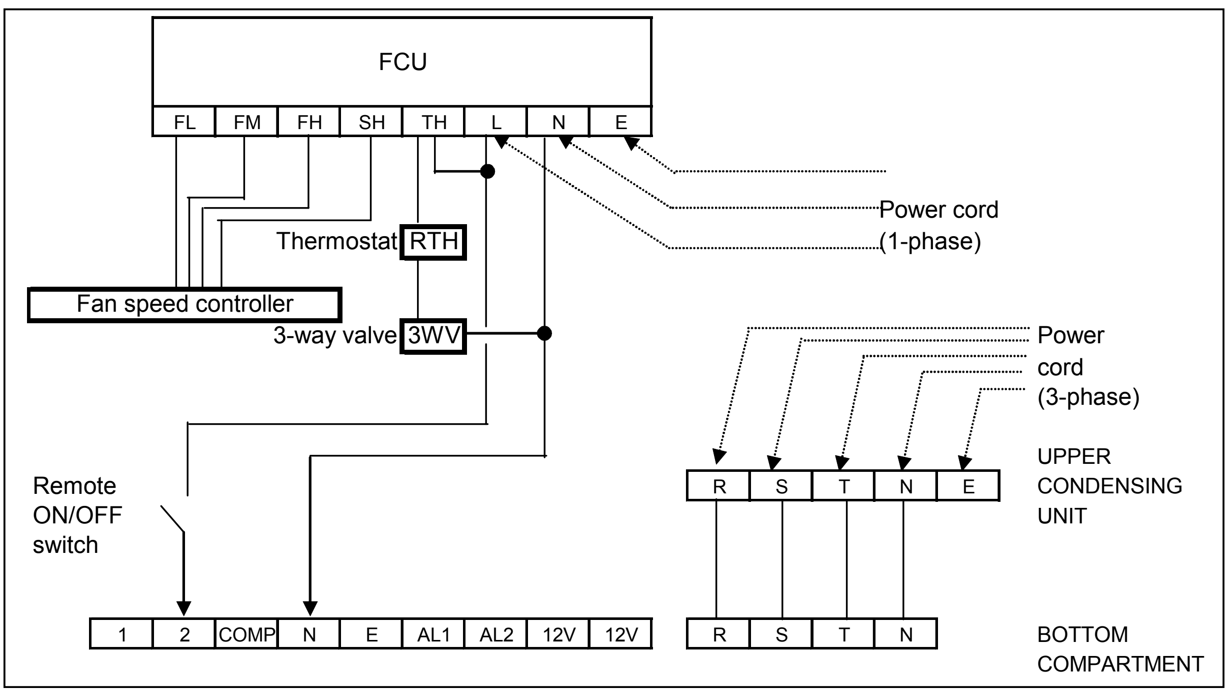


In this method, the fan coil unit will not control the chiller. Rather, the demand for cooling is detected only by the entering water temperature sensor. Thus, the compressor will cycle ON/OFF accordingly. But the water pump will run as long the remote switch is in the ON position.

AC 040A/050A/058A: Together with Fan Coil Unit

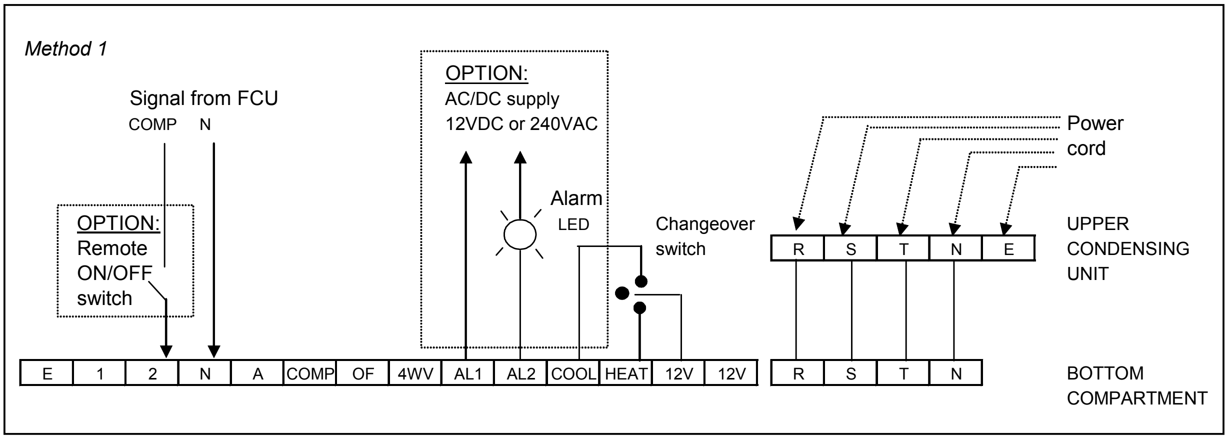


If the fan coil unit do not a controller board in it (e.g. CC-BW,SB-BW models), then the wiring termination will be as follows:



Note: External installation required for the fan speed controller and room thermostat (not provided).

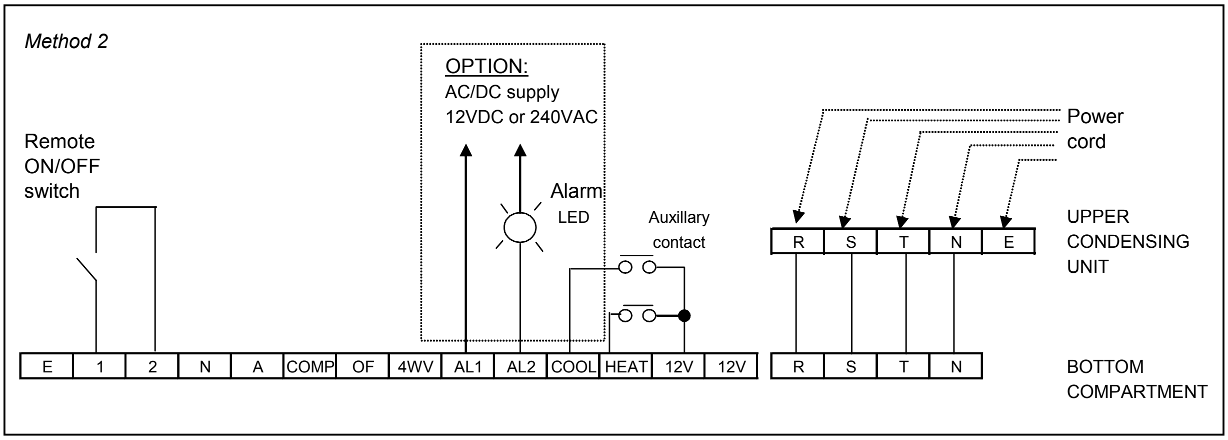
AC 040AR/050AR/058AR



This method is similar to the cooling only models whereby the FCU thermostat will determine the switching ON or OFF of the mini chiller unit. To select either the cooling or heating mode, an additional external changeover switch is used. This switch may be installed in the room itself for easy access.

Note: The changeover switch should have 3 steps: one for COOL, one for HEAT and one for STANDBY. The standby mode will automatically run the water pump when the air temperature sensor measures < 5°C even though the FCU is OFF.

This method is not preferred due to stopping of the water pump once the room load has been achieved. A better alternative to this is to use the "L" terminal from the fan coil unit and connect it to "2" instead.

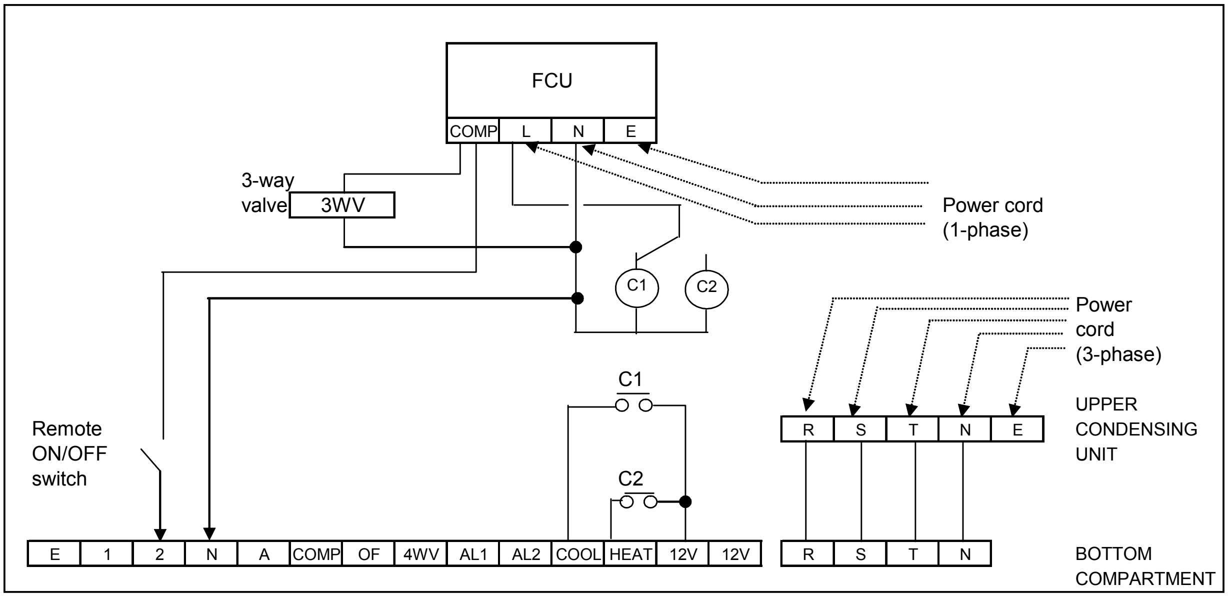


In this configuration, two auxillary relay contacts are connected to the COOL and HEAT terminals, depending on the mode selected. Selection is by means of an external switch. The chiller, and pump, will run when the REMOTE switch is ON.

See next page for more details.

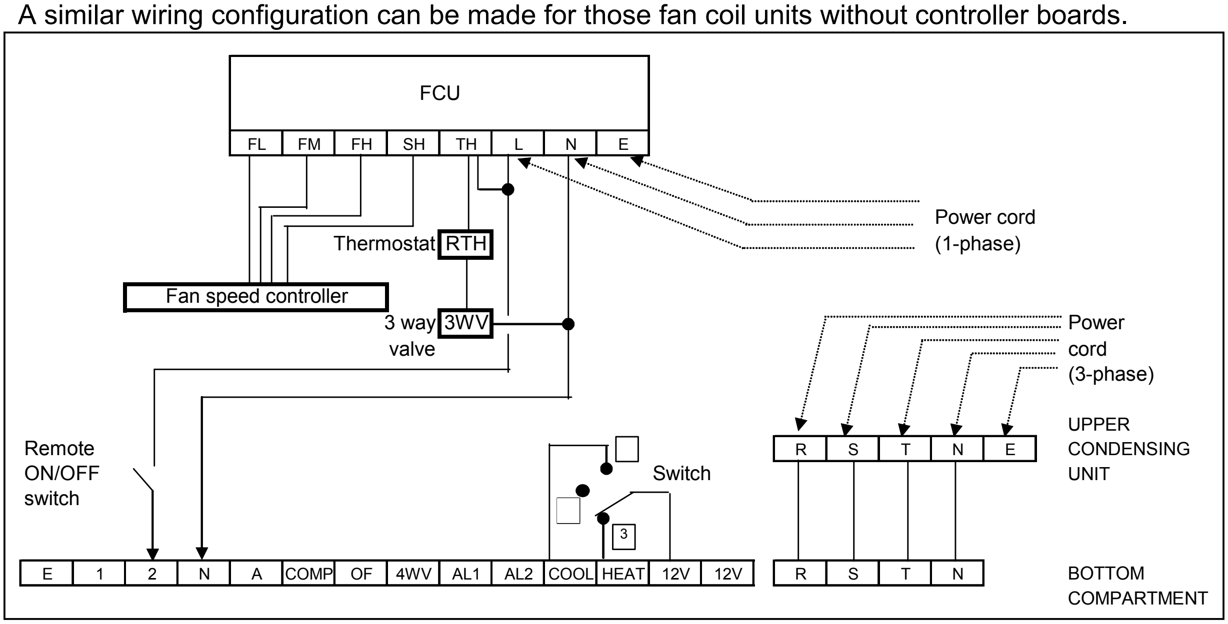
Note: The auxillary contacts are Normally Opened.

AC 040AR/050AR/058AR: together with Fan Coil Unit



C1 is the auxillary relay for cooling mode. C2 is the auxillary relay for heating mode.
If the selection switch is at the center, the chiller will go into Standby mode.
The compressor and water pump will run when activated by the FCU thermostat.

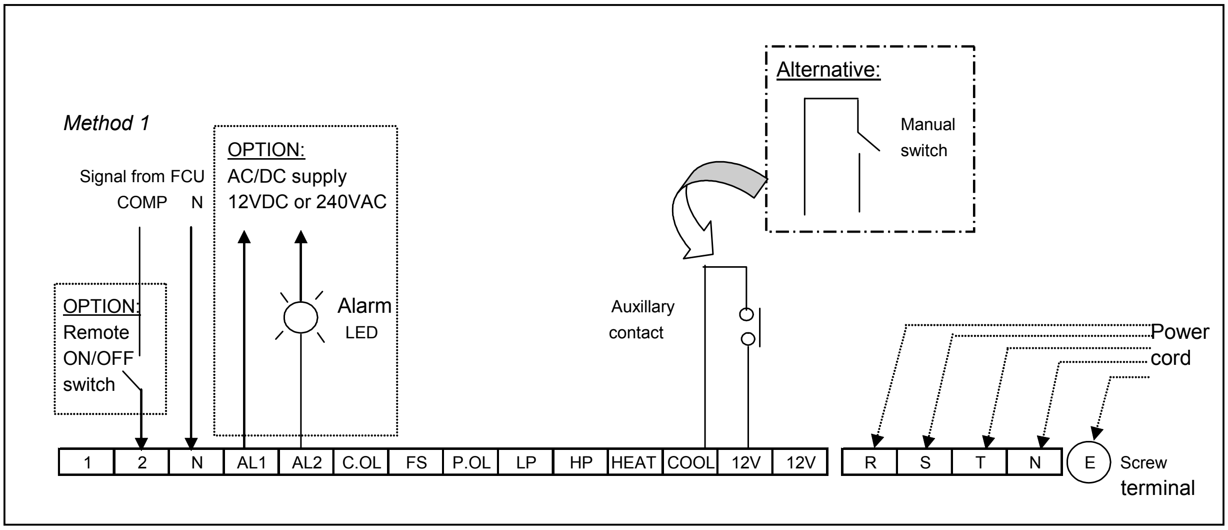
A similar wiring configuration can be made for those fan coil units without controller boards.



The chiller will go into cooling when the switch is at position 1, and heating mode at position 3.
At position 2, the chiller goes into standby mode.
This changeover switch can be located in the room itself or outside near the chiller unit.

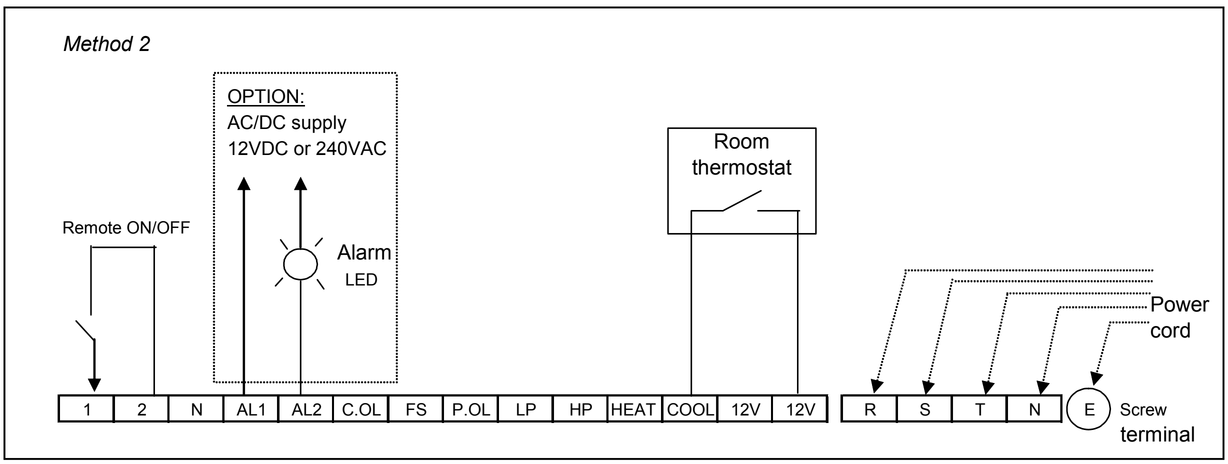
Note: The mode changeover is done by using manual switching.

AC 075B/100B/125B



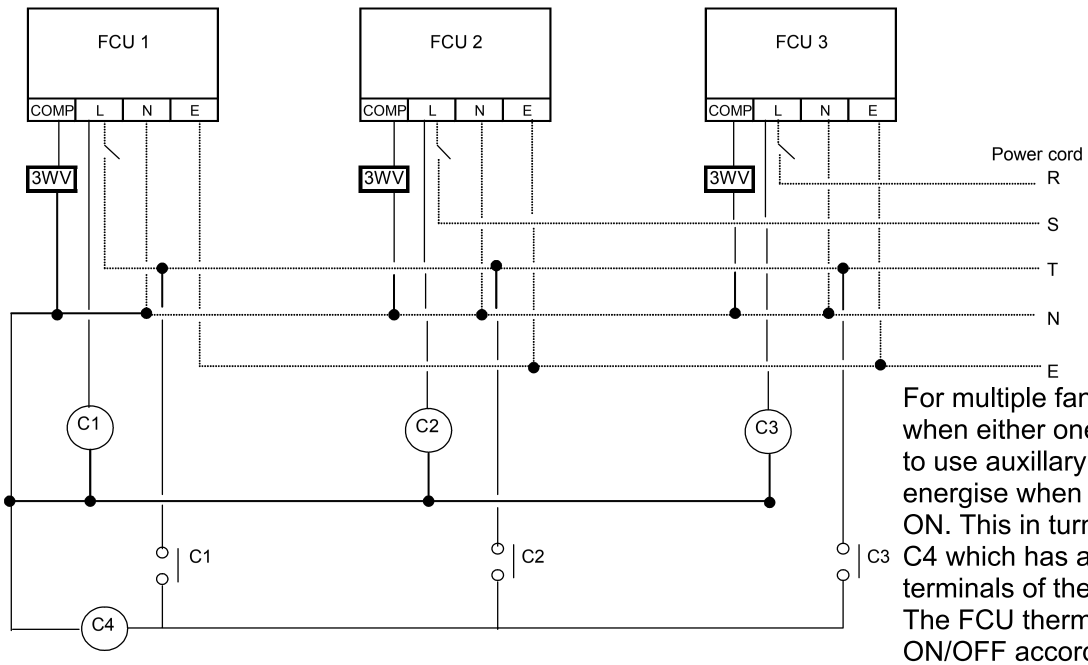
For this range of product, the cooling mode is initiated when the COOL and 12V terminals are connected together. A manual switch or an auxillary relay contact can be used for this purpose.

Since this larger chillers are usually installed with multiple fan coil units, the control signal wire from them to the chillers is more complicated. See next page for more details.

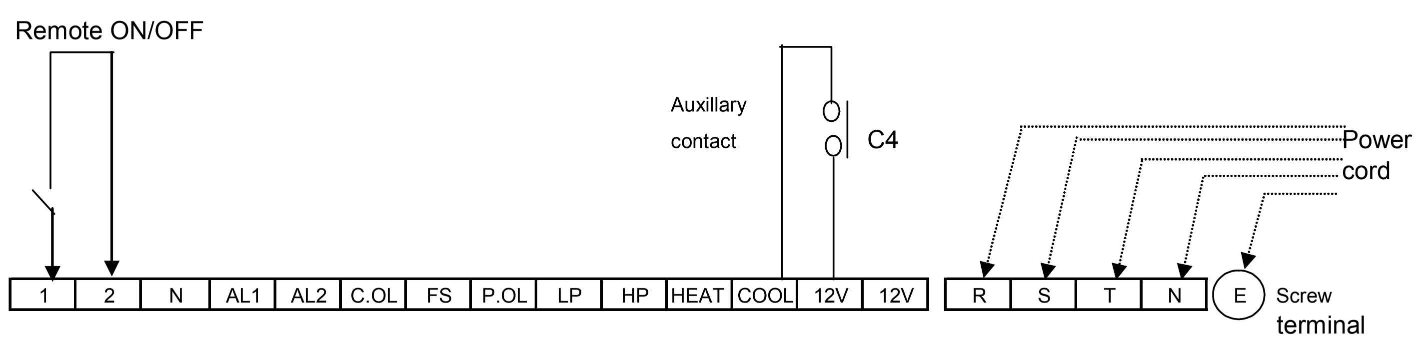


For this option, a room thermostat is used to initiate the cooling cycle. The water pump and compressor will operate when the REMOTE switch is in the ON position, and together when the thermostat switch contact is energised. The fan coil units will not affect the cycling ON/OFF of the chiller, rather the room thermostat will cycle the compressor according to the load demand.

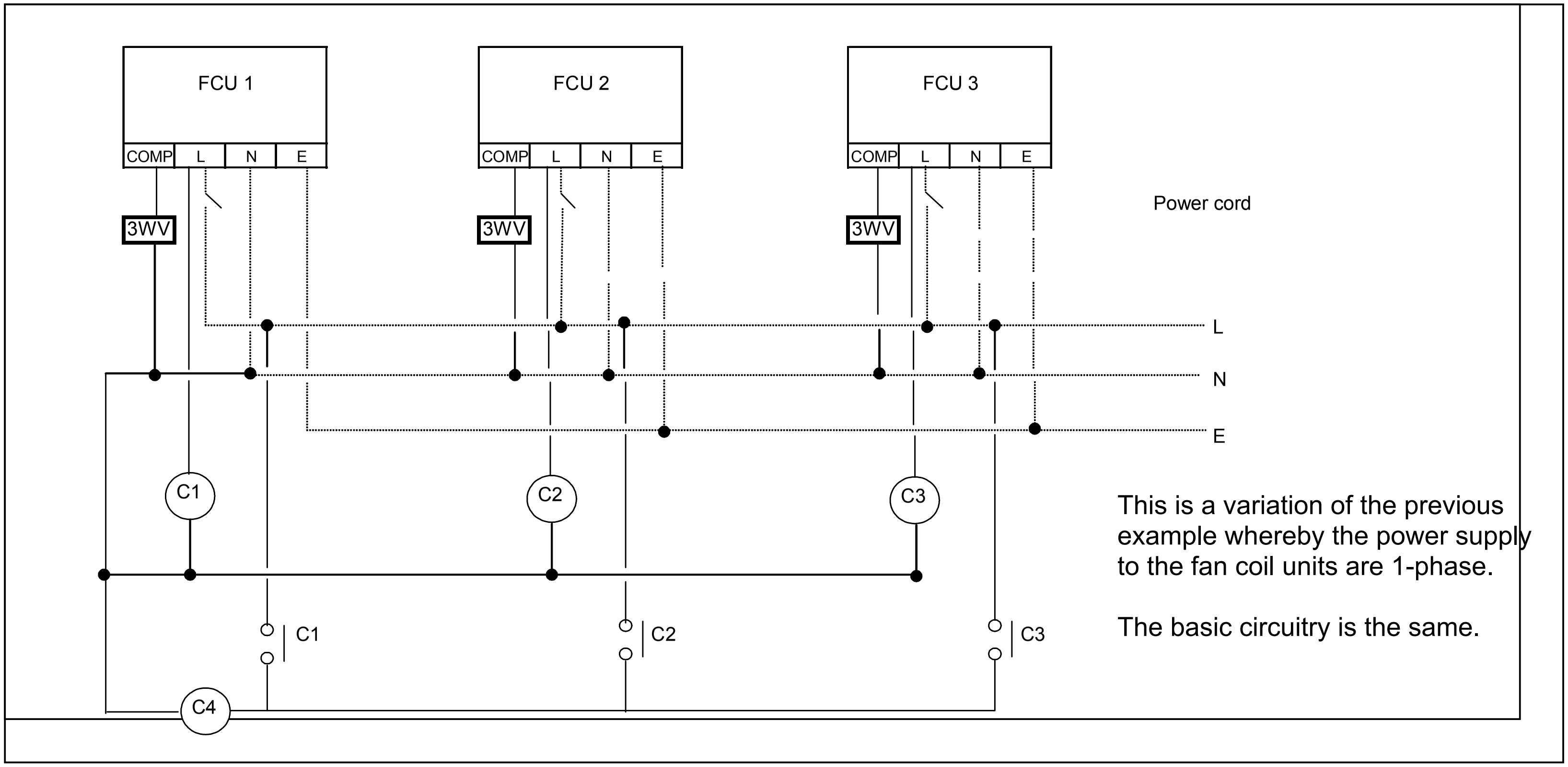
AC 075B/100B/125B: together with multiple Fan Coil Units



For multiple fan coil units, the chiller must operate when either one of them is ON. To do this, we need to use auxillary relay C1, C2 and C3 which will energise when the corresponding fan coil unit is ON. This in turn will then energise auxillary relay C4 which has a contact with the COOL and 12V terminals of the chiller, to initiate the cooling mode. The FCU thermostat will cycle the compressor ON/OFF according to the load demand.

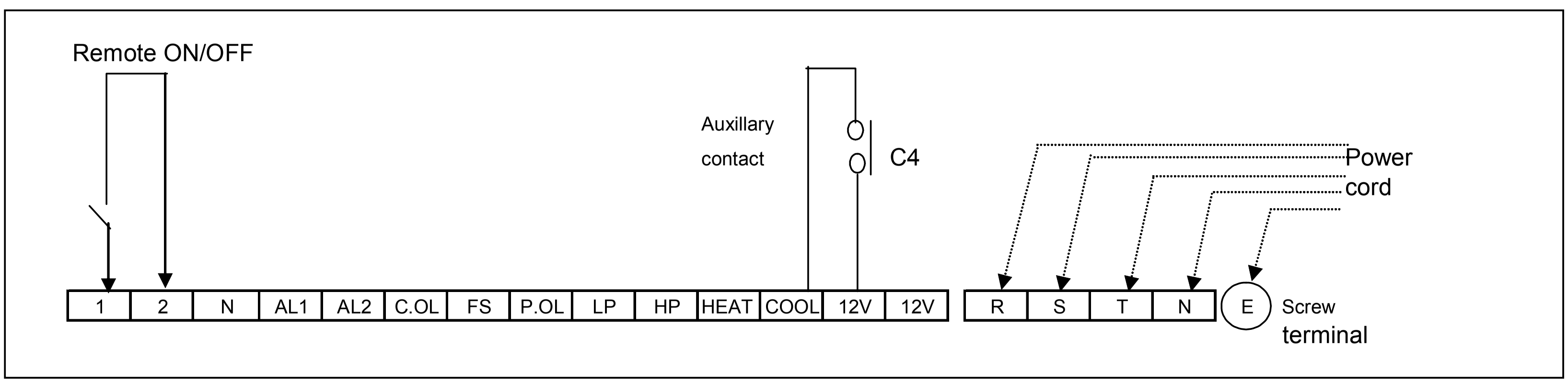


AC 075B/100B/125B: together with multiple Fan Coil Units

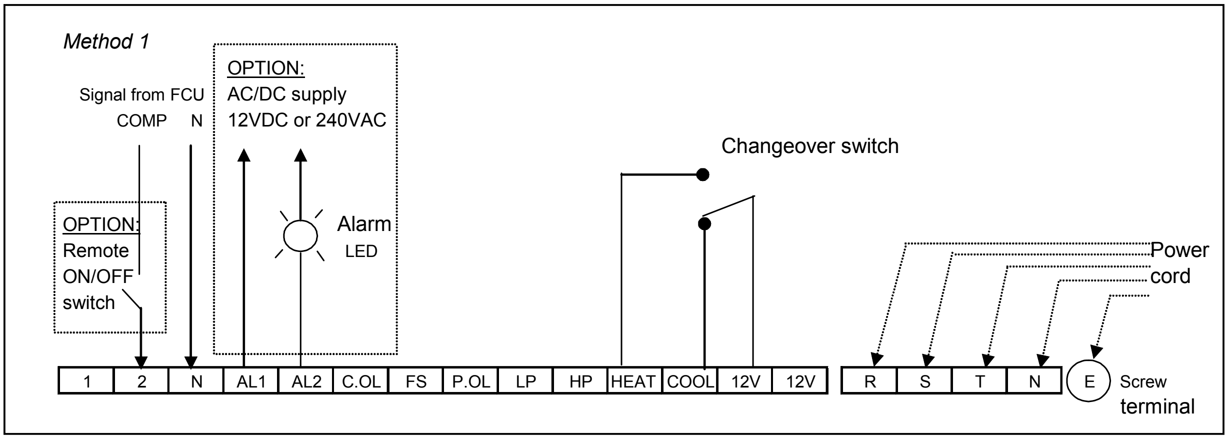


This is a variation of the previous example whereby the power supply to the fan coil units are 1-phase.

The basic circuitry is the same.



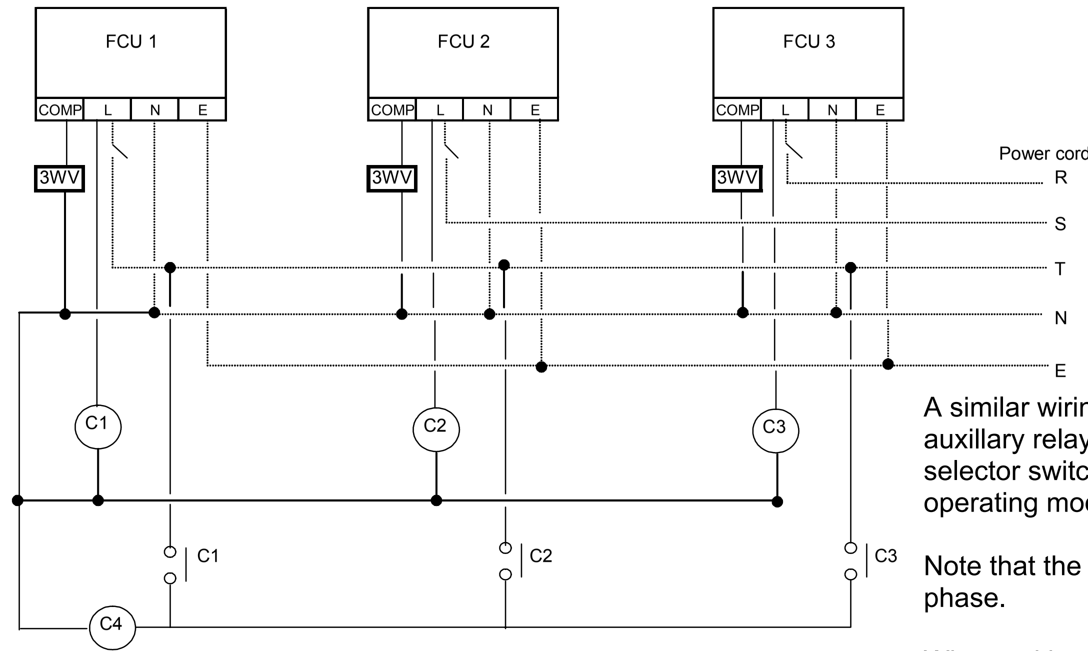
AC 075BR/100BR/125BR



The wiring configuration for this heat pump version is very similar to the cooling only model. The only difference is the manual mode changeover switch between the COOL and HEAT terminals.

The following example will show how the connection is made with the multiple fan coil units.

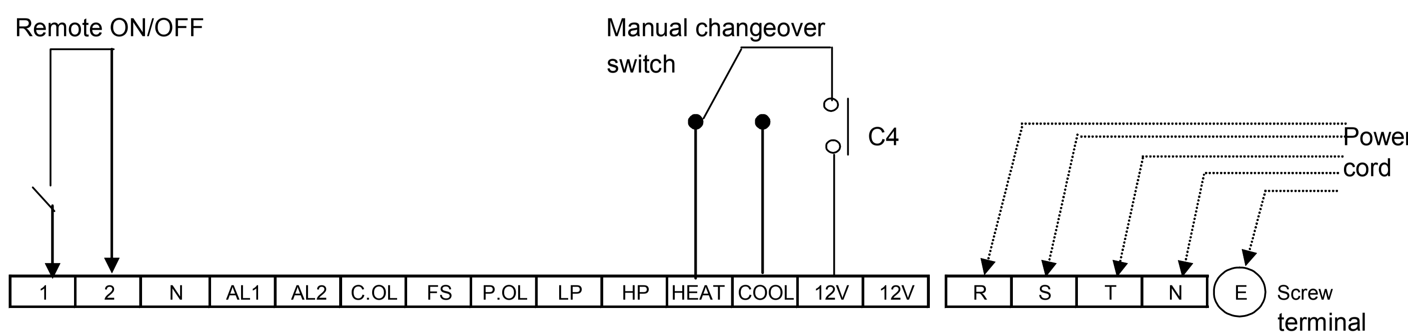
AC 075BR/100BR/125BR: together with multiple Fan Coil Units



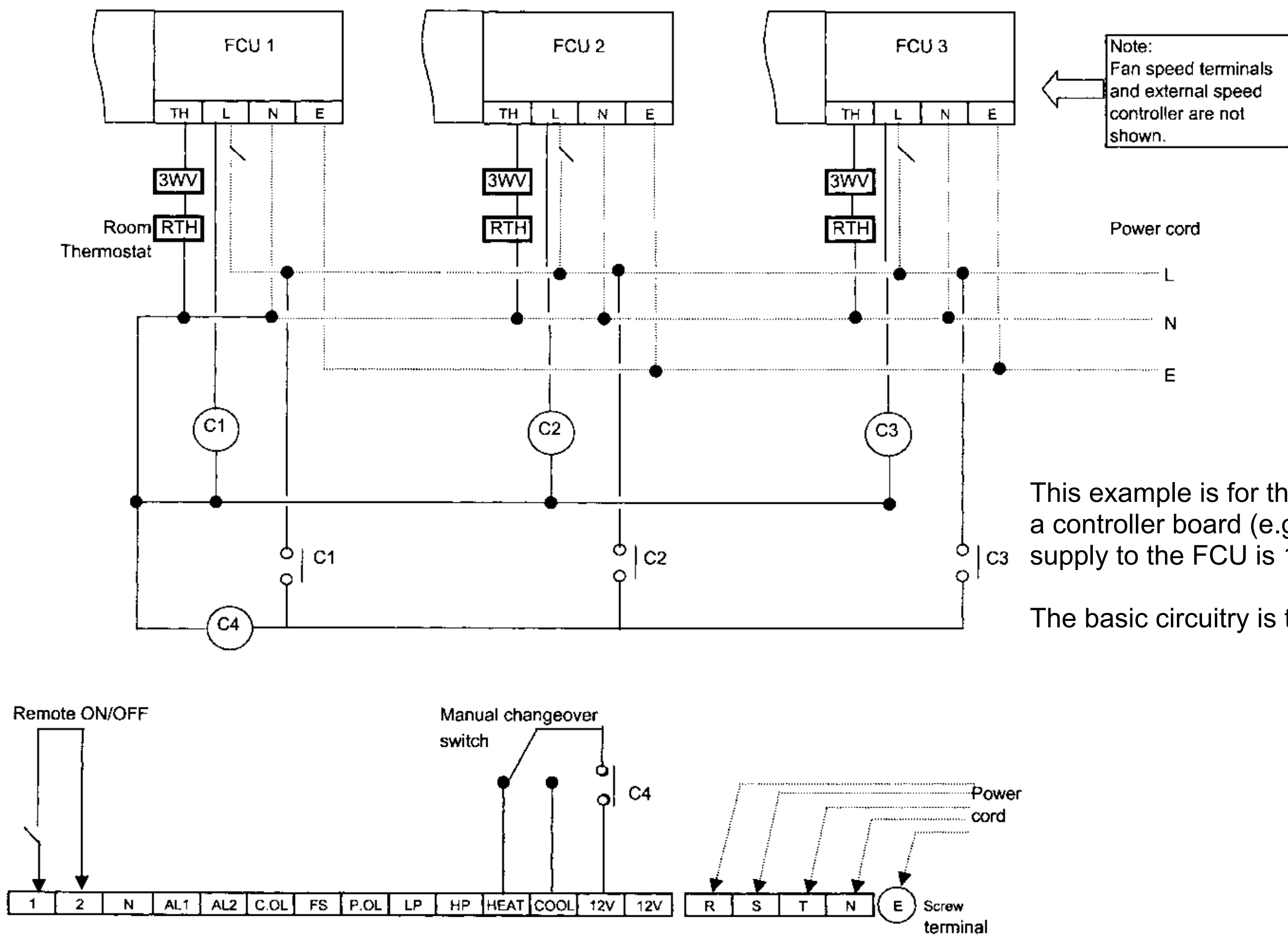
A similar wiring configuration is shown here. The auxillary relay contact C4 will energise but a manual selector switch must be turned to select the required operating mode.

Note that the power supply to the fan coil units is 3-phase.

When neither the COOL nor HEAT mode is selected the chiller will go into Standby mode.



AC 075BR/100BR/125BR: together with multiple Fan Coil Units



This example is for the fan coil units without a controller board (e.g. CC-BW). The power supply to the FCU is 1-phase.

The basic circuitry is the same as before.

Wiring configuration [for series C mini chillers]

For the AC 80/100/120/150- C/CR series, the control box is located just on top of the compartment doors. The controller PCB is mounted inside and all the necessary wiring terminations are made available via terminal blocks for field connection.

There are 3 terminal blocks in the unit:

1

4WV1	4WV2	HTR	ALL IN	ALL OUT	ENSAVE	HP1	LP1	FL	HP2	LP2	CP1A	CP2A	CP1B	CP2B

2

L	L	L	L1	L1	L1	L1	FM1	FM2	N	N	N	N	N	

3

R	S	T	N

The terminals which are available for field connections are: R, S, T, N, ALL IN, ALL OUT, and ENSAVE.

The main power supply (415V/3 phase/50 Hz) goes to the R, S, T and N terminals.
The ALL IN and ALL OUT are alarm output terminals which can be connected to an alarm indicating device (e.g. a siren). The output voltage is 240 VAC. The connection is optional.

The ENSAVE terminal acts as a remote ON/OFF terminal to operate the chiller:

a) A remote ON/OFF switch can be connected to power ON or OFF the chiller unit.

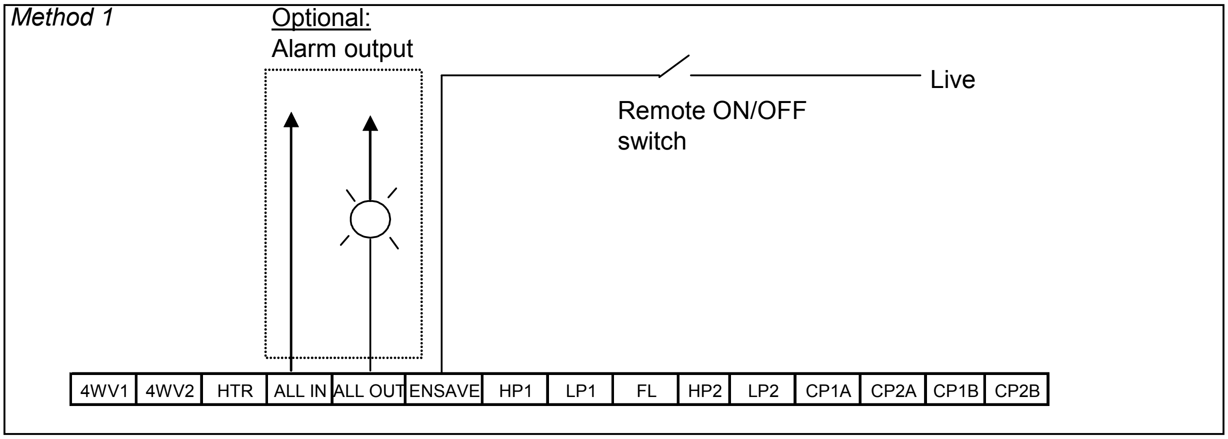
b) Fan coil units can be linked together with the chiller through this terminal, i.e. when the FCU sends a signal to the ENSAVE, the chiller will run. Or, if no FCU is running, the chiller will power OFF.

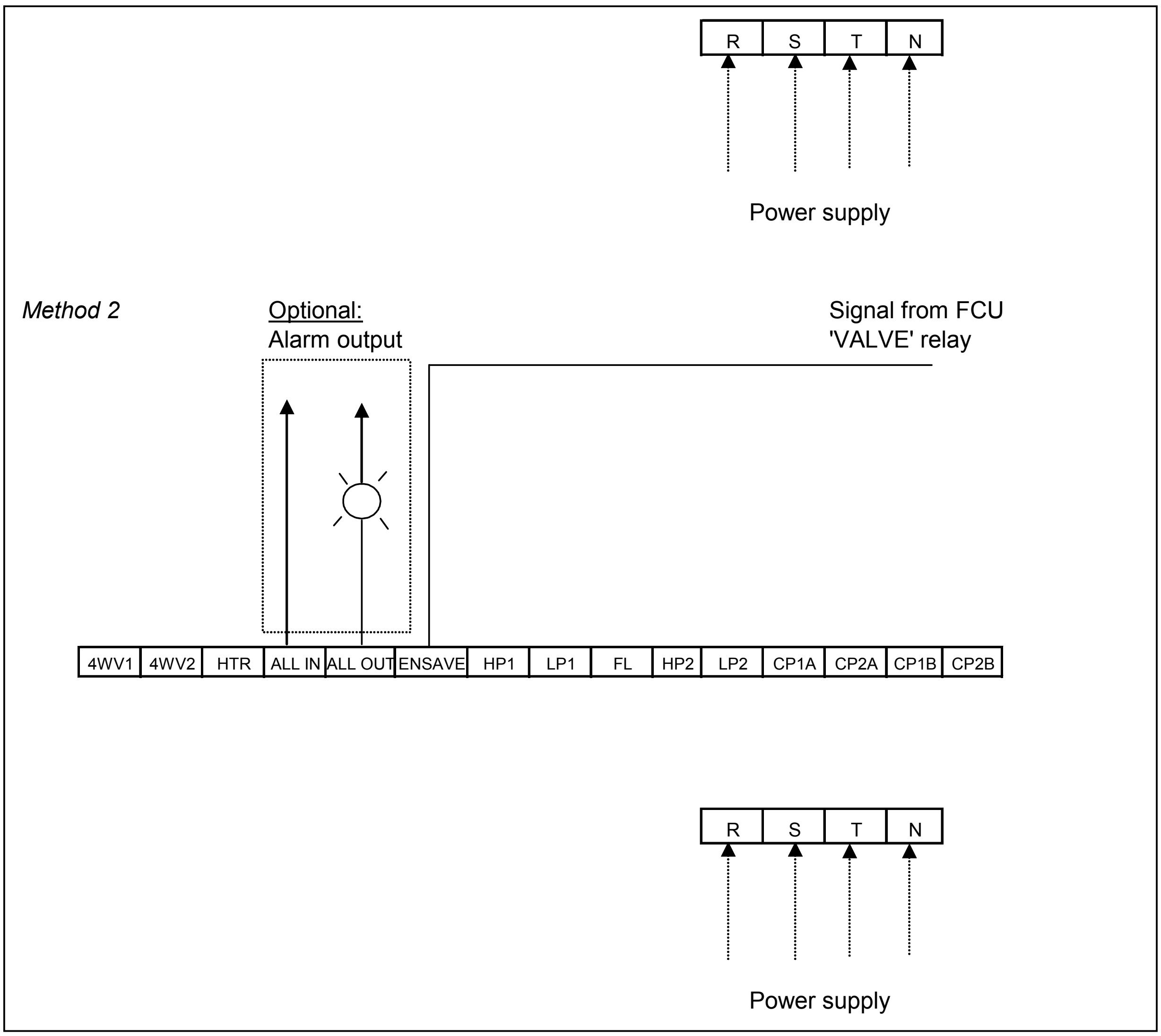
However, if the ENSAVE terminal is used in such a manner, it is not possible to change the chiller operating parameters. The last memory settings will be used instead.

If the ENSAVE terminal is not used, the chiller then will operate by means of the LCD wired remote controller. To allow this, the jumper JP6 must be present on the board. < to allow ENSAVE, pull out this JP6 jumper >

The wired remote controller has a wire length of 20 meters to allow it to be mounted in the indoor room. With this remote controller, all the chiller parameters are set and the chiller performance can be monitored.

AC 80/100/120/150C/CR





Wiring configuration [for series A(E) and B(E) mini chillers]

The 'E' specifications for the series A and B mini chillers have been specially developed for the European market. This range of chillers use **CAREL** controllers to operate.

Carel is a popular controller brand name in Italy, and it has been widely used in air-cooled chillers in the European market. The model of Carel controller used for our chillers is the µCompact, named because of the small size.
It is slotted in front of the control box panel and all connecting wires are done at the back via two terminal blocks.

1

GO	B1	B2	B3	ID5	ID3	ID1
G	GND	GND	Y	GND	ID4	ID2

2

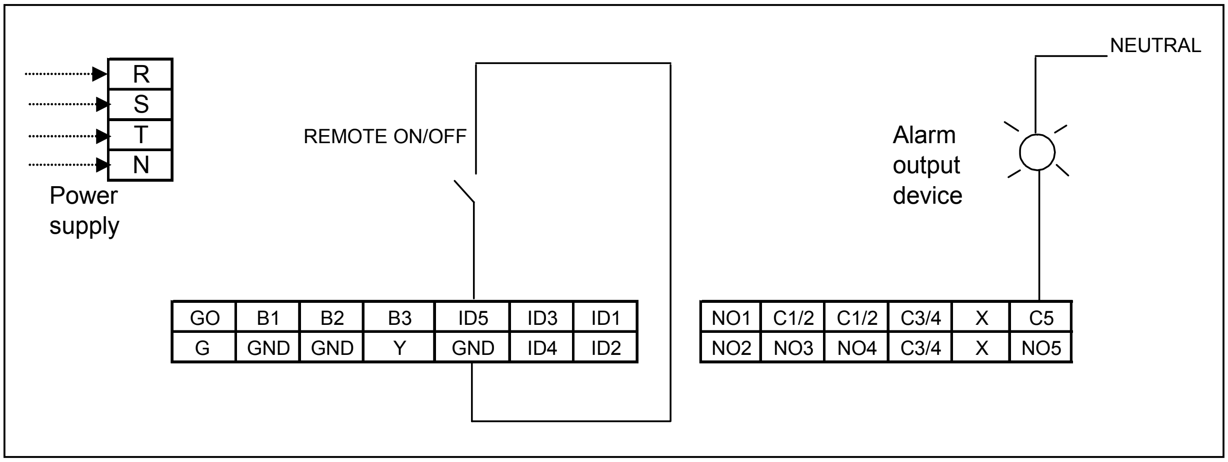
NO1	C 1/2	C 1/2	C 3/4	X	C5
NO2	NO3	NO4	C 3/4	X	NO5

Other than that, there is also a power input terminal block (R, S, T, N) to connect the main incoming power supply (415V/3-phase/50 Hz).

All necessary wire connections have been made ready to the Carel controller. Two optional field wire connections are available:

a) remote ON/OFF switch - via terminal ID5
b) alarm output - via terminal C5

Carel Controller Field Wiring

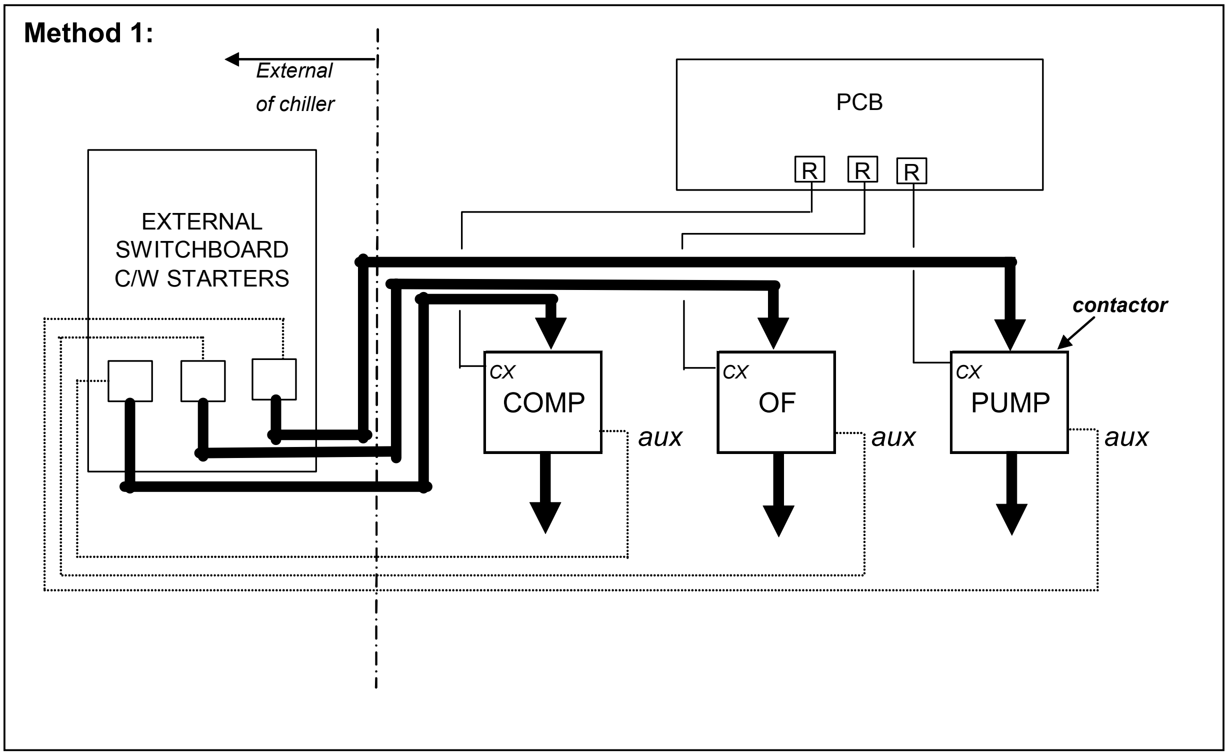


External Starter Board

In some instances, external starter boards are required to fulfill local wiring regulations.
For example, using auto-transformer to start the compressor. Some countries may ask for special starters for the compressor.

Some modification to the control box will be required to accomodate such installations.
Basically, an additional switch board is used to house the starters. This board will be placed externally near to the chiller unit. The internal wiring connection of the chiller must be changed so that the external board can "communicate" with the chiller PCB controller.

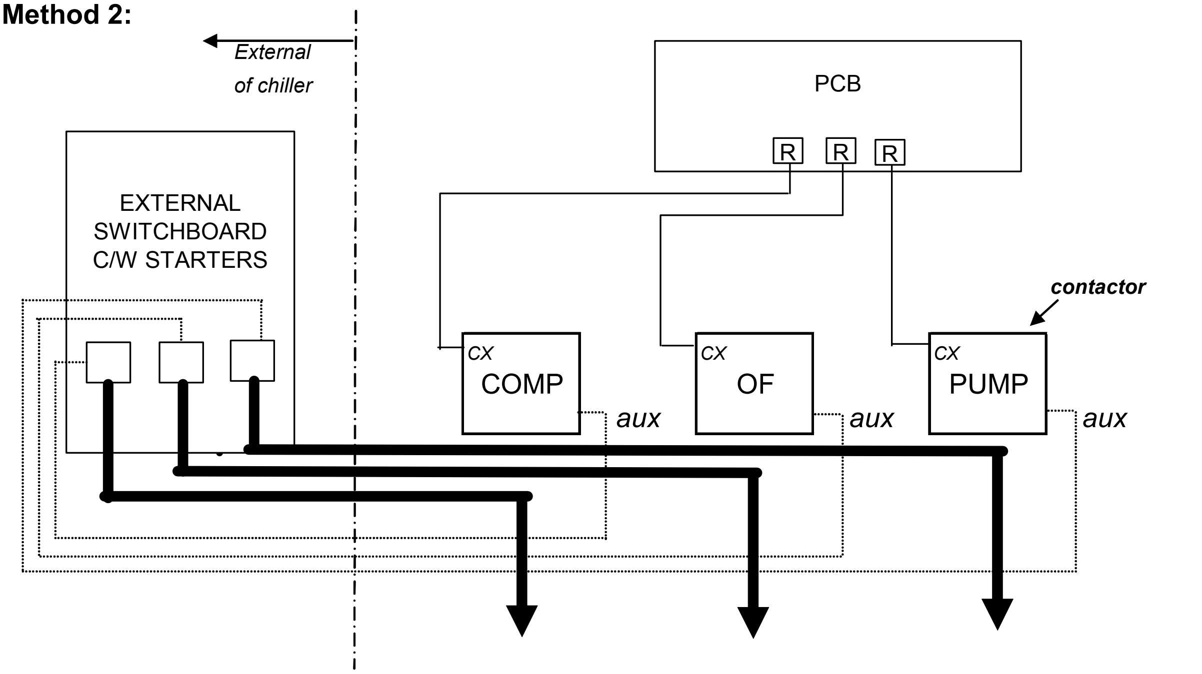
The following are some examples of such modifications:



In this method, the power supply to the contactor of the compressor (COMP), fan motor (OF) and pump (PUMP)is removed and replaced with the supply from the external switchboard. The PCB will still control the the contactor energizing coils (CX) via the board relays (R). Once energized, the auxillary contactor of the contactors (aux) (Normally Open) will send a signal to the starters in the external switchboard to supply the power.

All the safety devices in the chiller will still be in operation.

Method 2:



This method is the same as the previous one, with the exception that the staters will supply the power directly to the compressor, fan motor and pump. The contactors in the chiller unit only act to provide an auxillary signal to activate the starters in the external board.

Because of this, the overload protection of the compressor (CO) and pump (PO) will no longer function in the PCB. Rather, the overload protection is now dependent on the overload settings in the external board.
All the other safety protection devices will still be in operation.

Method 3:

For the third method, the entire control box is not used at all. Rather the entire power switching and protection is taken up by the external board.
Power cables from the external board will be connected to the terminal blocks of the control box. All contactors and PCB is bypassed.

This method is not recommended because of the importance of proper protection of the water side, i.e. anti-freeze and water temperature setting. Transferring the wiring to the external board may result in incorrect or insufficient protection.

Among these 3 methods, Method 1 is the preferred way to install the external starter switchboard. This is because the protection system of the chiller is relatively "untouched" by the addition of the external board.

In any way, such modifications must only be done by qualified personnel. All components in the external board must be properly sized. Follow local or international regulations for guidance. The installed system must be properly commissioned to ensure that the original chiller protection system is still in a good working condition.

Maintenance switch

A manual switch is provided inside the chiller control box to allow switching OFF of the system during maintenance servicing of the chiller.

Do not mistaken this switch as the REMOTE switch described in the earlier pages.

Before attempting to perform service, turn OFF this switch and then turn OFF the main incoming power supply to the chiller.

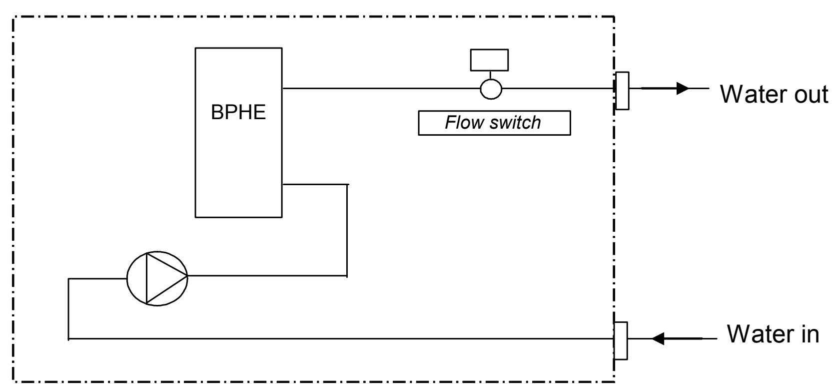
Section 12: Flow Switch

The function of the flow switch is to switch off the chiller unit when a low water flow rate condition is detected in the piping. Such occurances may happen due to:

1. pump failure
2. blocked BPHE
3. accidental closing of shut-off valves
4. failure of control valves

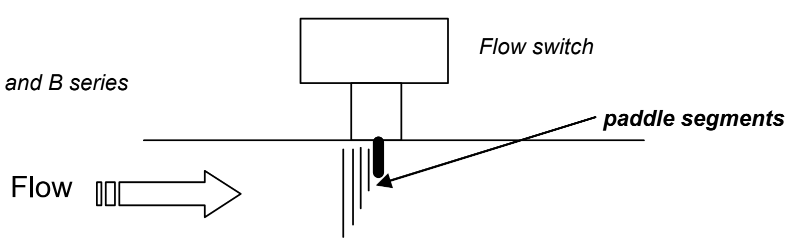
This protection against low water flow rate is necessary to prevent the water from freezing in the BPHE. Ice formation in between the plates in the BPHE will cause cracking.

The mini chiller has a flow switch installed in the piping, at the following location:



The flow switch used in the chiller is JOHNSON CONTROLS model F61KB or F61SB. ##
However, for field replacements, other brands of equivalent sizes may be used.
The flow switch is of the paddle type whereby the switch is connected mechanically to a length of stainless steel paddles which the water flow will impact upon. As a result, the paddle will move in the flow direction and thus closes the electrical contact.
The length of the paddles can be adjusted by selecting the number of segments to use. The paddles can also be trimmed with a pair of scissors to suit requirement.

Note ## *Or equivalent; used only in A and B series chillers.*

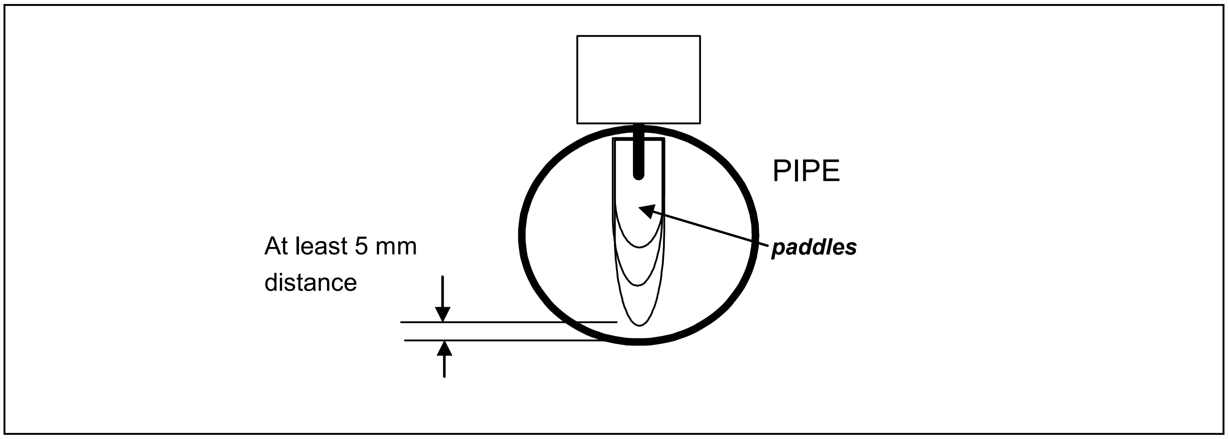


The length of the paddles is very important:

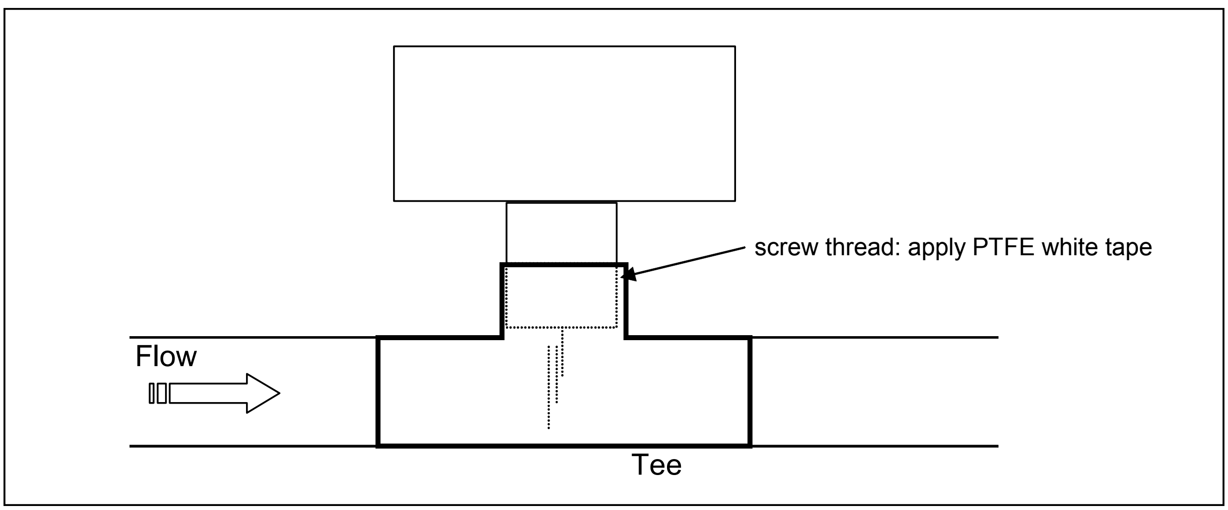
a. If the length is too short, the switch may not contact or if the flow rate is very strong, the paddle may deform.

b. If the length is too long, the paddle may touch the internal surface of the pipe and becomes stuck inside.

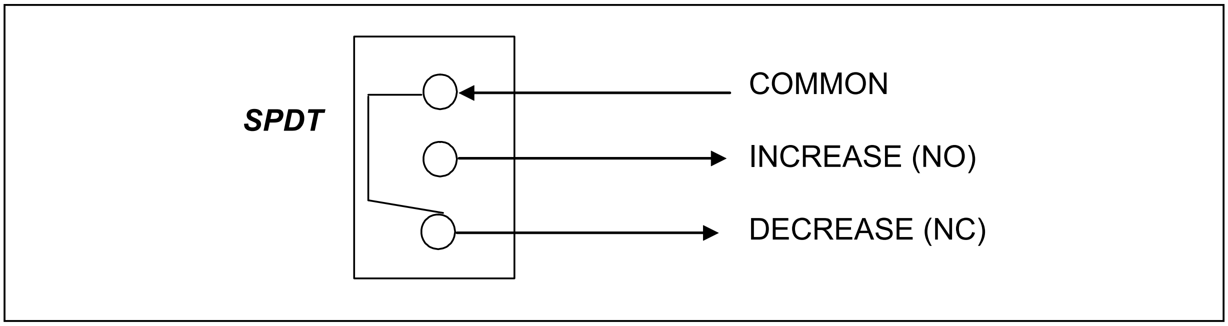
As a general rule of thumb, the length of the paddle should be at least **5 mm** above the bottom of the pipe surface.



The flow switch is also mounted vertically with the paddles in a downward position. It is screwed into the connecting piping (1-1/4") via a tee adaptor.



The switch in the flow switch is a SPDT (Single Pole, Double Throw) type. It has a common terminal and two contacts. One contact will activate when there is an increase in flow, whereas the other will activate when there is a decrease in flow. Each flow switch will have it's own 'activation' flowrate setting. Appendix 17 gives an example for such settings for the F61 flow switch.



Note: We can also call the 'decrease' contact as Normally Close (NC) contact whereas the 'increase' terminal as Normally Open (NO) contact.
When water flows through, the NC contact will open and the NO contact will close.

In the mini chiller unit, the NO contact is connected to the PCB controller via the FS terminal. When the contact closes, a 12V signal is received by the controller indicating that the water flow is OK. When the contact opens, the absence of this signal will prompt the controller to give an error code 'FS' on the LED display.

Some of the typical problems encountered when the FS error code occurred are:

a. the paddle has broken/cracked/twisted
b. the paddle has stuck in the pipe
c. the switch mechanism has jammed - e.g. due to debris
d. wrong wiring of the NO and NC terminals (reversed)
e. failure of the switch contacts - e.g. due to shorting
f. wrong adjustment setting of the switch
g. air lock in the water pump
h. insufficient water in the system

In the event that the flow switch must be replaced:

1. Drain out all the water in the system.
2. Remove the wiring connections in the switch and remove the switch from the tee adaptor.
3. Replace with a new switch and reconnect the wire. Manually test the switch by pushing the paddle. If OK, there should be an audible 'click' sound. Check sufficient length of paddles. Screw the switch back into the piping.
4. Refill the system with water. Purge out any air by releasing the air lock hole on the pump.
5. Check for water leakage.
6. Test run and confirm switch operation.

Adjustments

The flow switch comes with a factory pre-set setting. Due to the different applications at site, it may be necessary to perform some adjustments to the flow switch to allow it to function properly.

Such adjustments are done to cater for the flow rate requirements. To do this, turn the adjustment screw clockwise or anticlockwise with a screwdriver. For the F61 switch, this screw is located next to the SPDT switch. What this screw does is to adjust the spring tension which holds the switch together.
Turning the screw clockwise will release the spring tension, therefore, a lesser flow rate will activate the switch. Conversely, turning the screw anticlockwise will increase the spring tension, therefore a greater flow rate is needed to activate the switch.

It is recommended that during trouble-shooting of the flow switch, this screw adjustment is checked for wrong settings which could cause the system to trip.

Weather proofing

Since the flow switch is exposed to the external elements, and also because of the wet operating environment, it is vital that the flow switch cover is screwed on tightly and properly.

For the F61SB model, the cover comes with a piece of rubber gasket around the edges to prevent moisture from entering the switch.
Do not remove this gasket from the cover! Make sure that the gasket is seated correctly along the edges before the four screws are tighten.

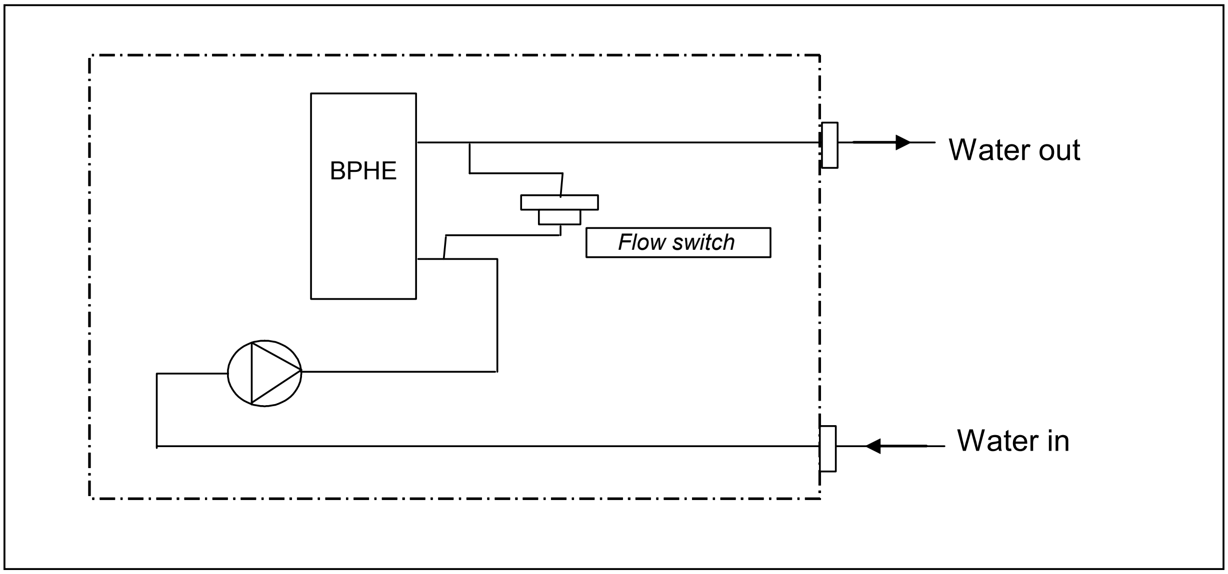
Some flow switches have an 'inverted cup' cover which prevents entry of moisture into the switch. Such switches do not have a gasket. Nevertheless, it is vital that the cover sits properly and the holding screws tighten securely. Example of this is the F61KB model.

In the same manner, care must be taken that the incoming cable into the switch is sufficiently sealed to prevent moisture from entering the switch.

Failure to do so may cause shorting of the terminals and corrosion of the internal parts of the switch.

Another type of flow switch used in the mini chiller units is the **differential pressure flow switch.**

This flow switch works by measuring the difference in pressure between the inlet and outlet to detect the flow. The schematic diagram is as follows:



The flow switch model used is SFS 050.

The main advantages of using this type of flow switch is:

a) It does not have moving parts, i.e. it is more rugged and reliable
b) It does not require any adjustments
c) The internal parts are sealed, i.e. it has good water-proofing.

The flow switch has three wires coming out of it, i.e. common (black), normally open (blue) and normally closed (brown). The wiring in the chilller has been configured whereby the common and normally open wires are connected to the PCB.
This means that when there is sufficient water flow, the switch contact will close to give a 240 VAC signal to the PCB.

The operating pressure differential to close the NO contact is 50 mbar, whereas to open it is 27 mbar.

Connection of the switch to the water pipe is done with two flexible hoses, screwed in with threaded couplings to access valves. This facilitates easy replacement of the switch as it is not necessary to drain away all the water in the system during servicing.

Section 13: System Balancing

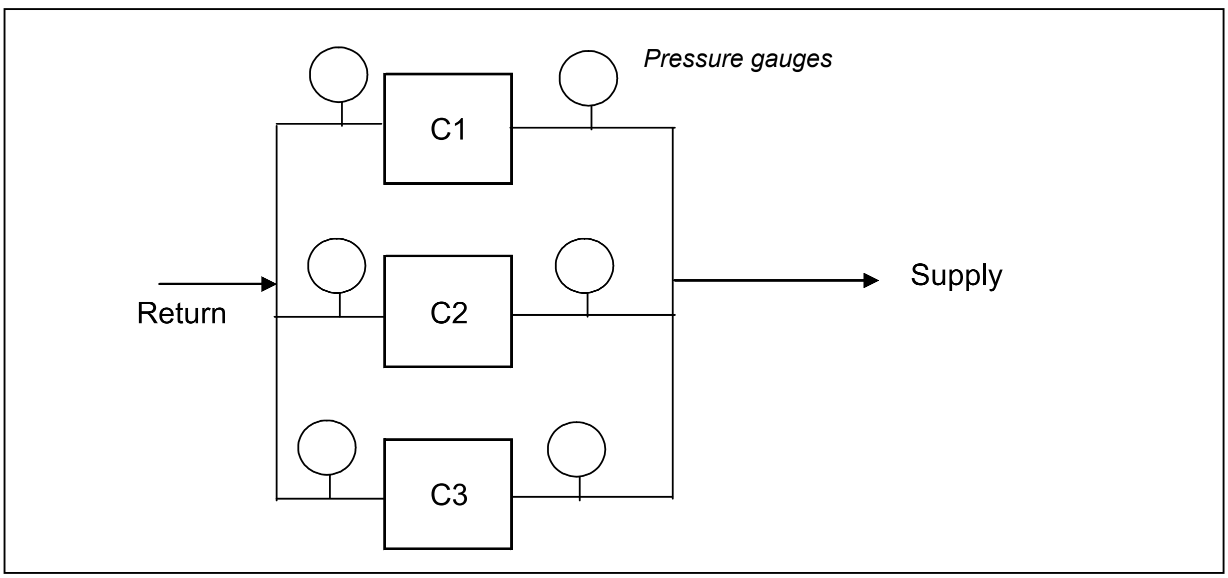
In the previous sections, we have mentioned the importance of ensuring proper balancing of water in the chillers and fan coil units. The act of balancing is to distribute the correct amount of water flowing through the chillers and fan coil units, in accordance to the design specifications. Incorrect balancing can cause unbalance loading of the chillers and different performance characteristics of the fan coil units.

Such balancing is usually done when we have multiple chiller units and multiple fan coil units in parallel to each other.

Before we can perform the system balancing, we must first know what the design specifications are for the chillers and fan coil units. We need to know the required water flow rates through these equipment. References to the Technical Manual must be made available. Water pressure drop characteristics of these equipment must also be known.

Once we have all these information, we will next need to do some measurements. **Without any measurement data, we cannot do balancing.** The following are some examples of such measurements:

1. **Multiple chillers in parallel**



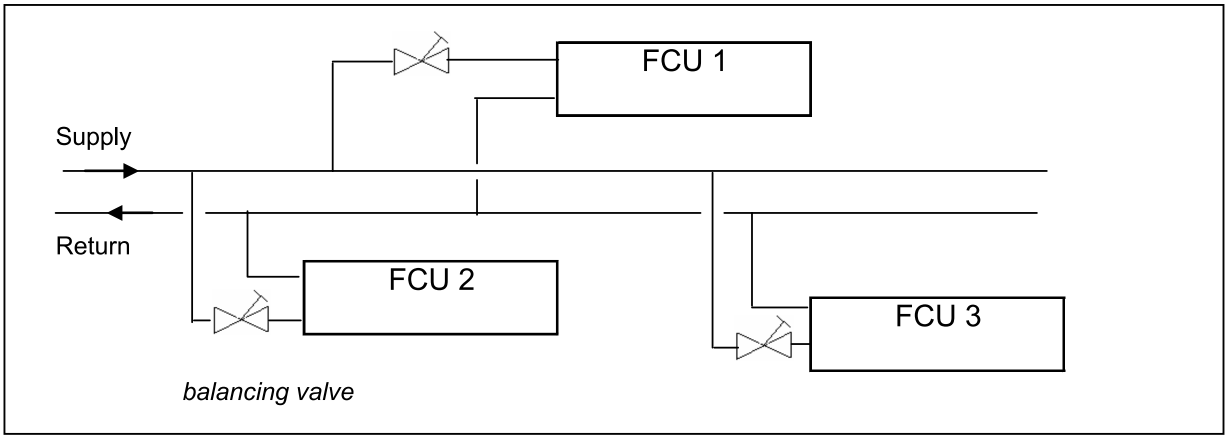
To do balancing, we will measure the water pressure on the supply side of each chiller. These will give an approximate head pressure developed by the each pump in the chiller. By using the corresponding pump curves, we can then determine the water flow rate through the chiller. Compare the data with the design specifications.

If the system friction loss is high, the head pressure indicated will be higher than the design value. Conversely, if the system friction is low, the head pressure will also be low.

Adjustments of the throttling valves (e.g. globe valves, balancing valves) are then made to ensure sufficient flow rate through each chiller.

We can also measure the water temperature difference between the supply and return side of each chiller to check if the balancing is sufficient or not. The correct result should be about **4 - 5 °C**.

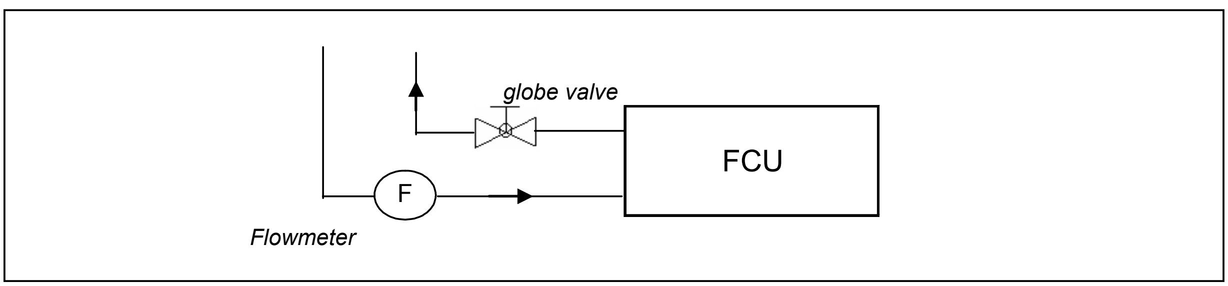
2. Multiple fan coil units: direct flowrate measurement



To directly measure the flowrate, we need to install balancing valves into each of the fan coil units. Each balancing valve will have an inlet and an outlet port to allow connection to a pressure meter. By measuring this pressure drop across the valve itself, the flowrate can be determined by using the valve calibration charts. See Appendix 18 for an example.

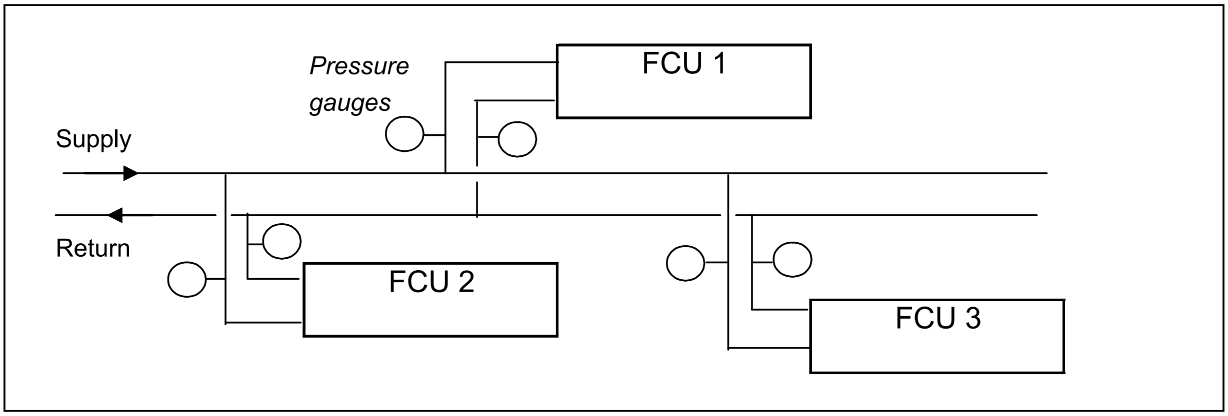
Compare these data with the design specifications. Adjust the balancing valves where necessary to obtain the required flowrate.

Note 1: It is also possible to install a flowmeter along the supply line together with a globe valve, to perform the same function as above. An orifice type flowmeter may be suitable in such case.



Note 2 : The balancing valves can also be installed for the multiple chillers as in example 1 above to measure the flow rate.

3. Multiple Fan Coil Units: Indirect Flowrate Measurement



The objective is the still the same, i.e. to measure the flow rate through each fan coil unit. However, in this example, the pressure drop across each fan coil unit is measured and the flow rate is then obtained indirectly from the fan coil water pressure drop performance charts. See Appendix 19 for an example.

Such charts are available from the Technical Manual of the fan coil units.

Again, adjustments can be made to the flowrate by using the throttling valves in accordance to the design specifications.

For both example 2 and 3, the balancing can be counter-checked by measuring the water temperature difference between the entering and leaving. A result of **4 - 5 °C** is expected.

3. Temperature measurement

In the absence of all the flowmeters, pressure gauges and balancing valves, the only possible way to do a simple balancing is by measuring the water temperature difference between the entering and leaving. A reading of 4 - 5 °C is then used as an indication of sufficient balancing.

However, this method is not so accurate due to several reasons:

a. The temperature difference is dependent on the entering air temperature.
   Usually, colder air produces a lower temperature difference due to a lower loading.

b. The temperature difference is dependent on the amount of air flowing through the coil heat exchanger. Lower air volume gives a higher temperature difference.

Section 14: Chiller Shut Down

The following procedures must considered when the mini chiller is shut down for long periods of time:

1. Do not totally disconnect the power supply to the chiller unit. This will allow the compressor crankcase heater to energise and prevent refrigerant migration during the shut down period.

2. The chiller is most vulnerable at shut down during cold weather conditions where there is a danger of the water in the pipes freezes up. To help prevent this from happening:

a. Set the chiller into the STANDBY mode (i.e. no mode selection on the controller)
In this mode, the controller will force ON the water pump when the ambient air is lower than 5°C. At the same time, the BPHE anti-freeze heater will also energise to heat up the water.

If the air temperature goes lower than 2°C, the controller will force ON the chiller unit to go into HEATING mode.

Therefore, the power supply to the chiller unit must not switch OFF.

b. If it is not possible to have the power supply continuously ON to the chiller, then it is recommended to drain all the water in the system.
An alternative is to pump in glycol solution into the system. The concentration must be sufficient to cater for the lowest ambient temperature. Refer to Section 9 for guidelines.

Restart

When the chiller unit has idling for long periods of time under winter conditions, it is a good practice to recheck the water condition in the system. Run the water pump only and check for any cracking or leakages. If the system has been drained of water, refill and perform air venting.

Check if the crankcase heater has been in operation or not. If not, allow the compressor crankcase heater to heat it up for at least 8 to 12 hours prior to running it again.

Check also for condensation or ice build-up in the controller box. Wipe dry if moisture is present.

When restarting the compressor, check for any abnormal sound from the compressor, e.g. knocking sound. This is an indication of liquid compression which will damage the compressor. If such sounds are heard, switch off the compressor immediately.
Allow the crankcase heater to continue warming up the compressor. Repeat the restart again.

If the problem still persists, call for service technicians to rectify.

Table Steel Pipe Data

U.S. Nominal Size, in.	Nominal Size, mm	Schedule[a]	Wall Thickness t, mm	Inside Diameter d, mm	Surface Area: Outside, m^2/m	Surface Area: Inside, m^2/m	Cross-Section: Metal Area, mm^2	Cross-Section: Flow Area, mm^2	Mass: Pipe, kg/m	Mass: Water, kg/m	Working Pressure[c] ASTM A53 B to 200°C: Mfr. Process	Joint Type[b]	kPa (gage)
1/4	8	40 ST	2.24	9.25	0.043	0.029	80.6	67.1	0.631	0.067	CW	T	1296
		80 XS	3.02	7.67	0.043	0.024	101.5	46.2	0.796	0.046	CW	T	6006
3/8	10	40 ST	2.31	12.52	0.054	0.039	107.7	123.2	0.844	0.123	CW	T	1400
		80 XS	3.20	10.74	0.054	0.034	140.2	90.7	1.098	0.091	CW	T	5654
1/2	15	40 ST	2.77	15.80	0.067	0.050	161.5	196.0	1.265	0.196	CW	T	1476
		80 XS	3.73	13.87	0.067	0.044	206.5	151.1	1.618	0.151	CW	T	5192
3/4	20	40 ST	2.87	20.93	0.084	0.066	214.6	344.0	1.68	0.344	CW	T	1496
		80 XS	3.91	18.85	0.084	0.059	279.7	279.0	2.19	0.279	CW	T	4695
1	25	40 ST	3.38	26.64	0.105	0.084	318.6	557.6	2.50	0.558	CW	T	1558
		80 XS	4.55	24.31	0.105	0.076	412.1	464.1	3.23	0.464	CW	T	4427
1-1/4	32	40 ST	3.56	35.05	0.132	0.110	431.3	965.0	3.38	0.965	CW	T	1579
		80 XS	4.85	32.46	0.132	0.102	568.7	827.6	4.45	0.828	CW	T	4096
1-1/2	40	40 ST	3.68	40.89	0.152	0.128	515.5	1 313	4.05	1.313	CW	T	1593
		80 XS	5.08	38.10	0.152	0.120	689.0	1 140	5.40	1.140	CW	T	3972
2	50	40 ST	3.91	52.50	0.190	0.165	690.3	2 165	5.43	2.165	CW	T	1586
		80 XS	5.54	49.25	0.190	0.155	953	1 905	7.47	1.905	CW	T	3799
2-1/2	65	40 ST	5.16	62.71	0.229	0.197	1 099	3 089	8.62	3.089	CW	W	3675
		80 XS	7.01	59.00	0.229	0.185	1 454	2 734	11.40	2.734	CW	W	5757
3	80	40 ST	5.49	77.93	0.279	0.245	1 438	4 769	11.27	4.769	CW	W	3323
		80 XS	7.62	73.66	0.279	0.231	1 946	4 261	15.25	4.261	CW	W	5288
4	100	40 ST	6.02	102.26	0.359	0.321	2 048	8 213	16.04	8.213	CW	W	2965
		80 XS	8.56	97.18	0.359	0.305	2 844	7 417	22.28	7.417	CW	W	4792
6	150	40 ST	7.11	154.05	0.529	0.484	3 601	18 639	28.22	18.64	ERW	W	4799
		80 XS	10.97	146.33	0.529	0.460	5 423	16 817	42.49	16.82	ERW	W	8336
8	200	30	7.04	205.0	0.688	0.644	4 687	33 000	36.73	33.01	ERW	W	3627
		40 ST	8.18	202.7	0.688	0.637	5 419	32 280	42.46	32.28	ERW	W	4433
		80 XS	12.70	193.7	0.688	0.608	8 234	29 460	64.51	29.46	ERW	W	7626
10	250	30	7.80	257.5	0.858	0.809	6 498	52 060	50.91	52.06	ERW	W	3344
		40 ST	9.27	254.5	0.858	0.800	7 683	50 870	60.20	50.87	ERW	W	4178
		XS	12.70	247.7	0.858	0.778	10 388	48 170	81.39	48.17	ERW	W	6116
		80	15.06	242.9	0.858	0.763	12 208	46 350	95.66	46.35	ERW	W	7453
12	300	30	8.38	307.1	1.017	0.965	8 307	74 060	65.09	74.06	ERW	W	3096
		ST	9.53	304.8	1.017	0.958	9 406	72 970	73.70	72.97	ERW	W	3641
		40	10.31	303.2	1.017	0.953	10 158	72 190	79.59	72.21	ERW	W	4020
		XS	12.70	298.5	1.017	0.938	12 414	69 940	97.28	69.96	ERW	W	5157
		80	17.45	289.0	1.017	0.908	16 797	65 550	131.62	65.57	ERW	W	7419
14	350	30 ST	9.53	336.6	1.117	1.057	10 356	88 970	81.15	88.96	ERW	W	3316
		40	11.10	333.4	1.117	1.047	12 013	87 290	94.13	87.30	ERW	W	3999
		XS	12.70	330.2	1.117	1.037	13 681	85 610	107.21	85.63	ERW	W	4695
		80	19.05	317.5	1.117	0.997	20 142	79 160	157.82	79.17	ERW	W	7453
16	400	30 ST	9.53	387.4	1.277	1.217	11 876	117 800	93.06	117.8	ERW	W	2903
		40 XS	12.70	381.0	1.277	1.197	15 708	114 000	123.09	114.0	ERW	W	4109
18	450	ST	9.53	438.2	1.436	1.376	13 396	150 800	104.98	150.8	ERW	W	2579
		30	11.10	435.0	1.436	1.367	15 556	148 600	121.90	148.6	ERW	W	3110
		XS	12.70	431.8	1.436	1.357	17 735	146 450	138.97	146.4	ERW	W	3654
		40	14.27	428.7	1.436	1.347	19 863	144 300	155.65	144.3	ERW	W	4185
20	500	20 ST	9.53	489.0	1.596	1.536	14 916	187 700	116.88	187.4	ERW	W	2324
		30 XS	12.70	482.6	1.596	1.516	19 762	182 900	154.85	182.9	ERW	W	3289
		40	15.06	477.9	1.596	1.501	23 325	179 400	182.78	179.4	ERW	W	4006

[a] Numbers are schedule numbers per ASME *Standard* B36.10M; ST = Standard; XS = Extra Strong.

[b] T = Thread; W = Weld

[c] Working pressures were calculated per ASME B31.9 using furnace butt-weld (continuous weld, CW) pipe through 100 mm and electric resistance weld (ERW) thereafter. The allowance A has been taken as

(1) 12.5% of t for mill tolerance on pipe wall thickness, *plus*

(2) An arbitrary corrosion allowance of 0.64 mm for pipe sizes through NPS 2 and 1.65 mm from NPS 2½ through 20, *plus*

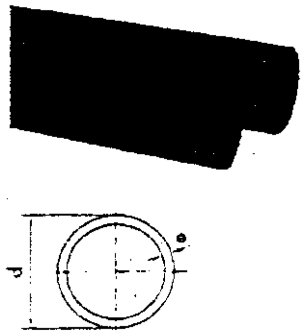
(3) A thread cutting allowance for sizes through NPS 2.

Because the pipe wall thickness of threaded standard pipe is so small after deducting the allowance A, the mechanical strength of the pipe is impaired. It is good practice to limit standard threaded pipe pressure to 620 kPa (gage) for steam and 860 kPa (gage) for water.

Table Copper Tube Data

U.S. Nominal Size, in.	Type	Wall Thickness t, mm	Diameter: Outside D, mm	Diameter: Inside d, mm	Surface Area: Outside, m^2/m	Surface Area: Inside, m^2/m	Cross Section: Metal Area, mm^2	Cross Section: Flow Area, mm^2	Mass: Tube, kg/m	Mass: Water, kg/m	Working Pressure[a,b,c] ASTM B88 to 120°C MPa (gage): Annealed	Working Pressure[a,b,c] ASTM B88 to 120°C MPa (gage): Drawn
1/4	K	0.89	9.53	7.75	0.030	0.0244	24	47	0.216	0.047	5.868	11.004
	L	0.76	9.53	8.00	0.030	0.0250	21	50	0.188	0.050	5.033	9.432
3/8	K	1.24	12.70	10.21	0.040	0.0320	45	82	0.400	0.082	6.164	11.556
	L	0.89	12.70	10.92	0.040	0.0344	33	94	0.295	0.094	4.399	8.253
	M	0.64	12.70	11.43	0.040	0.0360	24	103	0.216	0.103	3.144	5.895
1/2	K	1.24	15.88	13.39	0.050	0.0421	57	141	0.512	0.141	4.930	9.246
	L	1.02	15.88	13.84	0.050	0.0436	48	151	0.424	0.151	4.027	7.543
	M	0.71	15.88	14.45	0.050	0.0454	34	164	0.302	0.164	2.820	5.282
5/8	K	1.24	19.05	16.56	0.060	0.0521	70	215	0.622	0.215	4.109	7.702
	L	1.07	19.05	16.92	0.060	0.0530	60	225	0.539	0.225	3.523	6.605
3/4	K	1.65	22.23	18.92	0.070	0.0594	106	281	0.954	0.281	4.668	8.757
	L	1.14	22.23	19.94	0.070	0.0628	75	312	0.677	0.312	3.234	6.061
	M	0.81	22.23	20.60	0.070	0.0646	55	333	0.488	0.333	2.303	4.309
1	K	1.65	28.58	25.27	0.090	0.0792	139	502	1.249	0.502	3.634	6.812
	L	1.27	28.58	26.04	0.090	0.0817	109	532	0.973	0.532	2.792	5.240
	M	0.89	28.58	26.80	0.090	0.0841	77	564	0.691	0.564	1.958	3.668
1-1/4	K	1.65	34.93	31.62	0.110	0.0994	173	785	1.543	0.785	2.972	5.571
	L	1.40	34.93	32.13	0.110	0.1009	147	811	1.316	0.811	2.517	4.716
	M	1.07	34.93	32.79	0.110	0.1030	114	845	1.015	0.845	1.924	3.599
	DWV	1.02	34.93	32.89	0.110	0.1033	108	850	0.967	0.850	1.827	3.427
1-1/2	K	1.83	41.28	37.62	0.130	0.1183	226	1 111	2.025	1.111	2.786	5.226
	L	1.52	41.28	38.23	0.130	0.1201	190	1 148	1.701	1.148	2.324	4.351
	M	1.24	41.28	38.79	0.130	0.1219	157	1 181	1.399	1.182	1.896	3.558
	DWV	1.07	41.28	39.14	0.130	0.1228	135	1 203	1.204	1.203	1.627	3.048
2	K	2.11	53.98	49.76	0.170	0.1564	343	1 945	3.070	1.945	2.455	4.606
	L	1.78	53.98	50.42	0.170	0.1585	292	1 997	2.606	1.997	2.069	3.951
	M	1.47	53.98	51.03	0.170	0.1603	243	2 045	2.171	2.045	1.717	3.220
	DWV	1.07	53.98	51.84	0.170	0.1628	177	2 111	1.585	2.111	1.241	2.331
2-1/2	K	2.41	66.68	61.85	0.209	0.1942	487	3 004	4.35	3.004	2.275	4.268
	L	2.03	66.68	62.61	0.209	0.1966	413	3 079	3.69	3.079	1.917	3.592
	M	1.65	66.68	63.37	0.209	0.1990	337	3 154	3.02	3.154	1.558	2.917
3	K	2.77	79.38	73.84	0.249	0.2320	666	4 282	5.96	4.282	2.193	4.109
	L	2.29	79.38	74.80	0.249	0.2350	554	4 395	4.95	4.395	1.813	3.392
	M	1.83	79.38	75.72	0.249	0.2378	446	4 503	3.98	4.503	1.448	2.717
	DWV	1.14	79.38	77.09	0.249	0.2423	281	4 667	2.51	4.667	0.903	1.696
3-1/2	K	3.05	92.08	85.98	0.289	0.2701	852	5 806	7.62	5.806	2.082	3.903
	L	2.54	92.08	87.00	0.289	0.2733	714	5 944	6.39	5.944	1.738	3.254
	M	2.11	92.08	87.86	0.289	0.2761	596	6 063	5.33	6.063	1.441	2.703
4	K	3.40	104.78	97.97	0.329	0.3078	1084	7 538	9.69	7.538	2.041	3.827
	L	2.79	104.78	99.19	0.329	0.3115	895	7 727	8.00	7.727	1.675	3.144
	M	2.41	104.78	99.95	0.329	0.3139	776	7 846	6.94	7.846	1.448	2.717
	DWV	1.47	104.78	101.83	0.329	0.3200	478	8 144	4.27	8.144	0.883	1.655
5	K	4.06	130.18	122.05	0.409	0.3834	1610	11 699	14.39	11.70	1.965	3.682
	L	3.18	130.18	123.83	0.409	0.3889	1266	12 042	11.32	12.04	1.531	2.875
	M	2.77	130.18	124.64	0.409	0.3917	1108	12 201	9.91	12.20	1.338	2.510
	DWV	1.83	130.18	126.52	0.409	0.3975	737	12 572	6.59	12.57	0.883	1.655
6	K	4.88	155.58	145.82	0.489	0.4581	2309	16 701	20.64	16.70	1.972	3.696
	L	3.56	155.58	148.46	0.489	0.4663	1698	17 311	15.18	17.31	1.434	2.696
	M	3.10	155.58	149.38	0.489	0.4694	1484	17 525	13.27	17.53	1.255	2.351
	DWV	2.11	155.58	151.36	0.489	0.4755	1016	17 993	9.09	17.99	0.855	1.600
8	K	6.88	206.38	192.61	0.648	0.6050	4314	29 137	38.56	29.14	2.096	3.930
	L	5.08	206.38	196.22	0.648	0.6163	3212	30 238	28.71	30.24	1.544	2.903
	M	4.32	206.38	197.74	0.648	0.6212	2741	30 710	24.50	30.71	1.317	2.468
	DWV	2.77	206.38	200.84	0.648	0.6309	1771	31 680	15.83	31.62	0.841	1.579
10	K	8.59	257.18	240.00	0.808	0.7541	6705	45 241	59.93	45.15	2.096	3.937
	L	6.35	257.18	244.48	0.808	0.7681	5004	46 942	44.73	46.94	1.551	2.910
	M	5.38	257.18	246.41	0.808	0.7742	4259	47 686	38.07	47.69	1.317	2.468
12	K	10.29	307.98	287.40	0.968	0.9028	9621	64 873	85.99	64.87	2.103	3.937
	L	7.11	307.98	293.75	0.968	0.9229	6722	67 771	60.09	67.77	1.455	2.724
	M	6.45	307.98	295.07	0.968	0.9269	6112	68 382	54.63	68.38	1.317	2.468

[a] When using soldered or brazed fittings, the joint determines the limiting pressure.
[b] Working pressures were calculated using ASME *Standard* B31.9 allowable stresses. A 5% mill tolerance has been used on the wall thickness. Higher tube ratings can be calculated using the allowable stress for lower temperatures.
[c] If soldered or brazed fittings are used on hard drawn tubing, use the annealed ratings. Full-tube allowable pressures can be used with suitably rated flare or compression-type fittings.



PVC-U Pipes

Material:	PVC-U, Polyvinyl Chloride DIN 8061
Color:	RAL 7011-dark-grey
Dimension:	DIN 8062
Pipe length:	5m, with plain ends

Pipe serie – S 4, nominal pressure PN 10

d	PIN	Code				e					Kg/m	
25	10	161 017 082				1.5					0.174	
32	10	161 017 083				1.8					0.264	
40	10	161 017 084				1.9					0.350	
50	10	161 017 085				2.4					0.552	
63	10	161 017 086				3.0					0.854	
75	10	161 017 087				3.6					1.220	
90	10	161 017 088				4.3					1.750	
110	10	161 017 089				5.3					2.610	
125	10	161 017 090				6.0					3.340	
140	10	161 017 091				6.7					4.180	
160	10	161 017 092				7.7					5.470	
180	10	161 017 093				8.6					6.880	
225	10	161 017 094				10.8					10.800	

Pipe serie – S 6,25, nominal pressure PN16

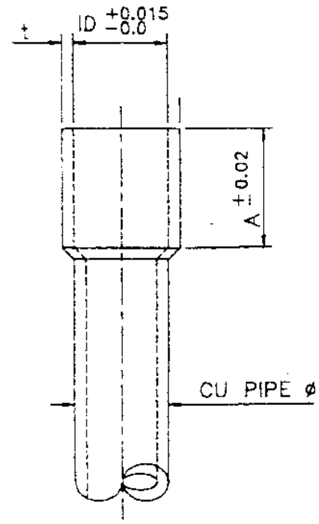
d	PN	Code				et					Kg/m	
12	16	161 017 104				1.0					0.055	
16	16	161 017 105				1.2					0.090	
20	16	161 017 106				1.5					0.137	
25	16	161 017 107				1.9					0.212	
32	16	161 017 108				2.4					0.342	
40	16	161 017 109				3.0					0.525	
50	16	161 017 110				3.7					0.809	
63	16	161 017 111				4.7					1.290	
75	16	161 017 112				5.6					1.820	
90	16	161 017 113				6.7					2.610	
110	16	161 017 114				8.2					3.900	
125	16	161 017 115				9.3					5.010	
140	16	161 017 116				10.4					6.270	
160	16	161 017 117				11.9					8.170	

Pipe serie – S 4, nominal pressure PN 25

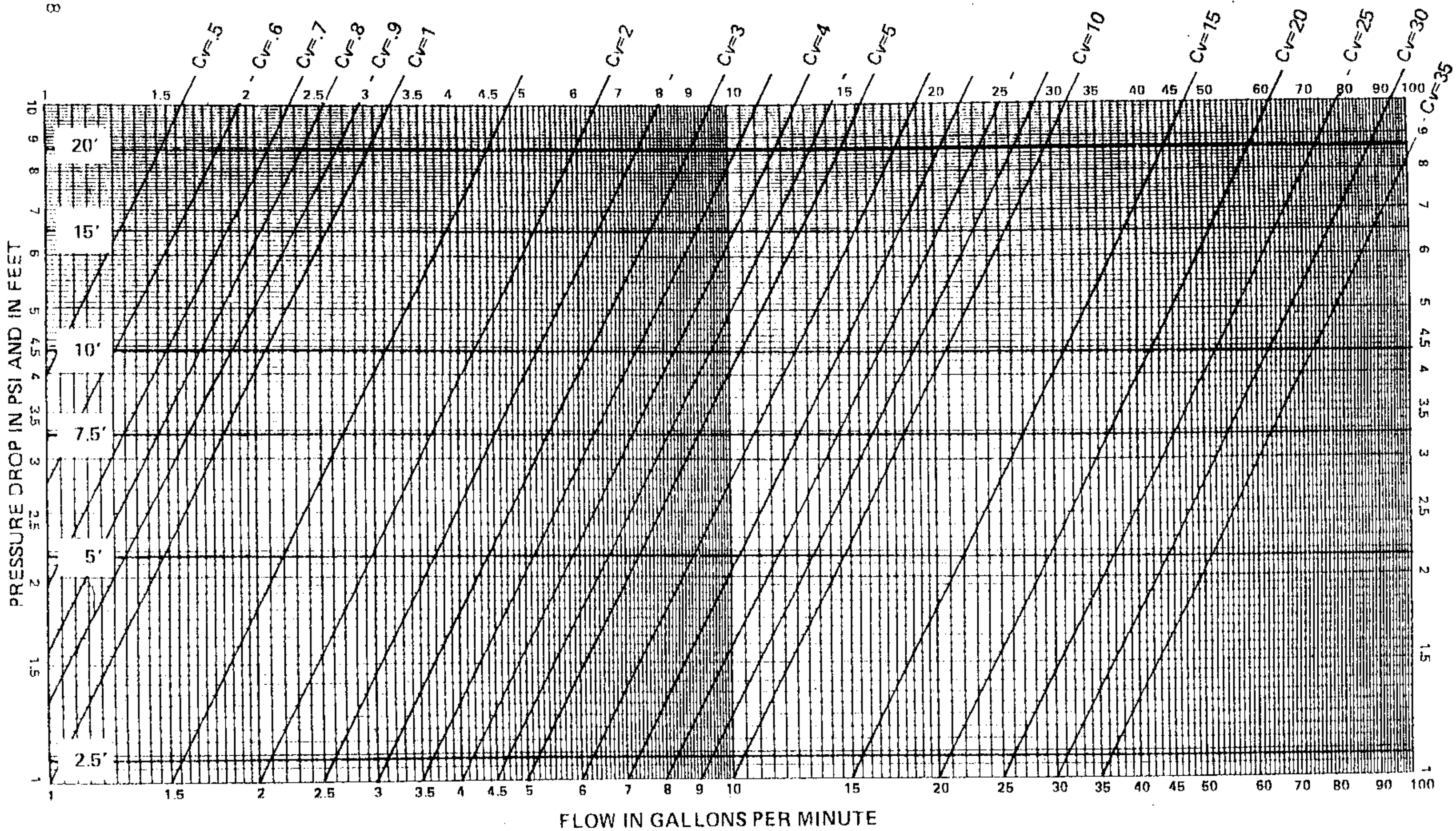
d	PN	Code				et					Kg/m	
6	25	161 017 126				1.0					0.025	
8	25	161 017 127				1.0					0.035	
10	25	161 017 128				1.2					0.053	

COPPER TUBE EXPANDING SPECIFICATION

CU PIPE Φ		DIMENSION A (mm)	
(MM)	(INCH)	MACHINE	MANUAL
6.35	1/4	8	6
7.63	5/16	8	7
9.52	3/8	10	7
12.70	1/2	10	10
15.87	5/8	15	13
19.05	¾	20	17
22.23	7/8	20	15
25.40	1	20	15
28.60	1 1/8	20	15

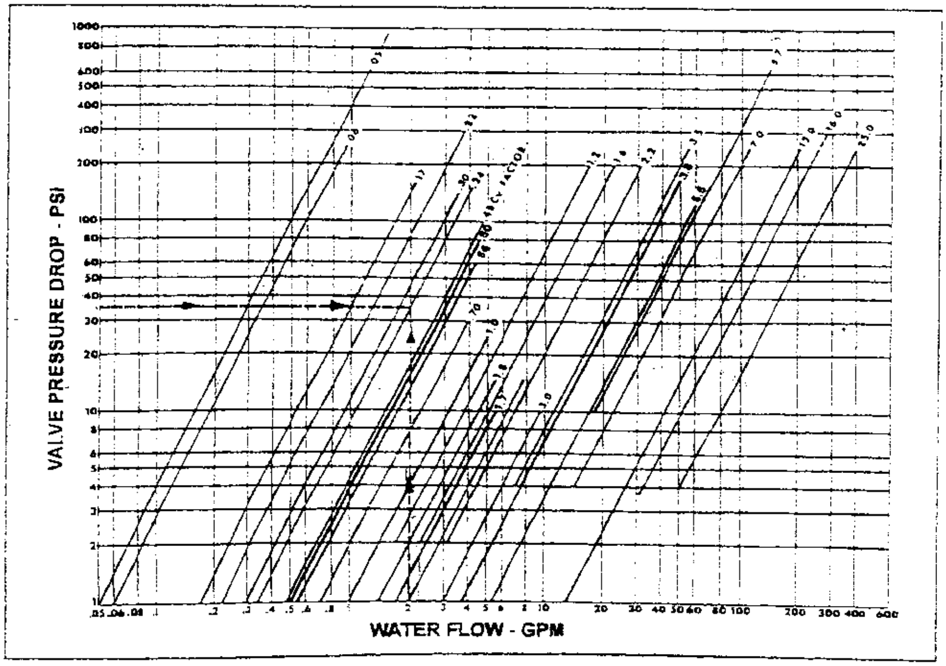


GRAPH OF PRESSURE DROP – VS – FLOW FOR VARIOUS C_V RATINGS



FORMULA $Q = C_V\sqrt{H_{PSI}} = .66\,C_V\sqrt{H_{FT}}$

$H_{FT} = 2.31\,H_{PSI}$



Water Capacity Graph:

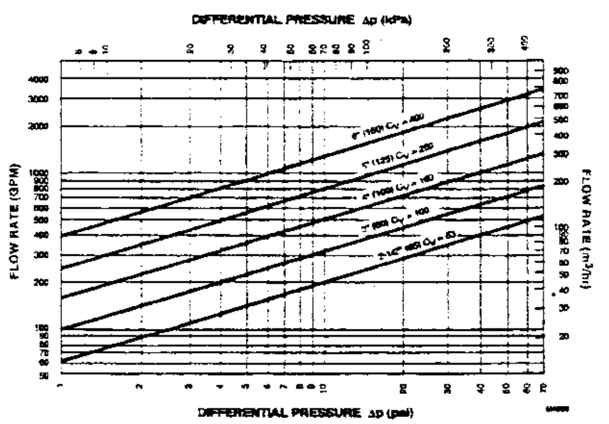


CHART 3 – FRICTION LOSS FOR CLOSED PIPING SYSTEMS

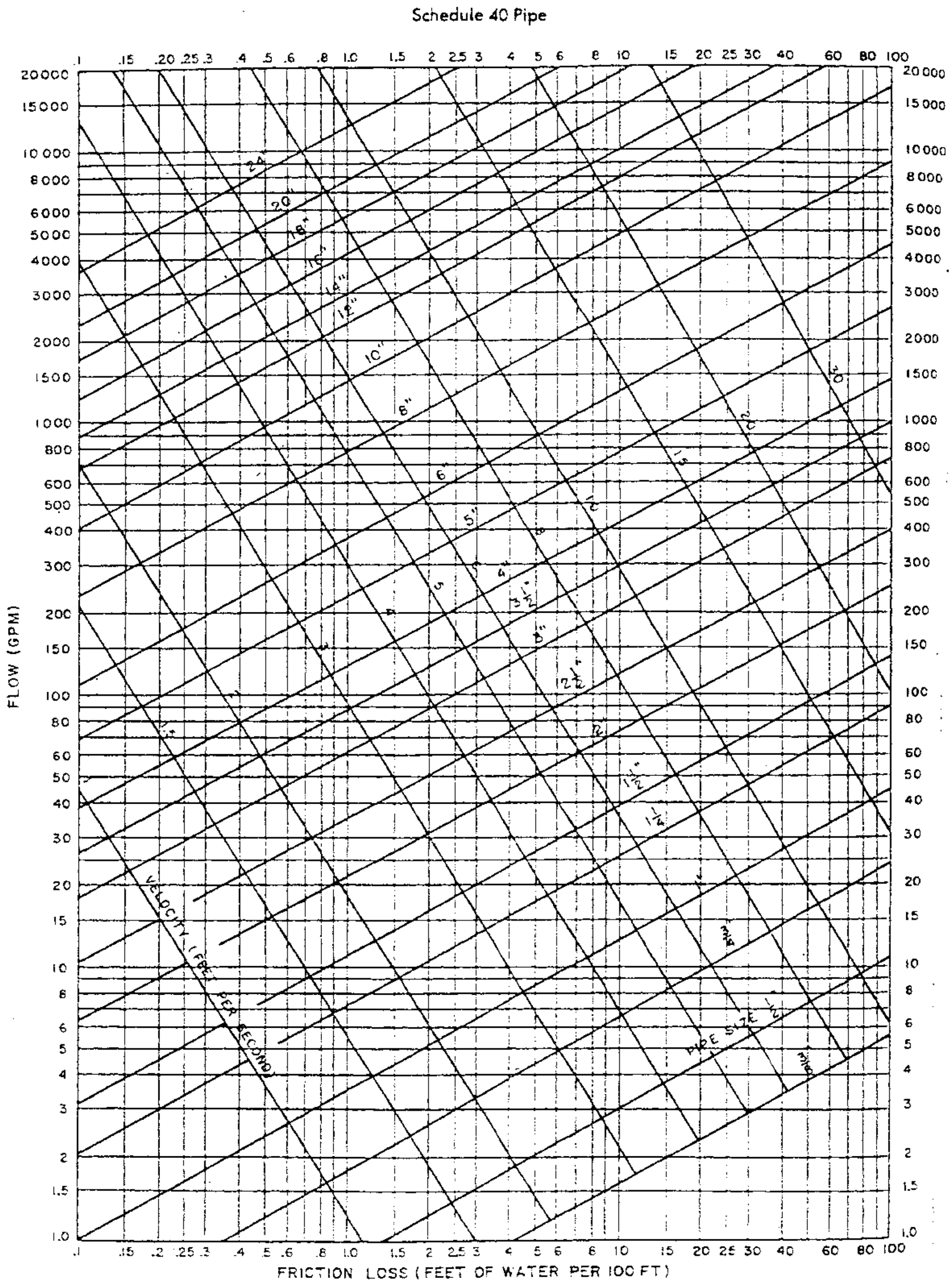


CHART 4 – FRICTION LOSS FOR OPEN PIPING SYSTEMS

Schedule 40 Pipe

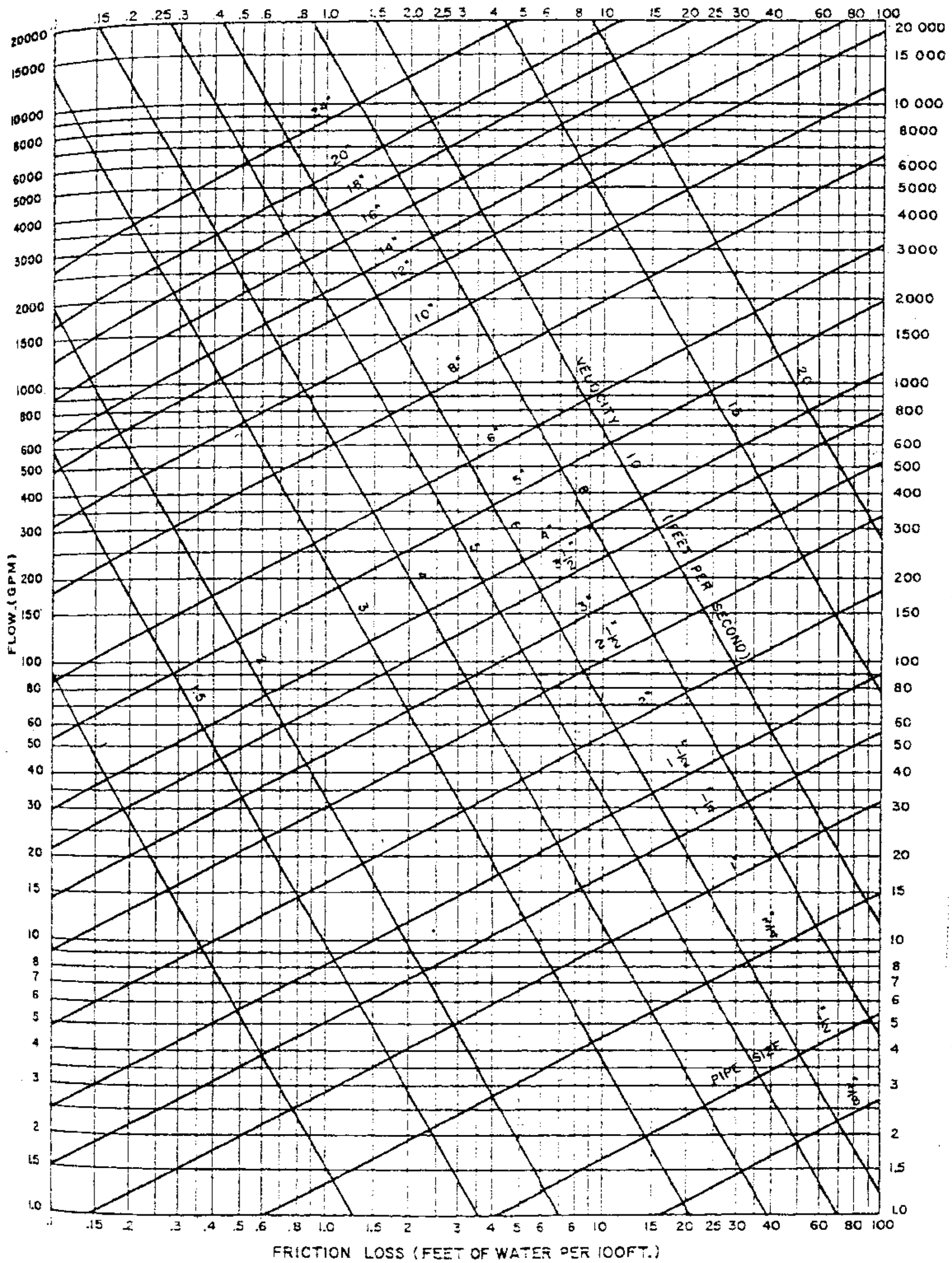
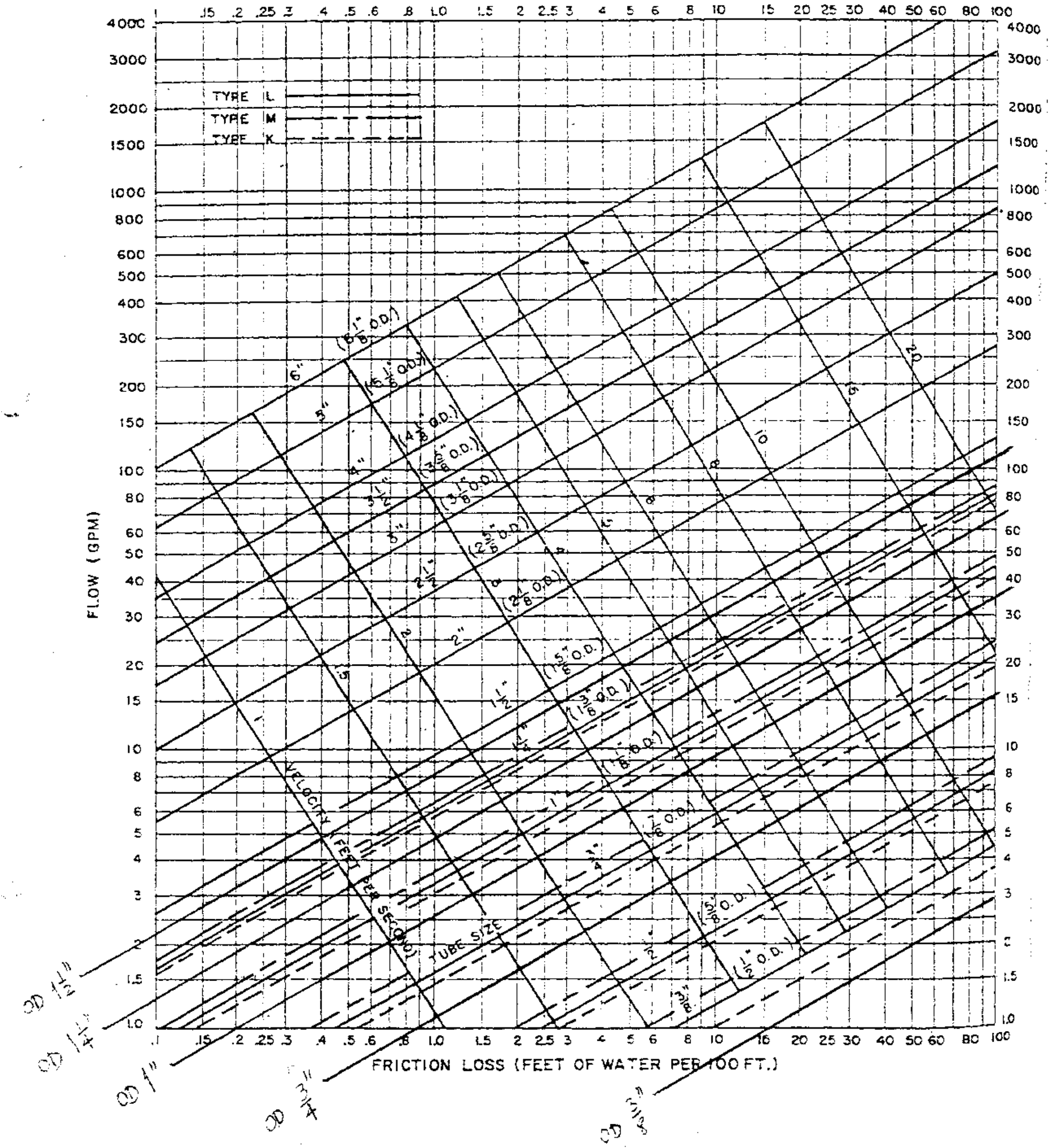


CHART 5 – FRICTION LOSS FOR CLOSED AND OPEN PIPING SYSTEMS

Copper Tubing



Hazen & Wiilioms Flow Diagram for SSS PIPE
up #0 300 mm Diameter. [U-PVC]

TECHNICAL INFORMATION

(F54)

Head Loss in meters/1000 meters of pipe line

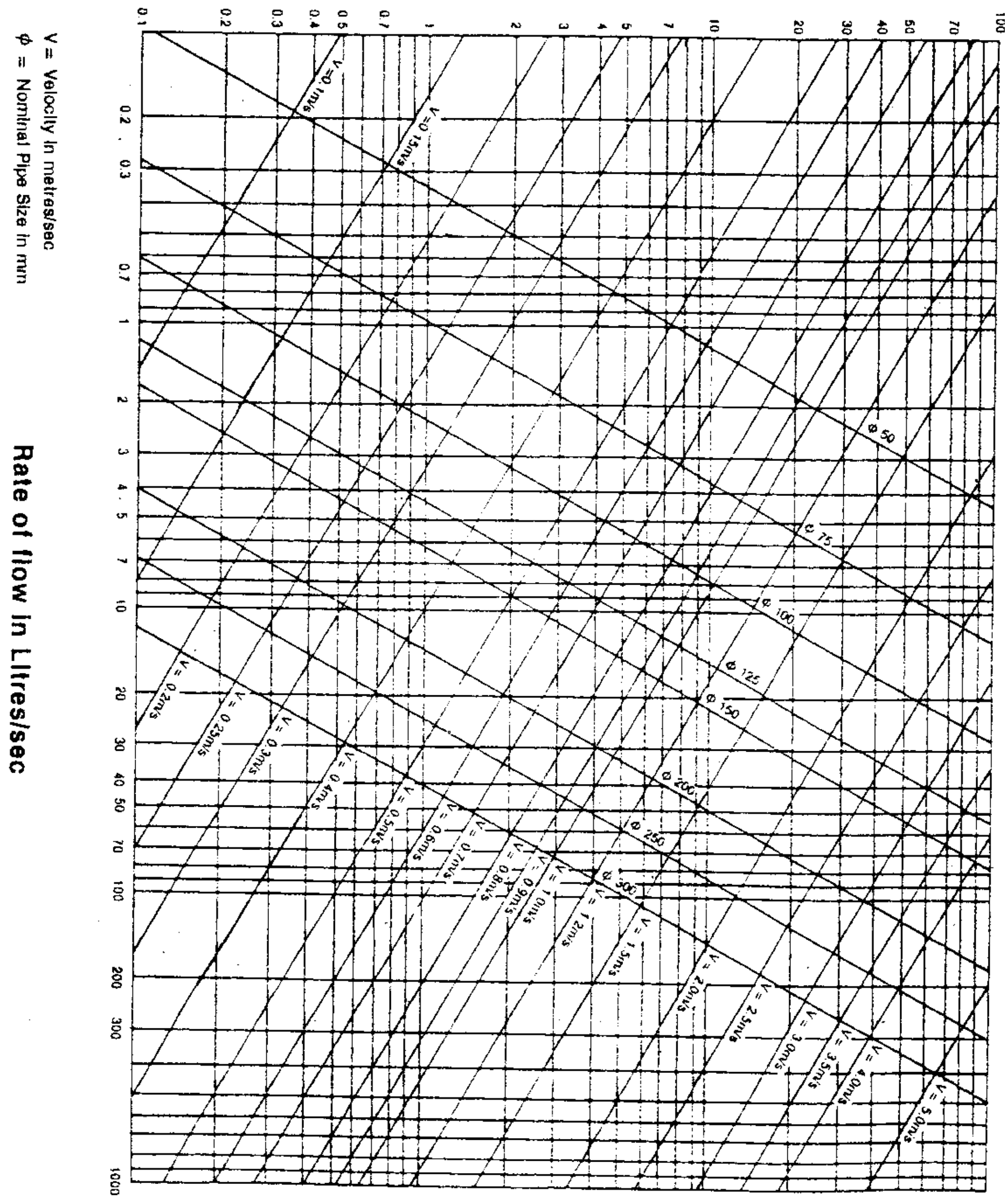
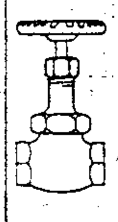
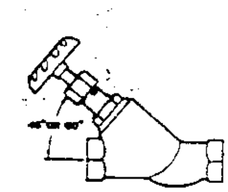
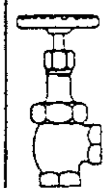
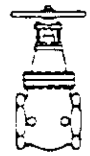
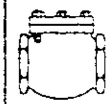
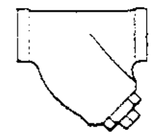
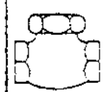


TABLE 10—VALVE LOSSES IN EQUIVALENT FEET OF PIPE*

Screwed, Welded, Flanged, and Flared Connections

NOMINAL PIPE OR TUBE SIZE (in.)	GLOBE†	60°-Y	45°-Y	ANGLE†	GATE††	SWING CHECK‡	Y-TYPE STRAINER‡‡ Flanged End	Y-TYPE STRAINER‡‡ Screwed End	LIFT CHECK
									
⅜	17	8	6	6	0.6	5	—	—	
½	18	9	7	7	0.7	6	—	3	
¾	22	11	9	9	0.9	8	—	4	Globe & Vertical Lift Same as Globe Valve**
1	29	15	12	12	1.0	10	—	5	
1¼	38	20	15	15	1.5	14	—	9	
1½	43	24	18	18	1.8	16	—	10	
2	55	30	24	24	2.3	20	27	14	
2½	69	35	29	29	2.8	25	28	20	
3	84	43	35	35	3.2	30	42	40	
3½	100	50	41	41	4.0	35	48	—	
4	120	58	47	47	4.5	40	60	—	
5	140	71	58	58	6	50	80	—	
6	170	88	70	70	7	60	110	—	
8	220	115	85	85	9	80	150	—	
10	280	145	105	105	12	100	190	—	
12	320	165	130	130	13	120	250	—	Angle Lift Same as Angle Valve
14	360	185	155	155	15	135	—	—	
16	410	210	180	180	17	150	—	—	
18	460	240	200	200	19	165	—	—	
20	520	275	235	235	22	200	—	—	
24	610	320	265	265	25	240	—	—	

* Losses are for all valves in fully open position and strainers clean.

** These losses do not apply to valves with needle point type seats.

Losses also apply to the in-line, ball type check valve.

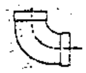
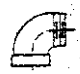
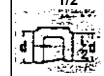
*** For "Y" pattern globe lift check valve with seat approximately equal to the nominal pipe diameter, use values of 60º "Y" valve for loss.

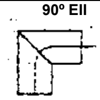
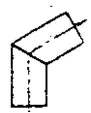
\# Regular and short pattern plug cock valves, when fully open, have same loss as gate valve. For valve losses of short pattern plug cocks above 6 ins check manufacturer.

For .045 thru 3/16 in. perforations with screens 50% clogged, loss is doubled.

TABLE 11-FITTING LOSSES IN EQUIVALENT FEET OF PIPE

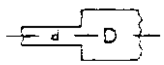
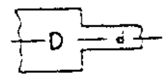
Screwed, Welded, Flanged, and Flared Connections

NOMINAL PIPE OR TUBE SIZE (in.)	SMOOTH BEND ELBOWS						SMOOTH BEND TEES			
	90º Std*	90º Long Rad. **	90º Street*	45º Std*	45º Street*	180º Std*	Straight-Thru Flow			
							Flow-Thru Branch 	No Reduction 	Reduced 1/4 	Reduced 1/2 
3/8	1.4	0.9	2.3	0.7	1.1	2.3	2.7	0.9	1.2	1.4
½	1.6	1.0	2.5	0.8	1.3	2.5	3.0	1.0	1.4	1.6
3/4	2.0	1.4	3.2	0.9	1.6	3.2	4.0	1.4	1.9	2.0
1	2.6	1.7	4.1	1.3	2.1	4.1	5.0	1.7	2.3	2.6
1 1/4	3.3	2.3	5.6	1.7	3.0	5.6	7.0	2.3	3.1	3.3
1 ½	4.0	2.6	6.3	2.	3.4	6.3	8.0	2.6	3.7	4.0
2	5.0	2.3	8.2	2.6	4.5	8.2	10	3.3	4.7	5.0
2 ½	6.0	4.1	10	3.2	5.2	10	12	4.1	5.6	6.0
3	7.5	5.0	12	4.0	6.4	12	15	5.0	7.0	7.5
3 1/2	9.0	5.9	15	4.7	7.3	15	18	5.9	8.0	9.0
4	10	6.7	17	5.2	8.5	17	21	6.7	9.0	10
5	13	8.2	21	6.5	11	21	25	8.2	12	13
6	16	10	25	7.9	13	25	30	10	14	16
8	20	13	-	10	-	33	40	13	18	20
10	25	16	-	13	-	42	50	16	23	25
12	30	19	-	16	-	50	60	19	26	30
14	34	23	-	18	-	55	68	23	30	34
16	38	26	-	20	-	62	78	26	35	38
18	42	29	-	23	-	70	85	29	40	42
20	50	33	-	26	-	81	100	33	44	50
24	60	40	-	30	-	94	115	40	50	60

NOMINAL PIPE OR TUBE SIZE (in.)	MITRE ELBOWS			
	90º Ell 	60º Ell 	45º Ell 	30º Ell 
3/8	2.7	1.1	0.6	0.3
½	3.0	1.3	0.7	0.4
¾	4.0	1.6	0.9	0.5
1	5.0	2.1	1.0	0.7
1 ¼	7.0	3.0	1.5	0.9
1 ½	8.0	3.4	1.8	1.1
2	10	4.5	2.3	1.3
2 ½	12	5.2	2.8	1.7
3	15	6.4	3.2	2.0
3 ½	18	7.3	4.0	2.4
4	21	8.5	4.5	2.7
5	25	11	6.0	3.2
6	30	13	7.0	4.0
8	40	17	9.0	5.1
10	50	21	12	7.2
12	60	25	13	8.0
14	68	29	15	9.0
16	78	31	17	10
18	85	37	19	11
20	100	41	22	13
24	115	49	25	16

* R/D approximately equal to 1. ** R/D approximately equal to 1.5.

TABLE 12 -SPECIAL FITTING LOSSES IN *EQUIVALENT FEET OF PIPE*

NOM-PIPE OR TUBE SIZE(in.)	SUDDEN ENLARGEMENT* d/D			SUDDEN CONTRACTION* d/D			SHARP EDGE*		PIPE PROJECTION*	
	1/4	1/2	3/4	1/4	1/2	3/4	Entrance	Exit	Entrance	Exit
										
3/8	1.4	0.8	0.3	0.7	0.5	0.3	1.5	0.8	1.5	1.1
½	1.8	1.1	0.4	0.9	0.7	0.4	1.8	1.0	1.8	1.5
¾	2.5	1.5	0.5	1.2	1.0	0.5	2.8	1.4	2.8	2.2
1	3.2	2.0	0.7	1.6	1.2	0.7	3.7	1.8	3.7	2.7
1 ¼	4.7	3.0	1.0	2.3	1.8	1.0	5.3	2.6	5.3	4.2
1 ½	5.8	3.6	1.2	2.9	2.2	1.2	6.6	3.3	6.6	5.0
2	8.0	4.8	1.6	4.0	3.0	1.6	9.0	4.4	9.0	6.8
2 ½	10	6.1	2.0	5.0	3.8	2.0	12	5.6	12	8.7
3	13	8.0	2.6	6.5	4.9	2.6	14	7.2	14	11
3 ½	15	9.2	3.0	7.7	6.0	3.0	17	8.5	17	13
4	17	11	3.8	9.0	6.8	3.8	20	10	20	16
5	24	15	5.0	12	9.0	5.0	27	14	27	20
6	29	22	6.0	15	11	6.0	33	19	33	25
8	-	25	8.5	-	15	8.5	47	24	47	35
10	-	32	11	-	20	11	60	29	60	46
12	-	41	13	-	25	13	73	37	73	57
14	-	-	16	-	-	16	86	45	86	66
16	-	-	18	-	-	18	96	50	96	77
18	-	-	20	-	-	20	115	58	115	90
20	-	-	-	-	-	-	142	70	142	108
24	-	-	-	-	-	-	163	83	163	130

* Enter table for losses at smallest diameter “d”.

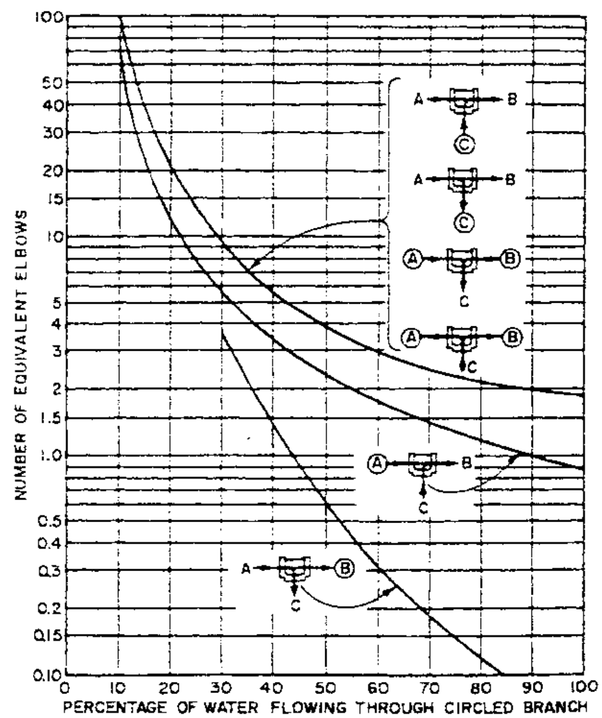
Table 6 Equivalent Lengths in Metres of Pipe for 90º Elbows

Velocity, m/s	Pipe Size, mm 15	20	25	32	40	50	65	90	100	125	150	200	250	300
0.33	0.4	0.5	0.7	0.9	1.1	1.4	1.6	2.0	2.6	3.2	3.7	4.7	5.7	6.8
0.67	0.4	0.6	0.8	1.0	1.2	1.5	1.8	2.3	2.9	3.6	4.2	5.3	6.3	7.6
1.00	0.5	0.6	0.8	1.1	1.3	1.6	1.9	2.5	3.1	3.8	4.5	5.6	6.8	8.0
1.33	0.5	0.6	0.8	1.1	1.3	1.7	2.0	2.5	3.2	4.0	4.6	5.8	7.1	8.4
1.67	0.5	0.7	0.9	1.2	1.4	1.8	2.1	2.6	3.4	4.1	4.8	6.0	7.4	8.8
2.00	0.5	0.7	0.9	1.2	1.4	1.8	2.2	2.7	3.5	4.3	5.0	6.2	7.6	9.0
2.35	0.5	0.7	0.9	1.2	1.5	1.9	2.2	2.8	3.6	4.4	5.1	6.4	7.8	9.2
2.67	0.5	0.7	0.9	1.3	1.5	1.9	2.3	2.8	3.6	4.5	5.2	6.5	8.0	9.4
3.00	0.5	0.7	0.9	1.3	1.5	1.9	2.3	2.9	3.7	4.5	5.3	6.7	8.1	9.6
3.33	0.5	0.8	0.9	1.3	1.5	1.9	2.4	3.0	3.8	4.6	5.4	6.8	8.2	9.8

Table 7 Iron and Copper Elbow Equivalents[a]

Fitting	Iron Pipe	Copper Tubing
Elbow, 90º	1.0	1.0
Elbow. 45º	0.7	0.7
Elbow, 90° long turn	0.5	0.5
Elbow, welded, 90°	0.5	0.5
Reduced coupling	0.4	0.4
Open return bend	1.0	1.0
Angle radiator valve	2.0	3.0
Radiator or convector	3.0	4.0
Boiler or heater	3.0	4.0
Open gate valve	0.5	0.7
Open globe valve	12.0	17.0

Source: Giesecke(1926) and Giesecke and Badgett(1931, 1932a)
[a]See Table 6 for equivalent length of one elbow.



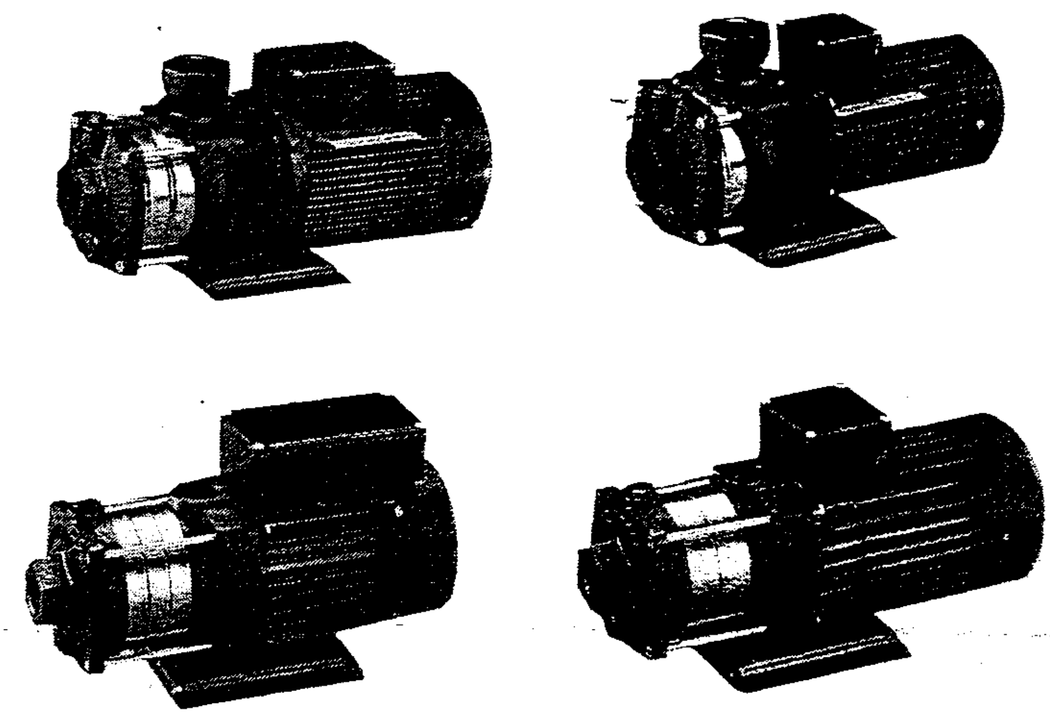
Notes 1. Chart is based on straight tees.(.e., branches A, B, and C are the same size).
2. Pressure toss in desired circuit obtained by selecting the proper curve according to illustrations, determining the flow at the circled branch, and multiplying the pressure loss for the same size elbow at the flow rate in the circled branch by the equivalent elbows indicated.
3. When the size of an outlet is reduced, the equivalent elbows shown in the chart do not apply. Therefore, the maximum loss for any circuit for any flow will not exceed 2 elbow equivalents at the maximum flow occurring in any branch of the tee.
4. Top curve is average of 4 curves, one for each circuit shown.

Fig. 4 Elbow Equivalents of Tees at Various Flow Conditions (Giesecke and Badgett 1931, 1932b)

CH

APPENDIX 8

Product Information
FC-012



GRUNDFOS®

General Data

Applications

The CH range of compact horizontal centrifugal pumps are designed for a wide range of applications including industrial, commercial and domestic water pressure boosting and distribution in:

- Industrial Systems
- Pressure Boosting
- Horticultural Irrigation
- Washing Machines
- Liquid Transfer

as well as many specialized applications on packaged equipment.

Pumped Liquids

Thin, clean, non-aggressive and non-explosive liquids without solid particles or fibres.

O-rings in EPDM rubber are used as standard. Pump version fitted with O-rings in Viton is available for pumping liquids containing mineral oils.

Operation Conditions

Liquid Temperature Range: 0°C to +90°C.

Maximum Ambient Temperature: +55°C.

Maximum operating pressure depends on the temperature of the pumped liquid, see table.

Max. Operating Pressure	1 MPa (10 bar)	0.6 MPa (6 bar)
CH 2 CH 4	0°C to 40°C	41°C to 90°C
CH 8 CH 12	0°C to 55°C	56°C to 90°C

Min. Inlet Pressure: Acc. to the NPSH curve + a safety margin of 1.0 m.

Max. Inlet Pressure: 6 bars for CH 2 and CH 4.
10 bars for CH 8 and CH 12.

Pump

The CH pump is a non self-priming horizontal centrifugal pump with mechanical shaft seal. The pump has small physical dimensions, axial suction port and radial discharge port and is mounted on a baseplate.

Both pump and continuously rated motor unit are of integral design, and particular attention has been paid to quietness and smooth operation.

Pipe connections, see table.

Materials

Pos. no.	Pump Components	Materials	DIN W.-Nr.
1	Suction chamber	Grey cast iron	0.6020
2	Drain plug/priming plug	Steel	1.0718
3	Intermediate chamber	Stainless steel	1.4301
4	Pump shaft	Stainless steel	1.4057/1.4401
5	Impeller	Stainless steel	1.4301
6	Spacing pipe	Stainless steel	1.4301/1.4305
7	Shaft seal faces	Carbon/ceramics	
8	Spring	Stainless steel	1.4310
9	Pump head	Grey cast iron	0.6020
10	Base plate	Painted steel	10330.3
	O-rings	EPDM or Viton	

Connections	CH 2	CH 4	CH 8	CH12
Axial Suction Port	Rp 1	Rp 1 Rp 1 ¼	Rp 1 ½	Rp 1 ½
Radial Discharge Port	Rp 1	Rp 1	Rp 1 ¼	Rp 1 ½
Drain Port Priming Port	Rp ⅜	Rp ⅜	Rp ½	Rp ½

Motor

The pump is coupled with a totally enclosed, fan-cooled Grundfos squirrel-cage motor.

Enclosure Class: IP 44.

Insulation Class: F.

Standard Voltages: 1 x 220 – 240 V,
3 x 380 – 415 V, 50 Hz

Single-phase motors have a built-in thermal overload unit.

Three-phase motors must be connected to a motor starter in accordance with local regulations.

Performance Curves

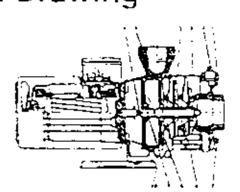
The curves are based on the actual speed, a kinematic viscosity of 1 mm^2/s and a density of 1000 kg/m^3.

Curve tolerance according to ISO 2548, Annex B.

Electrical Data

Pump Type	P_1 [W]		$I_{1/1}$ [A]		
	1 x 220 V 1 x 240 V	3 x 380 V 3 x 415 V	1 x 220 V	1 x 240 V	3 x 380 V 3 x 415 V
CH 2-30	330	330	2.30	2.60	1.10
CH 2-40	395	435	2.70	2.90	1.20
CH 2-50	500	500	3.40	3.80	1.10
CH 4-20	360	370	2.50	2.70	1.20
CH 4-30	490	515	3.60	3.30	1.40
CH 4-40	645	645	4.70	3.90	1.70
CH 4-50	670	880	5.60	5.80	2.10
CH 4-60	1000	1050	6.50	6.40	2.40
CH 8-20	465	485	3.10	3.20	1.40
CH 8-30	755	800	5.10	4.60	2.00
CH 8-40	955	1040	6.20	6.20	3.10
CH 8-50	1310	1315	8.40	8.20	3.40
CH 8-60	1410	1600	10.60	9.20	3.70
CH 12-20	765	830	5.50	4.90	2.10
CH 12-30	1090	1165	7.10	6.60	2.80
CH 12-40	1715	1760	10.90	10.10	4.10
CH 12-50	2070	2245	12.40	11.70	5.10
CH 12-60	–	2725	–	–	6.00

Sectional Drawing



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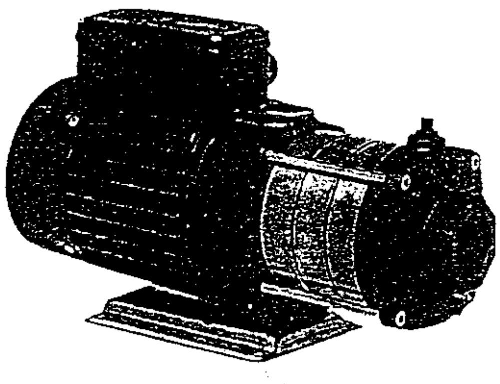
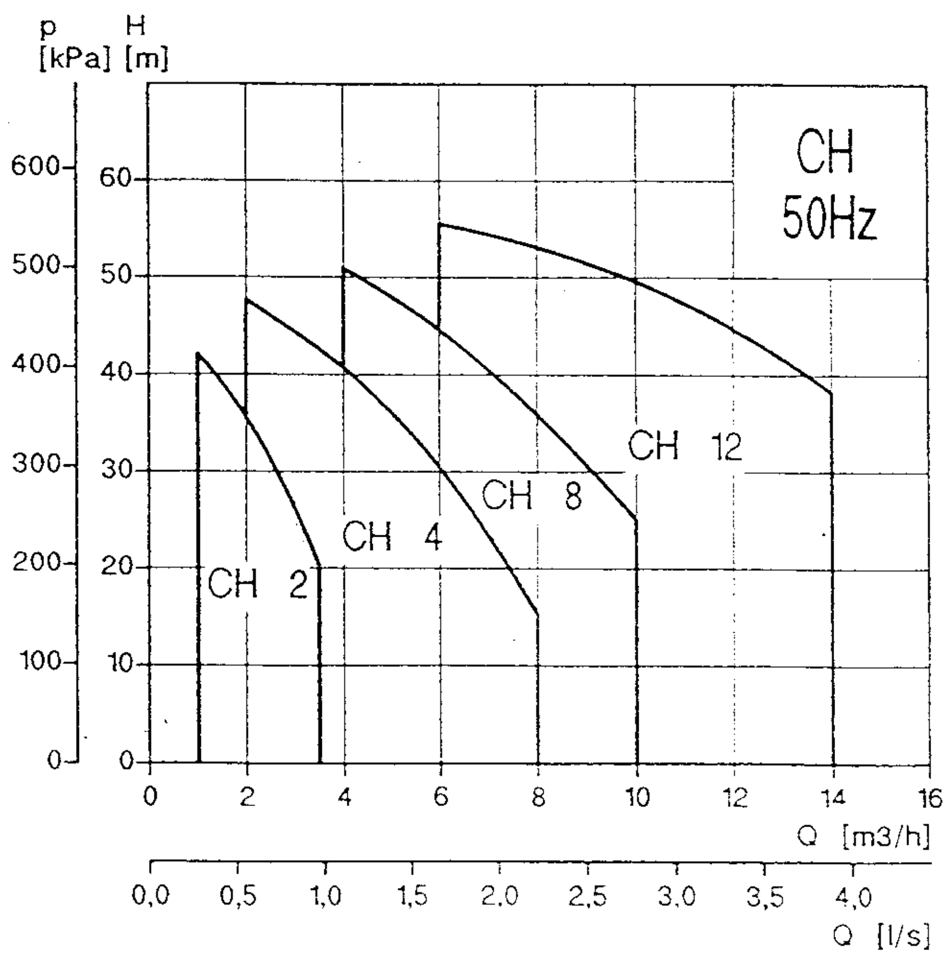


Horizontal Multistage End-Suction Pumps

For water boosting, circulation and transfer duties in domestic, commercial and industrial applications.

Their compact horizontal design is ideally suited to many installations where space is at a premium.



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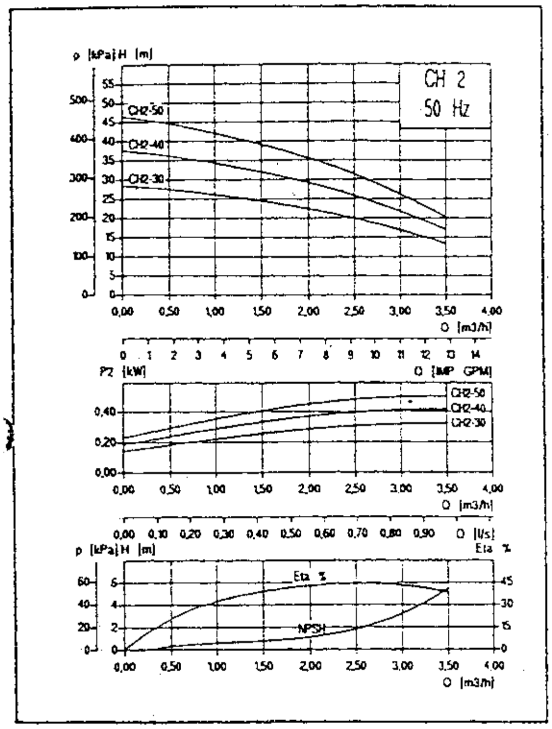
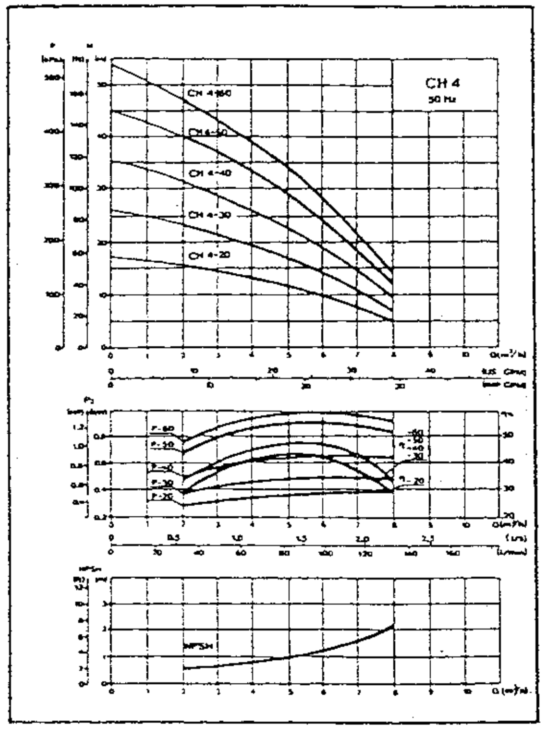
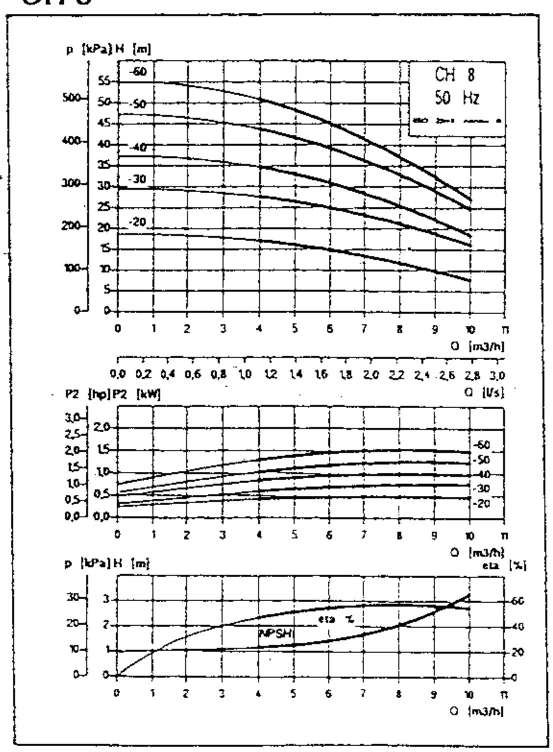
CH 2



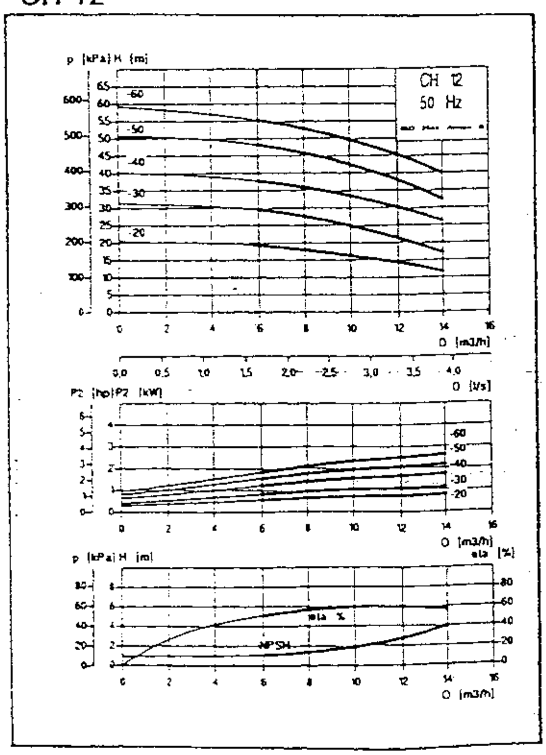
CH 4



CH 8



CH 12



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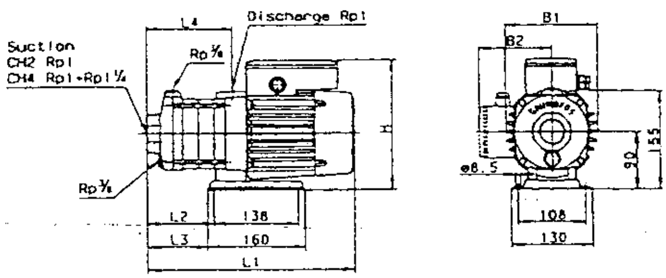
Dimensions and Weight

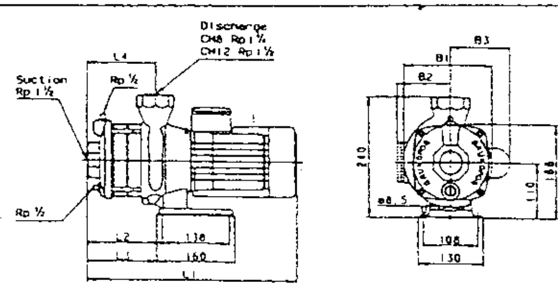
CH 2 and CH 4



Pump Type	L1 [mm]	L2 [mm]	L3 [mm]	L4 [mm]	B1 [mm]	B2 [mm]	H [mm]	Net Weight [kgs]
CH 2-30	324	92	81	117	146	115	205	11.4
CH 2-40	342	110	99	135	146	115	205	11.8
CH 2-50	360	128	117	154	146	115	205	12.2
CH 4-20	315	83	72	108	146	115	205	11.2
CH 4-30	341	110	99	135	146	115	205	11.9
CH 4-40	369	137	126	163	146	115	205	12.7
CH 4-50	438	164	153	190	142	135	225	15.8
CH 4-60	465	191	180	217	142	135	225	16.2

Dimensions and Weight

CH 8 and CH 12



Pump Type	L1 [mm]	L2 [mm]	L3 [mm]	L4 [mm]	B1 [mm]	B2 [mm]	B3 [mm]	H [mm]	Net Weight [kgs]
CH 8-20	327	90	79	77	177	109		240	15.7
CH 8-30	397	120	109	107	177	109		240	17.6
CH 8-40	397	120	109	107	177	109		240	19.3
CH 8-50	465	150	139	137	186	124	166	240	28.8
CH 8-60	465	150	139	137	186	124	166	240	28.8
CH 12-20	366	90	79	77	177	109		240	17.3
CH 12-30	397	120	109	107	177	109		240	19.1
CH 12-40	435	120	109	107	186	124	166	240	29.8
CH 12-50	465	150	139	137	186	124	166	240	30.3
CH 12-60	465	150	139	137	186	124		240	28.6

All information in this catalogue is subject to alterations.

GRUNDFOS

PRODUCT DESCRIPTION

General

The CH pump is a single or multistage, non self-priming centrifugal pump with mechanical shaft seal and through-going pump/motor shaft.

The pump is equipped with a GRUNDFOS fan-cooled, asynchronous motor with electrocoated stator housing and fan cover.

The CH is a light and compact pump/motor unit with horizontal suction port and vertical discharge port.

The pump is equipped with a base plate.

All movable parts in contact with the pumped liquid are made of stainless materials.

The discharge and suction chambers are made of electrocoated cast iron.

The base plate is made of electrocoated steel sheet.

Main Data

Unit of Measurement		CH 2		CH 4		CH 8		CH 12	
		50 Hz	60 Hz	50 Hz	60 Hz	50 Hz	60 Hz	50 Hz	60 Hz
Flow	m³/h	2.5	3.0	5.0	6.0	8.0	9.4	12.0	14.5
	IMP GPM	9.2	11	18.4	22.0	29.4	34.5	44.0	53.2
	US GPM	11	13.2	22.0	26.4	35.2	41.4	52.8	63.8
Head	metres	38	53	35	34	37	34	45	44
	feet	124	173	115	112	121	112	148	144
Minimum liquid temperature	°C	0	0	0	0	0	0	0	0
	°F	32	32	32	32	32	32	32	32
Maximum liquid temperature	°C	90	90	90	90	90	90	90	90
	°F	195	195	195	195	195	195	195	195
Maximum operating pressure at 0 to 40°C	MPa	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	bar	10	10	10	10	10	10	10	10
	psi	145	145	145	145	145	145	145	145
Maximum operating pressure at 41 to 90°C	MPa	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	bar	6	6	6	6	6	6	6	6
	psi	87	87	87	87	87	87	87	87
Mean speed	min^{-1}	2850	3450	2900	3500	2850	3450	2900	3500
Maximum ambient temperature	°C	55	55	55	55	55	55	55	55
Maximum relative humidity	%	95	95	95	95	95	95	95	95

Values of flow and head apply to the largest pumps of the range at their maximum efficiency.

CONSTRUCTION

General

The CH is an integral pump/motor unit with mechanical shaft seal.

Motor

GRUNDFOS fan-cooled, asynchronous motor which electrically is built especially for the CH pump.

The discharge chamber also functions as bearing end shield of the motor (drive end).

Discharge Chamber

The discharge chamber contains the discharge port of the pump and forms the seat of the stationary part of the shaft seal.

The base plate (with screws M6 x 10), the stator housing of the motor and staybolts are attached to the discharge chamber.

Suction Chamber

The suction chamber forms the end of the pump unit and contains the suction port.

The suction chamber contains priming and drain ports and gives attachment for staybolts.

The CH 2, CH 8 and CH 12 suction chambers are equipped with Teflon seals.

Shaft

Spline shaft which is pressed into the motor shaft.

Shaft Seal

Carbon/ceramics, EPDM or FPM (Viton) rubber.

Intermediate Chambers

The stainless steel intermediate chambers are from CR 2, CR 4 and CR 8 respectively.

The CH 2, CH 8 and CH 12 intermediate chambers are equipped with built-in Teflon seals.
The CH 4 intermediate chamber has no seal.

Pump sizes CH 4-50 and CH 4-60 are equipped with a CR 4 intermediate chamber with a built-in Teflon seal and a ceramic intermediate bearing.

Intermediate Bearing

In pump sizes CH 4-50 and CH 4-60 the stationary part of the intermediate bearing is made of ceramics whilst the rotating part on the spline shaft is made of tungsten carbide.

Impeller

All impellers for the CH range come from other pumps:

CH 2, ø90 from CR 2.

CH 4, ø95 from CR 4.

CH 8 and CH 12, ø98 from CHI 8 and CHI 12 respectively.

CH 8 and CH 12, ø130 from CHI 8 and CHI 12 respectively.

CH Introduction

Section 2

BENEFIT

- Compact design
- Horizontal pump (low mounting height)
- Wide temperature range, 0-90°C (wide range of applications)
- No special tools required for servicing
- Suitable for booster sets (low and compact set)
- Competitive price
- Well-known construction (CH 2, CH 4 and CHI product range)
- Suitable for mounting in industrial machines (circulation, washdown etc)
- High efficiency and low operating costs

TABLE 2.1 Variation of Atmospheric Pressure with Altitude

Altitude, ft	Average Pressure P_e PSIA	Average Pressure P_a ftH_2O, Up to 85°F
0	14.7	34.0
500	14.4	33.3
1,000	14.2	32.8
1,500	13.9	32.1
2,000	13.7	21.6
2,500	13.4	31.0
3,000	13.2	30.5
4,000	12.7	29.3
5,000	12.2	28.2
6,000	11.8	27.3
7,000	11.3	26.1
8,000	10.9	25.2
9,000	10.5	24.3
10,000	10.1	23.3
15,000	8.3	19.2
20,000	6.7	15.5

SOURCE: *Cameron Hydraulic Data*, 15th ed., Ingersoll Rand, Woodcliff Lake, N.J., 1977, p. 7-4; used with permission.

TABLE 2.3 Vapor Pressures and Specific Weights for Water for Temperatures from 32 to 212°F

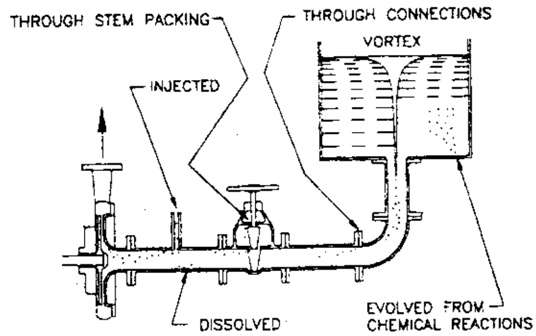
Temperature, °F	Absolute pressure, ftH_2O	Specific weight γ, lb/ft^3
32	0.20	62.42
40	0.28	62.42
45	0.34	62.42
50	0.41	62.38
55	0.49	62.38
60	0.59	62.34
65	0.71	62.34
70	0.84	62.26
75	1.00	62.23
80	1.17	62.19
85	1.38	62.15
90	1.62	62.11
95	1.89	62.03
100	2.20	62.00
105	2.56	61.92
110	2.97	61.84
115	3.43	61.80
120	3.95	61.73
130	5.20	61.54
140	6.78	61.39
150	8.75	61.20
160	11.19	61.01
170	14.19	60.79
180	17.85	60.57
190	22.28	60.35
200	27.60	60.13
210	33.96	59.88
212	35.38	59.81

SOURCE: *Cameron Hydraulic Data*, 15th ed., Ingersoll Rand, Woodcliff Lake, N.J., 1977; used with permission.

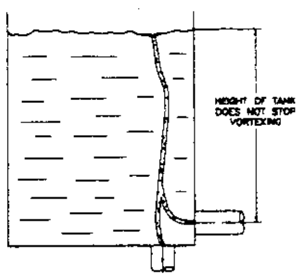
TABLE 2.4 Vapor pressures and specific weights for water, for Temperatures of 212 to 450°F

Temperature, °F	Absolute pressure, psia	Specific weight γ, lb/ft^3
212	14.70	59.81
220	17.19	59.63
230	20.78	59.38
240	24.97	59.10
250	29.83	58.82
260	35.43	58.51
270	41.86	58.24
280	49.20	57.94
290	57.56	57.64
300	67.01	57.31
320	89.66	56.66
340	118.01	55.96
360	153.03	55.22
380	195.77	54.47
400	247.31	53.65
420	308.83	52.80
440	381.59	51.92
450	422.6	51.55

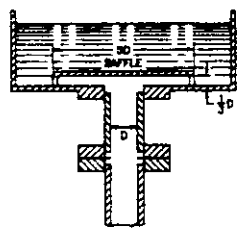
SOURCE: Joseph H. Keenan and Frederick G. Keyes, *Thermodynamic Properties of Steam*, Wiley, New York, 1936, p. 34; used with permission.



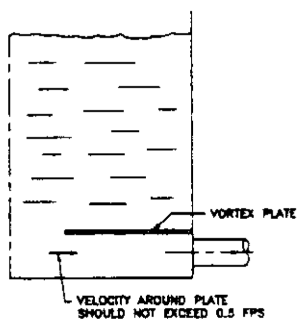
a. Centrifugal pumps and entrained-air problems.[5]



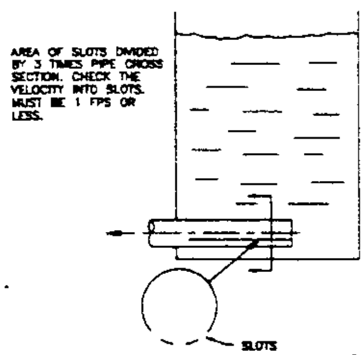
a. Vortexing in an open tank.



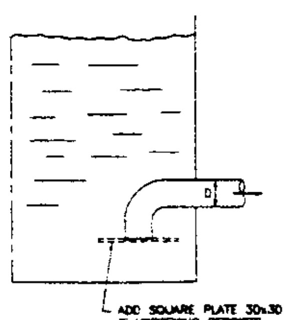
b. Baffle for bottom connection in an open tank.[7]



c. Vortex plate for side exit from tank.[8]



d. Slotted pipe in vortex breaker.[9]



a. Suction elbow in open tank.

Figure 6.8. Vortexing in HVAC pumps. *(From James H.Ingram, Suction side problems:* ***Gas entrainment, Pump and System Magazine, September 1994, p.****34.)*

Table 3 Thermodynamic Properties of Water at Saturation

Temp. t, °C	Absolute Pressure kPa p	Specific Volume, m³/kg Sat. Liquid v_f/v_f	Evap. v_{fg}/v_{fg}	Sat. Vapor v_g	Enthalpy, kJ/kg Sat. Liquid h_f/h_f	Evap. h_{fg}/h_{fg}	Sat. Vapor h_g	Entropy, kJ/(kg·K) Sat. Liquid s_f/s_f	Evap. s_{fg}/s_{fg}	Sat. Vapor s_g	Temp. °C
−60	0.00108	0.001082	90942.00	90942.00	−446.40	2836.27	2389.87	−1.6854	13.3065	11.6211	−60
−59	0.00124	0.001082	79858.69	79858.69	−444.74	2836.46	2391.72	−1.7667	13.2452	11.5677	−59
−58	0.00141	0.001082	70212.37	70212.37	−443.06	2836.64	2393.57	−1.6698	13.8145	11.5147	−58
−57	0.00161	0.001082	61805.35	61805.35	−441.38	2836.81	2395.43	−1.6620	13.1243	11.4623	−57
−56	0.00184	0.001082	54469.39	54469.39	−439.69	2836.97	2397.28	−1.6542	13.0646	11.4104	−56
−55	0.00209	0.001082	48061.05	48061.05	−438.00	2837.13	2399.12	−1.6464	13.0054	11.3590	−55
−54	0.00238	0.001082	42455.57	42455.57	−436.29	2837.27	2400.98	−1.6386	12.9468	11.3082	−54
−53	0.00271	0.001083	37546.09	37546.09	−434.59	2837.42	2402.83	−1.6308	12.8886	11.2578	−53
−52	0.00307	0.001083	33242.14	33242.14	−432.87	2837.55	2404.68	−1.6230	12.8309	11.2079	−52
−51	0.00348	0.001083	29464.67	29464.67	−431.14	2837.68	2406.53	−1.6153	12.7738	11.1585	−51
−50	0.00394	0.001083	26145.01	26145.01	−429.41	2837.80	2408.39	−1.6075	12.7170	11.1096	−50
−49	0.00445	0.001083	23223.69	23223.70	−427.67	2837.91	2410.24	−1.5997	12.6608	11.0611	−49
−48	0.00503	0.001083	20651.68	20651.69	−425.93	2838.02	2412.09	−1.5919	12.6051	11.0131	−48
−47	0.00568	0.001083	18383.50	18383.51	−424.27	2838.12	2413.94	−1.5842	12.5498	10.9656	−47
−46	0.00640	0.001083	16381.35	16381.36	−422.41	2838.21	2415.79	−1.5764	12.4949	10.9185	−46
−45	0.00721	0.001984	14612.35	14512.36	−420.65	2838.29	2417.65	−1.5686	12.4405	10.8719	−45
−44	0.00811	0.001084	13047.65	13047.66	−418.87	2838.37	2419.50	−1.5609	12.3866	10.8257	−44
−43	0.00911	0.001084	11661.85	11661.85	−417.09	2838.44	2421.35	−1.5531	12.3330	10.7799	−43
−42	0.01022	0.001084	10433.85	10433.85	−415.30	2838.50	2423.20	−1.5453	12.2799	10.7346	−42
−41	0.01147	0.001084	9344.25	9344.25	−413.50	2838.55	2425.05	−1.5376	12.2273	10.6897	−41
−40	0.01285	0.001084	8376.33	8376.33	−411.70	2838.60	2426.90	−1.5298	12.1750	10.6452	−40
−39	0.01438	0.001085	7515.86	7515.87	−409.88	2838.64	2428.76	−1.5221	12.1232	10.6011	−39
−38	0.01608	0.001085	6750.36	6750.36	−508.07	2838.67	1430.61	−1.5143	12.0718	10.5575	−38
−37	0.01796	0.001085	6068.16	6068.17	−406.24	2838.70	2432.46	−1.5066	12.0208	10.5142	−37
−36	0.02004	0.001085	5459.82	5459.82	−404.40	2838.71	2434.31	−1.4988	11.9702	10.4713	−36
−35	0.02235	0.001085	4917.09	4917.10	−402.56	2838.73	2436.16	−1.4911	11.9199	10.4289	−35
−34	0.02490	0.001085	4432.36	4432.37	−400.72	2838.73	2438.01	−1.4833	11.8701	10.3868	−34
−33	0.02771	0.001085	3998.71	3998.71	−398.86	2838.72	2439.86	−1.4756	11.8207	10.3451	−33
−32	0.03082	0.001086	3610.71	3610.71	−397.00	2838.71	2441.72	−1.4678	11.7716	10.3037	−32
−31	0.03424	0.001086	3263.20	3263.20	−395.12	2838.69	2443.57	−1.4601	11.7229	10.2628	−31
−30	0.03802	0.001086	2951.64	2951.64	−393.25	2838.66	2445.42	−1.4524	11.6746	10.2222	−30
−29	0.04217	0.001086	2672.03	2672.03	−391.36	2838.63	2447.27	−1.4446	11.6266	10.1820	−29
−28	0.04673	0.001086	2420.89	2420.89	−389.47	2838.59	2449.12	−1.4369	11.4790	10.1421	−28
−27	0.05174	0.001086	2195.23	2195.23	−387.57	2838.53	2450.97	−1.4291	11.5318	10.1026	−27
−26	0.05725	0.001087	1992.15	1992.15	−385.66	2838.48	2452.82	−1.4214	11.4849	10.0634	−26
−25	0.06329	0.001087	1809.35	1809.35	−383.74	2838.41	2454.67	−1.4137	11.4383	10.0246	−25
−24	0.06991	0.001087	1644.59	1644.59	−381.34	2838.34	2456.52	−1.4059	11.3921	9.9862	−24
−23	0.07716	0.001087	1495.98	1495.98	−379.89	2838.26	2458.37	−1.3982	11.3462	9.9480	−23
−22	0.08510	0.001087	1361.94	1361.94	−377.95	2838.17	2460.22	−1.3905	11.3007	9.9102	−22
−21	0.09378	0.001087	1240.77	1240.77	−376.01	2838.07	2462.06	−1.3828	11.2555	9.8728	−21
−20	0.10326	0.001087	1131.27	1131.27	−374.06	2837.97	2463.91	−1.3750	11.2106	9.8356	−20
−19	0.11362	0.001088	1032.18	1032.18	−372.10	2837.86	2465.76	−1.3673	11.1661	9.7988	−19
−18	0.12492	0.001088	942.46	942.47	−370.13	2837.74	2467.61	−1.3596	11.1218	9.7623	−18
−17	0.13725	0.001088	861.17	861.18	−368.15	2837.61	2469.46	−1.3518	11.0779	9.7261	−17
−16	0.15068	0.001088	787.48	787.49	−366.17	2837.47	2471.30	−1.3441	11.0343	9.6902	−16
−15	0.16530	0.001088	720.59	720.59	−364.18	2837.33	2473.15	−1.3364	10.9910	9.6546	−15
−14	0.18122	0.001088	659.86	659.86	−362.18	2837.18	2474.99	−1.3287	10.9480	9.6193	−14
−13	0.19852	0.001089	604.65	604.65	−360.18	2837.02	2476.84	−1.3210	10.9053	9.5844	−13
−12	0.21732	0.001089	554.45	554.45	−358.17	2836.85	2478.68	−1.3232	10.8629	9.5497	−12
−11	0.23774	0.001089	508.75	508.75	−356.15	2836.68	2480.53	−1.3055	10.8208	9.5153	−11
−10	0.25990	0.001089	467.14	467.14	−354.12	2836.49	2482.37	−1.2978	10.7790	9.4812	−10
−9	0.28393	0.001089	429.21	429.21	−352.08	2836.30	2484.22	−1.2901	10.7375	9.4474	−9
−8	0.30998	0.001090	394.64	394.64	−350.04	2836.10	2486.06	−1.2824	10.6962	9.4139	−8
−7	0.33819	0.001090	363.07	363.07	−347.99	2835.89	2487.90	−1.2746	10.6552	9.3806	−7
−6	0.36874	0.001090	334.25	334.25	−345.93	2835.68	2489.74	−1.2669	10.6145	9.3476	−6
−5	0.40176	0.001090	307.91	307.91	−343.87	2835.45	2491.58	−2.2592	10.4741	9.3149	−5
−4	0.43747	0.001090	283.83	283.83	−341.80	2835.22	2493.42	−1.2515	10.5340	9.2825	−4
−3	0.47606	0.001090	261.79	261.79	−339.72	2834.98	2495.26	−1.2438	10.4941	9.2503	−3
−2	0.51772	0.001091	241.60	241.60	−337.63	2834.72	2497.10	−1.2361	10.4544	9.2184	−2
−1	0.56267	0.001091	223.11	223.11	−335.53	2834.47	2498.93	−1.2284	10.4151	9.1867	−1
0	0.61115	0.001091	206.16	206.16	−333.43	2834.20	2500.77	−1.2206	10.3760	9.1553	0
0	0.6112	0.001000	206.141	206.143	−0.04	2500.81	2500.77	−0.0002	9.1555	9.1553	0
1	0.6571	0.001000	192.455	192.456	4.18	2498.43	2502.61	0.0153	9.1134	9.1286	1
2	0.7060	0.001000	179.769	179.770	8.39	2496.05	2504.45	0.0306	9.0716	9.1022	2
3	0.7580	0.001000	168.026	168.027	12.60	2493.68	2506.28	0.0459	9.0302	9.0761	3
4	0.8135	0.001000	157.137	157.138	16.81	2491.31	2508.12	0.0611	8.9890	9.0501	4
5	0.8725	0.001000	147.032	147.033	21.02	2488.94	2509.96	0.0763	8.9482	9.0244	5
6	0.9353	0.001000	137.653	137.654	25.22	2486.57	2511.79	0.0913	8.9077	8.9990	6
7	1.0020	0.001000	128.947	128.948	29.42	2484.20	2513.62	0.1064	8.8674	8.9738	7
8	1.0728	0.001000	120.850	120.851	33.62	2481.84	2515.46	0.1213	8.8273	8.9488	8
9	1.1481	0.001000	113.326	113.327	37.82	2479.47	2517.29	0.1362	8.7878	8.9245	9
10	1.2280	0.001000	106.328	106.329	42.01	2477.11	2519.12	0.1511	8.7484	8.8995	10
11	1.3127	0.001000	99.812	99.813	46.21	2474.74	2520.95	0.1659	8.7093	8.8752	11

Table 3 Thermodynamic Properties of Water at Saturation (*Continued*)

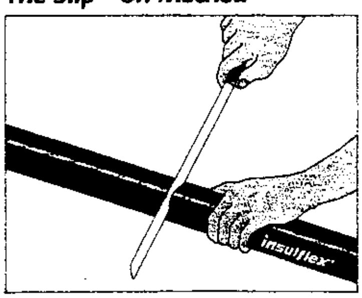
Temp. t, °C	Absolute Pressure kPa p	Specific Volume, m³/kg			Enthalpy, kJ/kg			Entropy, kJ/(kg·K)			Temp., °C
		Sat. Liquid v_f	Evap. v_{fg}	Sat. Vapor v_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Evap. s_{fg}	Sat. Vapor s_g	
12	1.4026	0.001001	93.743	93.744	50.40	2472.38	2522.78	0.1806	8.6705	8.8511	12
13	1.4978	0.001001	88.088	88.089	54.59	2470.02	2524.61	0.1953	8.6319	8.8272	13
14	1.5987	0.001001	82.815	82.816	58.78	2467.66	2526.44	0.2099	8.5936	3.8035	14
15	1.7055	0.001001	77.897	77.898	62.97	2465.30	2528.26	0.2244	8.5556	8.7801	15
16	1.8184	0.001001	73.307	73.308	67.16	2462.93	2530.09	0.2389	8.5178	8.7568	16
17	1.9380	0.001001	69.021	69.022	71.34	2460.57	2531.92	0.2534	8.4804	8.7338	17
18	2.0643	0.001002	65.017	65.018	75.53	2458.21	2533.74	0.2678	8.4431	8.7109	18
19	2.1978	0.001002	65.274	61.273	79.72	2455.85	2535.56	0.2821	8.4061	8.6883	19
20	2.3388	0.001002	57.774	57.773	83.90	2453.48	2537.38	0.2964	8.3694	8.6658	20
21	2.4877	0.001002	54.450	54.500	88.08	2451.12	2539.20	0.3107	8.3329	8.6436	21
22	2.6448	0.001002	51.433	51.434	92.27	2448.75	2541.02	0.3249	8.2967	8.6215	22
23	2.8104	0.001003	48.562	48.563	96.45	2446.39	2542.84	0.3390	8.2607	8.5996	23
24	2.9851	0.001003	45.872	45.873	100.63	2444.02	2544.65	0.3531	8.2249	8.5780	24
25	3.1692	0.001003	43.350	43.351	104.81	2441.66	2546.47	0.3672	8.1894	8.5565	25
26	3.3631	0.001003	40.985	40.986	108.99	2439.29	2548.28	0.3812	8.1541	8.5352	26
27	3.5673	0.001004	38.766	38.767	113.18	2436.92	2550.09	0.3951	8.1190	8.5141	27
28	3.7822	0.001004	36.682	36.683	117.36	2434.55	2551.90	0.4090	8.0842	8.4932	28
29	4.0083	0.001004	34.726	34.727	121.54	2432.17	2553.71	0.4229	8.0496	8.4724	29
30	4.2460	0.001004	32.889	32.889	125.72	2429.80	2555.52	0.4367	8.0152	8.4519	30
31	4.4959	0.001005	31.160	31.161	129.90	2427.43	2557.32	0.4505	7.9810	8.4315	31
32	4.7585	0.001005	29.535	29.536	134.08	2425.05	2559.13	0.4642	7.9471	8.4112	32
33	5.0343	0.001005	28.006	28.007	138.26	2422.67	2560.93	0.4779	7.9133	8.3912	33
34	5.3239	0.001006	26.567	26.568	142.44	2410.29	2562.73	0.4915	7.8790	8.3713	34
35	5.6278	0.001006	25.212	25.213	146.62	2417.91	2564.53	0.5051	7.8465	8.3516	35
36	5.9466	0.001006	23.935	23.936	150.80	2415.53	2566.33	0.5186	7.8134	8.3320	36
37	6.2810	0.001007	22.733	22.734	154.98	2413.14	2568.12	0.5321	7.7805	8.3127	37
38	6.6315	0.001007	21.599	21.600	159.16	2410.76	2569.91	0.5456	7.7479	8.2934	38
39	6.9987	0.001008	20.529	20.530	163.34	2408.37	2571.71	0.5590	7.7154	8.2744	39
40	7.3835	0.001008	19.520	19.521	167.52	2405.98	2573.50	0.5724	7.6831	8.2555	40
41	7.7863	0.001008	18.567	18.568	171.70	2403.58	2575.28	0.5857	7.6510	8.2367	41
42	8.2080	0.001009	17.667	17.668	175.88	2401.19	2577.07	0.5990	7.6191	8.2181	42
43	8.6492	0.001009	16.818	16.819	180.06	2398.79	2578.85	0.6122	7.5875	8.1997	43
44	9.1107	0.001010	16.014	16.015	184.24	2396.39	2580.63	0.6254	7.3560	8.1814	44
45	9.5932	0.001010	15.255	15.256	188.42	2393.99	2582.41	0.6386	7.5247	8.1632	45
46	10.0976	0.001010	14.537	14.538	192.60	2391.59	2584.19	0.6517	7.4936	8.1452	46
47	10.6246	0.001011	13.858	13.859	196.78	2389.18	2585.96	0.6648	7.4626	8.1274	47
48	11.1751	0.001011	13.214	13.215	200.97	2386.77	2587.74	0.6778	7.4319	8.1097	48
49	11.7500	0.001012	12.606	12.607	205.15	2384.36	2589.51	0.6908	7.4013	8.0921	49
50	12.3499	0.001012	12.029	12.029	209.33	2381.94	2591.27	0.7038	7.3709	8.0747	50
51	12.9759	0.001013	11.482	11.483	213.51	2379.53	2593.04	0.7167	7.3407	8.0574	51
52	13.6290	0.001013	10.964	10.965	217.70	2377.10	2594.80	0.7296	7.3107	8.0403	52
53	14.3100	0.001014	10.473	10.474	221.88	2374.68	2596.56	0.7424	7.2809	8.0233	53
54	15.0200	0.001014	10.001	10.008	226.06	2372.26	2598.32	0.7552	7.2512	8.0064	54
55	15.7597	0.001015	9.563	9.5663	230.25	2369.83	2600.07	0.7680	7.2217	7.9897	55
56	16.5304	0.001015	9.147	9.1468	234.43	2367.39	2601.82	0.7807	7.1924	7.9731	56
57	17.3331	0.001016	8.744	8.7489	238.61	2364.96	2603.57	0.7934	7.1632	7.9566	57
58	18.1690	0.001016	8.3690	8.3700	242.80	2362.52	2605.32	0.8061	7.1342	7.9403	58
59	19.0387	0.001017	8.0094	8.0114	246.99	2360.08	2607.06	0.8187	7.1054	7.9240	59
60	19.944	0.001017	7.6677	7.6697	251.17	2357.63	2608.80	0.8313	7.0767	7.9079	60
61	20.885	0.001018	7.3428	7.3438	255.36	2355.19	2610.54	0.8438	7.0482	7.8920	61
62	21.864	0.001018	7.0337	7.0347	259.54	2352.73	2612.28	0.8563	7.0198	7.8761	62
63	22.882	0.001019	6.7397	6.7407	263.73	2350.28	2614.01	0.8688	6.9916	7.8604	63
64	23.940	0.001019	6.4599	6.4609	267.92	2347.82	2615.74	0.8812	6.9636	7.8448	64
65	25.040	0.001020	6.1935	6.1946	272.11	2345.36	2617.46	0.8936	6.9357	7.8293	65
66	26.180	0.001020	5.9397	5.9409	276.30	2342.89	2619.19	0.9060	6.9080	7.8140	66
67	27.366	0.001021	5.6982	5.6992	280.49	2340.42	2620.90	0.9183	6.8804	7.7987	67
68	28.596	0.001022	5.4680	5.4690	284.68	2337.95	2622.62	0.9306	6.8530	7.7836	68
69	29.873	0.001022	5.2485	5.2495	288.87	2335.47	2624.33	0.9429	6.8257	7.7686	69
70	31.198	0.001023	5.0392	5.0402	293.06	2332.99	2626.04	0.9551	6.7986	7.7537	70
71	32.572	0.001023	4.8396	4.8407	297.25	2330.50	2627.75	0.9673	6.7716	7.7389	71
72	33.997	0.001024	4.6492	4.6502	301.44	2328.01	2629.45	0.9795	6.7448	7.7242	72
73	35.475	0.001025	4.4675	4.4685	305.63	2325.51	2631.15	0.9916	6.7181	7.7097	73
74	37.006	0.001025	4.2940	4.2951	309.83	2323.02	2632.84	1.0037	6.6915	7.6952	74
75	38.592	0.001026	4.1284	4.1294	314.02	2320.51	2634.53	1.0157	6.6651	7.6809	75
76	40.236	0.001026	3.9702	3.9712	318.22	2318.01	2636.22	1.0278	6.6389	7.6666	76
77	41.938	0.001027	3.8190	3.8201	322.41	2315.49	2637.90	1.0398	6.6127	7.6525	77
78	43.700	0.001028	3.6746	3.6756	326.61	2312.98	2639.58	1.0517	6.5867	7.6384	78
79	45.524	0.001028	3.5365	3.5375	330.81	2310.46	2641.26	1.0636	6.5609	7.6245	79

PIPE INSULATION

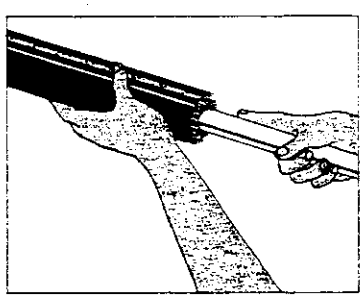
insulflex® tubing insulation is easy and quick to install. Insulflex should only be applied to pipes that are clean, dry and unheated. The slip-on method is used to insulate new pipes before they are installed or connected whereas the snap-on method is used when pipes have been installed and connected. Insulflex tubing can be cut to length or slit lengthwise with a sharp knife. The inner surface of tubing is lightly powdered to permit the tubing to be slipped easily over the pipe. Seal pipe ends with plugs while installing the tubing insulation to prevent powder from entering the refrigeration system.

It is important not to compress the tubing material as the insulation value may be degraded when compressed and condensation may occur on the compressed area. Select the right size tubing insulation for the pipe to be insulated. Avoid stretching the material over the pipe. The length of the insulation tubing should cover the section of the pipe to be insulated adequately, to ensure there will be no strain on the surfaces and joints. Seal all seams and butt joints with adhesive.

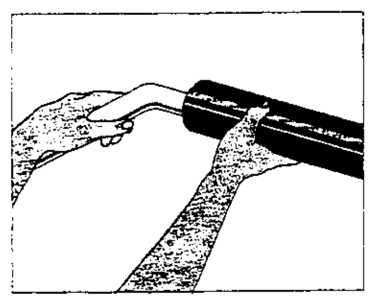
The Slip - On Method



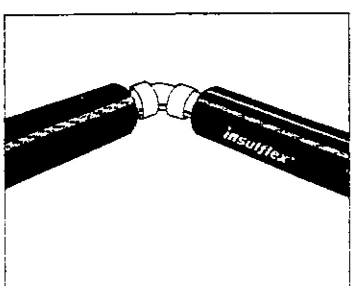
Make 90° cut with a sharp knife. The length should be slightly longer than section to be insulated to avoid stretching when joining the ends.



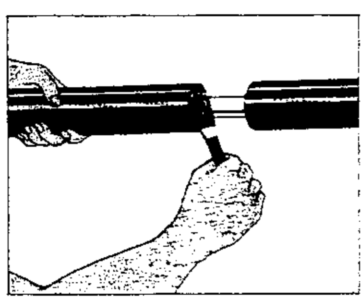
Slip full length of insulflex tubing over entire length of pipe.



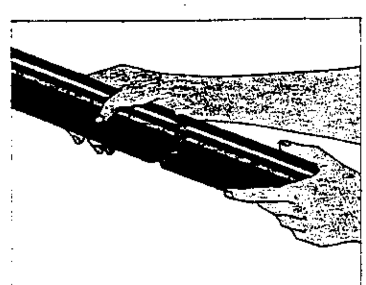
Insulflex tubing can be easily slipped over bent tubing of 45° angle, elbow bend or coupling.



Slip insulflex tubing into position and tightly against the 90° fittings.

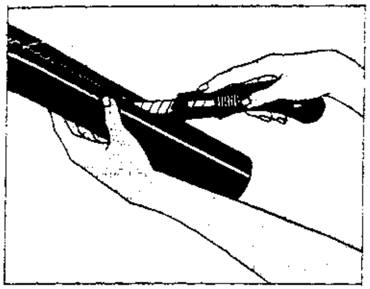


Brush all joints and seams with even coat of adhesive.

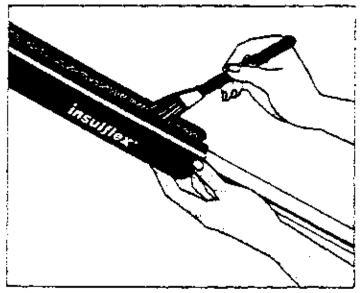


When adhesive is dry but tacky, join seams by pressing the surfaces together firmly.

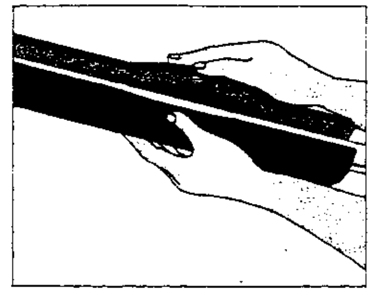
The Snap - On Method



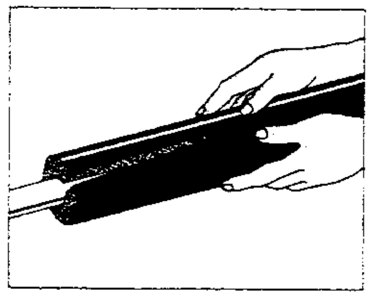
Cut unslit Insulflex tubing lengthwise with a sharp knife.



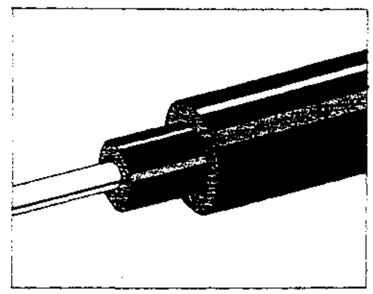
Snap the insulation over the pipe. Coat both slit seams evenly with adhesive.



Hold the coated seams apart while the adhesive dries.



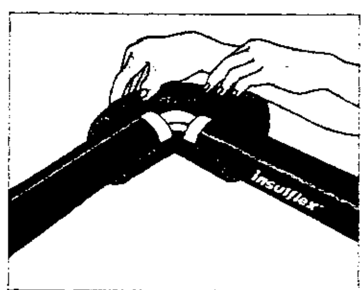
When adhesive is dry but tacky to touch, press together surfaces nearest to pipe first and then joint outer edges of the two surfaces.



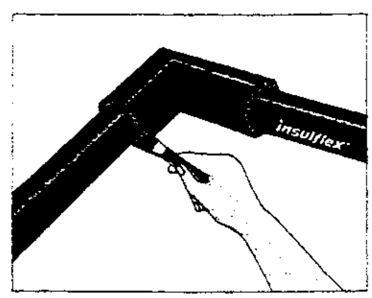
When insulating with two layers, stagger the lengthwise and butt joints.

Insulating Fittings

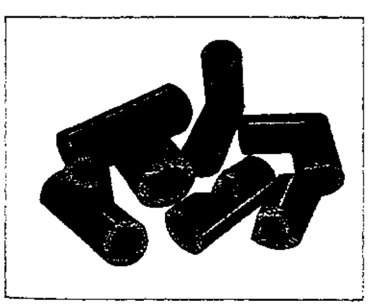
insulflex* Tubing can be easily cut and fabricated into fittings for either sweat or threaded joints like bends, T's and elbows, on both new and existing lines. For screwed fittings, sleeved fitting cover should be fabricated from tubing of same wall thickness as used on the pipe. The inner diameter of the fittings must be large enough to overlap the insulation on the straight pipe.



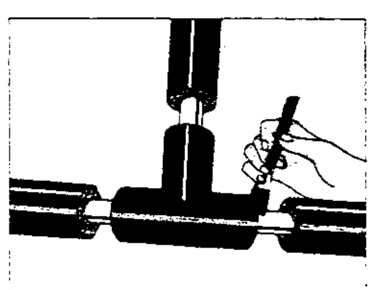
Snap the slit fitting cover in position over the joint.



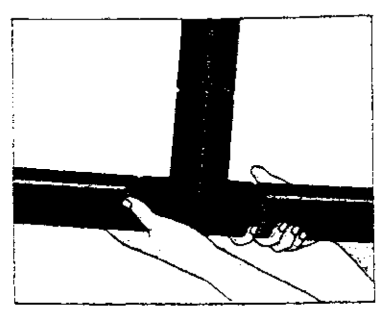
Apply adhesive on the slit seams. Press the seams firmly together when adhesive has dried. Brush in between overlap surfaces with adhesive.



Fabricate fittings by using 45° and 90° angles cut with adhesive. When adhesive has dried, slit the fittings through the centre.



Snap fitting cover in place and apply adhesive to all surfaces to be joined.

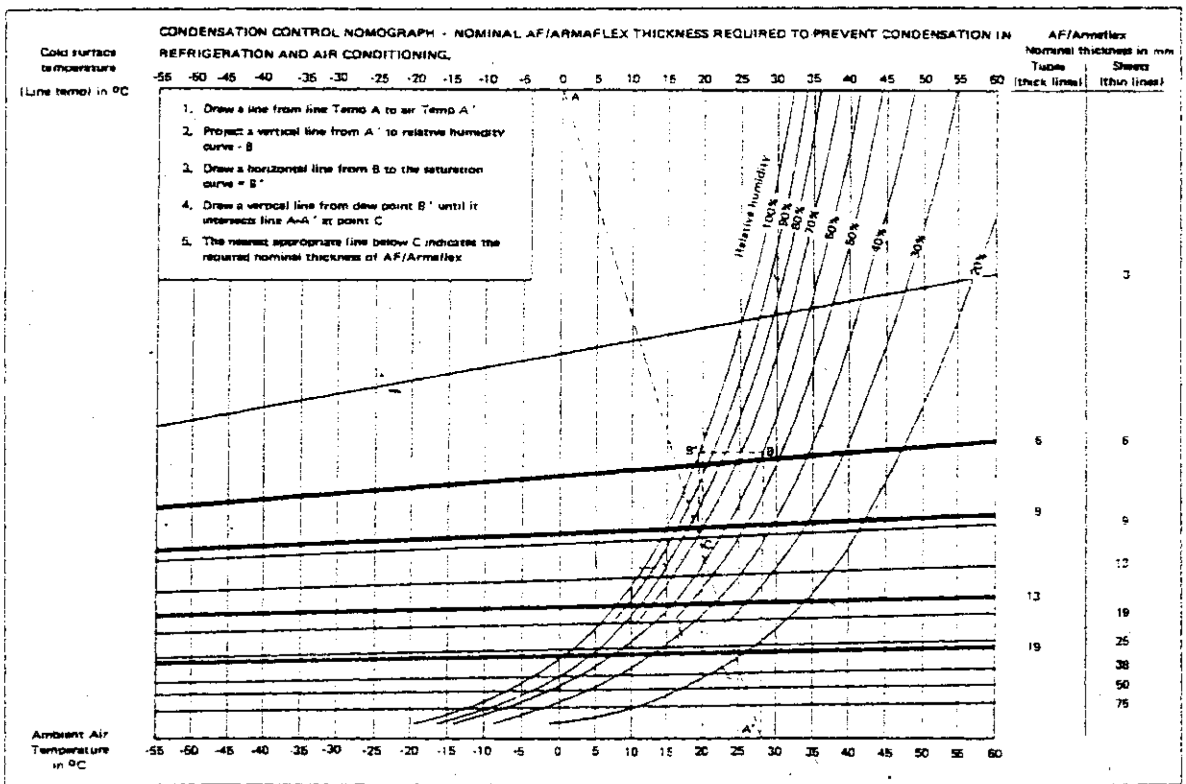


Press tubing firmly together when adhesive is dry but tacky to touch.

Nomograph. For thickness of AF/Armaflex

Insulation thicknesses are usually worked out using the AF/Armaflex "condensation control nomograph". The nomograph takes into account the special properties of AF/Armaflex, such as thermal conductivity and surface heat transfer coefficient, and can be used to calculate tube sizes for pipes of up to 114 mm external diameter and sheet sizes for insulating larger diameters pipes or air ducts.

The nomograph is applicable for all normally installed pipes (inside and outside) where there is free air convection. Where ventilation is inadequate (stagnant areas) and/or there are reflective coatings or metallic sheathings, the insulation thickness required must be worked out by calculation. This also applies where, e.g. in the case of very large temperature differences and/or high atmospheric humidity values, it is not possible to read off the required value from the nomograph or the reading is not sufficiently accurate.



An example using the Nomograph is shown above. The design conditions:-

Ambient temperature	28°C
Relative humidity	60%
Line temperature	0°C

Alongside the horizontal lines in the nomograph are the thicknesses for tube and sheet material. The nearest line below intersection point C indicates the thickness required i.e. for pipes, tubular material (13mm nominal thickness).

The engineered wall thickness of AF/Armaflex up to 19mm tubular material means that the correct insulation thickness can be automatically determined for all pipe diameters up to 114mm.

(The condensation control nomograph is available in A4 pads on request)

Table 4 Freezing and Boiling Points of Aqueous Solutions of Ethylene Glycol

Percent Ethylene Glycol		Freezing Point, °C	Boiling Point, °C at 100.7 kPa
By Mass	By Volume		
0.0	0.0	0.0	100.0
5.0	4.4	−1.4	100.6
10.0	8.9	−3.2	101.1
15.0	13.6	−5.4	101.7
20.0	18.1	−7.8	102.2
21.0	19.2	−8.4	102.2
22.0	20.1	−8.9	102.2
23.0	21.0	−9.5	102.8
24.0	22.0	−10.2	102.8
25.0	22.9	−10.7	103.3
26.0	23.9	−11.4	103.3
27.0	24.8	−12.0	103.3
28.0	25.8	−12.7	103.9
29.0	26.7	−13.3	103.9
30.0	27.7	−14.1	104.4
31.0	28.7	−14.8	104.4
32.0	29.6	−15.4	104.4
33.0	30.6	−16.2	104.4
34.0	31.6	−17.0	104.4
35.0	32.6	−17.9	105.0
36.0	33.5	−18.6	105.0
37.0	34.5	−19.4	105.0
38.0	35.5	−20.3	105.0
39.0	36.5	−21.3	105.0
40.0	37.5	−22.3	105.6
41.0	38.5	−23.2	105.6
42.0	39.5	−24.3	105.6
43.0	40.5	−25.3	106.1
44.0	41.5	−26.4	106.1
45.0	42.5	−27.5	106.7
46.0	43.5	−28.8	106.7
47.0	44.5	−29.8	106.7
48.0	45.5	−31.1	106.7
49.0	46.6	−32.6	106.7
50.0	47.6	−33.8	107.2
51.0	48.6	−35.1	107.2
52.0	49.6	−36.4	107.2
53.0	50.6	−37.9	107.8
54.0	51.6	−39.3	107.8
55.0	52.7	−41.1	108.3
56.0	53.7	−42.6	108.3
57.0	54.7	−44.2	108.9
58.0	55.7	−45.6	108.9
59.0	56.8	−47.1	109.4
60.0	57.8	−48.3	110.0
65.0	62.8	a	112.8
70.0	68.3	a	116.7
75.0	73.6	a	120.0
80.0	78.9	−46.8	123.9
85.0	84.3	−36.9	133.9
90.0	89.7	−29.8	140.6
95.0	95.0	−19.4	158.3

[a]Freezing points are below −50°C.

Table 5 Freezing and Boiling Points of Aqueous Solutions of Propylene Glycol

Percent Propylene Glycol		Freezing Point, °C	Boiling Point, °C at 100.7 kPa
By Mass	By Volume		
0.0	0.0	0.0	100.0
5.0	4.8	−1.6	100.0
10.0	9.6	−3.3	100.0
15.0	14.5	−5.1	100.0
20.0	19.4	−7.1	100.6
21.0	20.4	−7.6	100.6
22.0	21.4	−8.0	100.6
23.0	22.4	−8.6	100.6
24.0	23.4	−9.1	100.6
25.0	24.4	−9.6	101.1
26.0	25.3	−10.2	101.1
27.0	26.4	−10.8	101.1
28.0	27.4	−11.4	101.7
29.0	28.4	−12.0	101.7
30.0	29.4	−12.7	102.2
31.0	30.4	−13.4	102.2
32.0	31.4	−14.1	102.2
33.0	32.4	−14.8	102.2
34.0	33.5	−15.6	102.2
35.0	34.4	−16.4	102.8
36.0	35.5	−17.3	102.8
37.0	36.5	−18.2	102.8
38.0	37.5	−19.1	103.3
39.0	38.5	−20.1	103.3
40.0	39.6	−21.1	103.9
41.0	40.6	−22.1	103.9
42.0	41.6	−23.2	103.9
43.0	42.6	−24.3	103.9
44.0	43.7	−25.5	103.9
45.0	44.7	−26.7	104.4
46.0	45.7	−27.9	104.4
47.0	46.8	−29.3	104.4
48.0	47.8	−30.6	105.0
49.0	48.9	−32.1	105.0
50.0	49.9	−33.5	105.6
51.0	50.9	−35.0	105.6
52.0	51.9	−36.6	105.6
53.0	53.0	−38.2	106.1
54.0	54.0	−39.8	106.1
55.0	55.0	−41.6	106.1
56.0	56.0	−43.3	106.1
57.0	57.0	−45.2	106.7
58.0	58.0	−47.1	106.7
59.0	59.0	−49.0	106.7
60.0	60.0	−51.1	107.2
65.0	65.0	a	108.3
70.0	70.0	a	110.0
75.0	75.0	a	113.9
80.0	80.0	a	118.3
85.0	85.0	a	125.0
90.0	90.0	a	132.2
95.0	95.0	a	154.4

[a]Above 60% by mass, solutions do not freeze but become a glass.

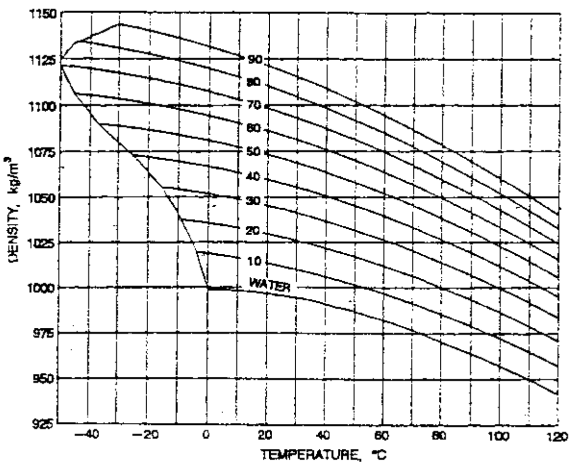


Fig. 9 Density of Aqueous Solutions of Industrially Inhibited Ethylene Glycol (vol. %)

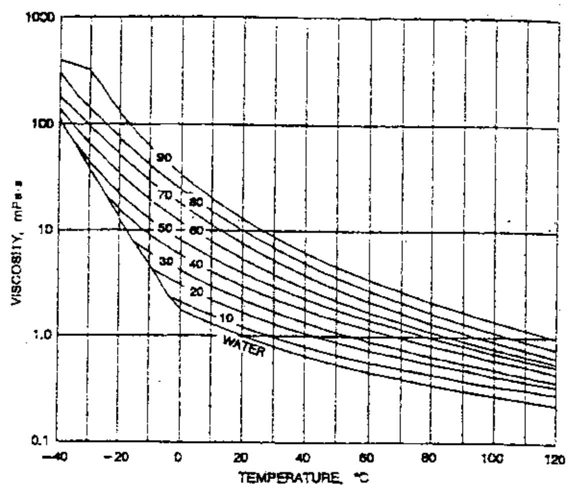


Fig. 12 Viscosity of Aqueous Solutions of Industrially Inhibited Ethylene Glycol(vol. %)

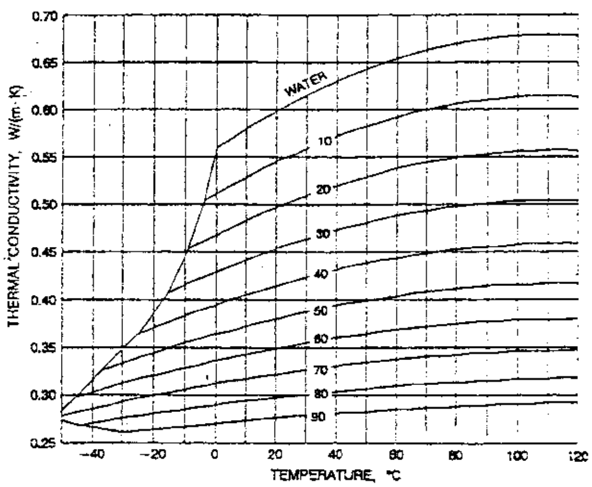


Fig. 10 Specific Heat of Aqueous Solutions of Industrially Inhibited Ethylene Glycol (vol. %)

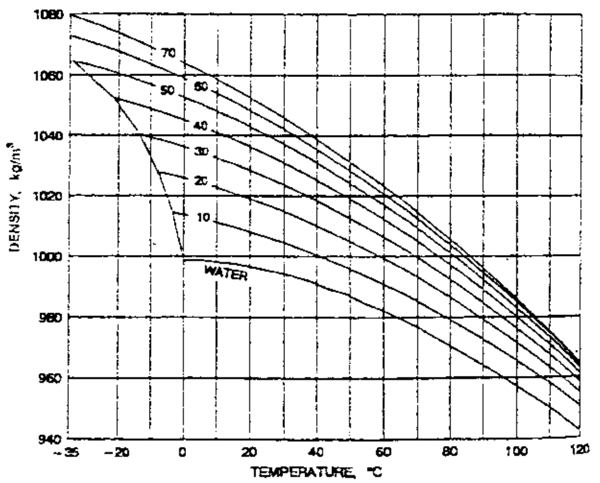


Fig. 13 Density of Aqueous Solutions of Industrially Inhabited Propylene Glycol (vol. %)

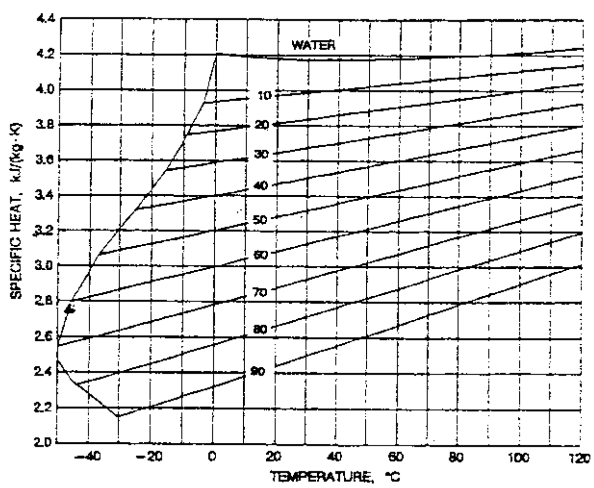


Fig. 11 Thermal Conductivity of Aqueous Solutions of Industrially Inhibited Ethylene Glycol (vol. %)

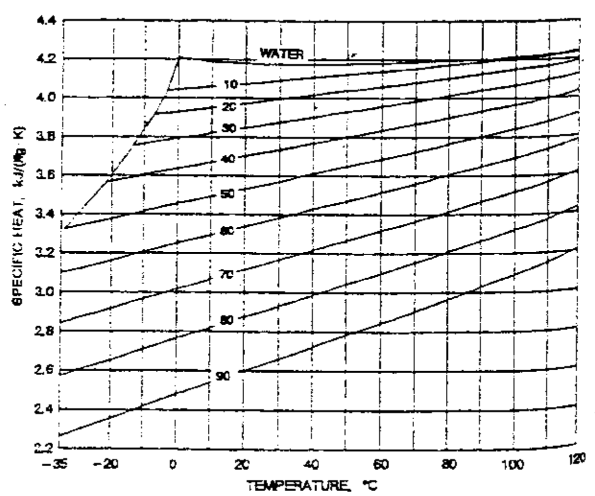


Fig. 14 Specific Heat of Aqueous Solutions of Industrially Inhibited Ethylene Glycol (vol. %)

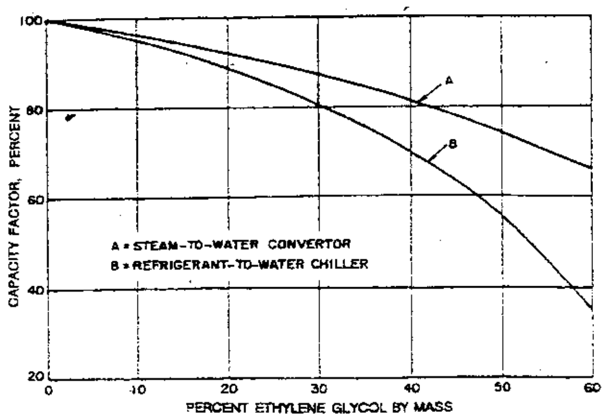


Fig. 29 Example of Effect of Aqueous Ethylene Glycol Solutions on Heat Exchanger Output

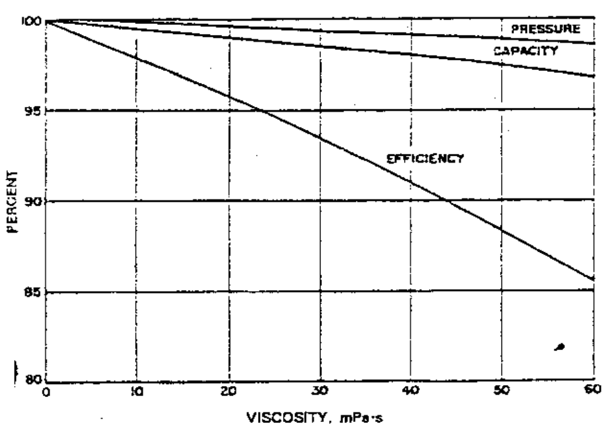


Fig. 30 Effect of Viscosity on Pump Characteristics

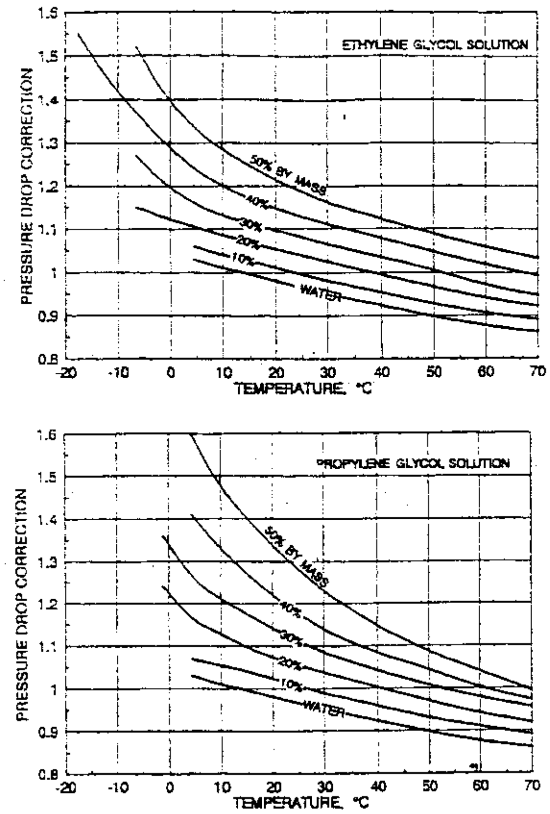


Fig. 31 Pressure Drop Correction for Glycol Solutions

Table 1: Typical Flow Rates

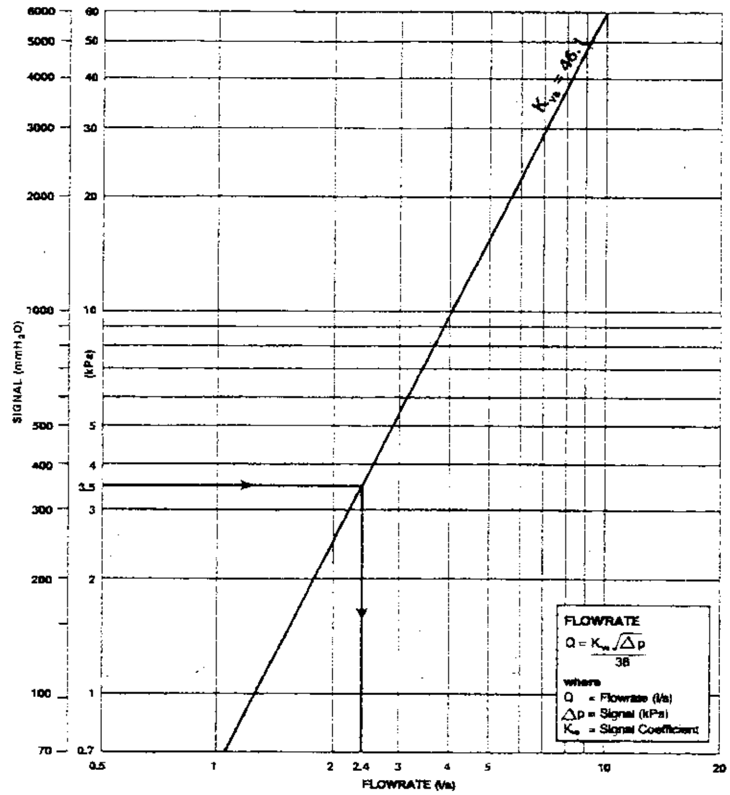
GPM (m^3/hr) Required to Actuate Switch											
Pipe Size (in.)		**1**	**1-1/4**	**1-1/2**	**2**	**2-1/2**	**3**	**4***	**5***	**6***	**8***
Minimum Adjustment	**Flow Increase R to Y Closes****	4.2 (1.0)	5.8 (1.3)	7.5 (1.7)	13.7 (3.1)	18.0 (4.1)	27.5 (6.2)	65.0 (14.8) 37.0† (8.4)	125.0 (28.4) 57.0† (12.9)	190.0 (43.1) 74.0† (16.8)	375.0 (85.2) 205.0† (46.6)
	Flow Decrease R to B Closes**	2.5 (0.6)	3.7 (0.8)	5.0 (1.7)	9.5 (2.2)	12.5 (2.8)	19.0 (4.3)	50.0 (11.4) 27.0† (6.1)	101.0 (22.9) 41.0† (9.3)	158.0 (35.9) 54.0† (12.3)	320.0 (72.7) 170.0† (38.6)
Maximum Adjustment	**Flow Increase R to Y Closes****	8.8 (1.0)	13.3 (1.3)	19.2 (1.7)	29.0 (3.1)	34.5 (7.8)	53.0 (12.0)	128.0 (29.1) 81.0† (13.4)	245.0 (55.6) 118.0† (26.8)	375.0 (85.2) 144.0† (32.7)	760.0 (172.6) 415.0† (94.2)
	Flow Decrease R to B Closes**	8.5 (1.9)	12.5 (2.8)	18.0 (4.1)	27.0 (6.1)	32.0 (7.3)	50.0 (11.4)	122.0 (27.7) 76.0† (17.3)	235 (53.4) 111.0† (25.2)	360.0 (81.8) 135.0† (30.7)	730.0 (165.8) 400.0† (90.8)

* Flow rates for these sizes are calculated.

† GPM figures are for a switch with a 6 in. paddle. For 4 in. and 5 in. line pipe, the 6 in. paddle is trimmed to a 4 in. and 5 in. length, respectively.

** For switching action, refer to Figure 2.

Flow Measurement
D901 · D911 · D941
Size 2 (50mm)



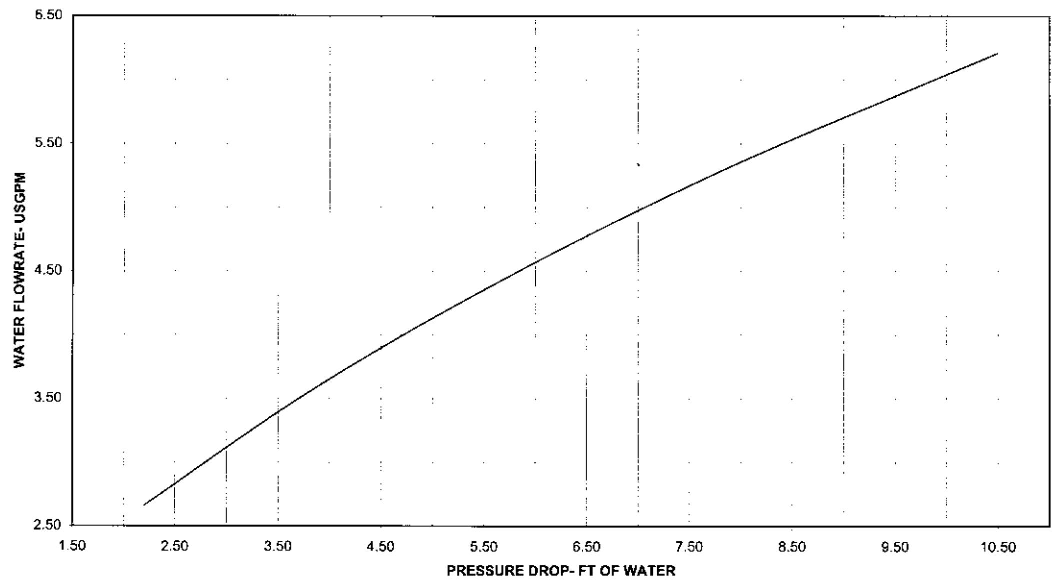
HEAD/PRESSURE LOSS
The loss resulting from the insertion of the device in a pipe system may be calculated by multiplying the signal by the appropriate factor:

Cat. No.	Factor
D901	0.41
D911	0.43
D941 (fully open)	2.27

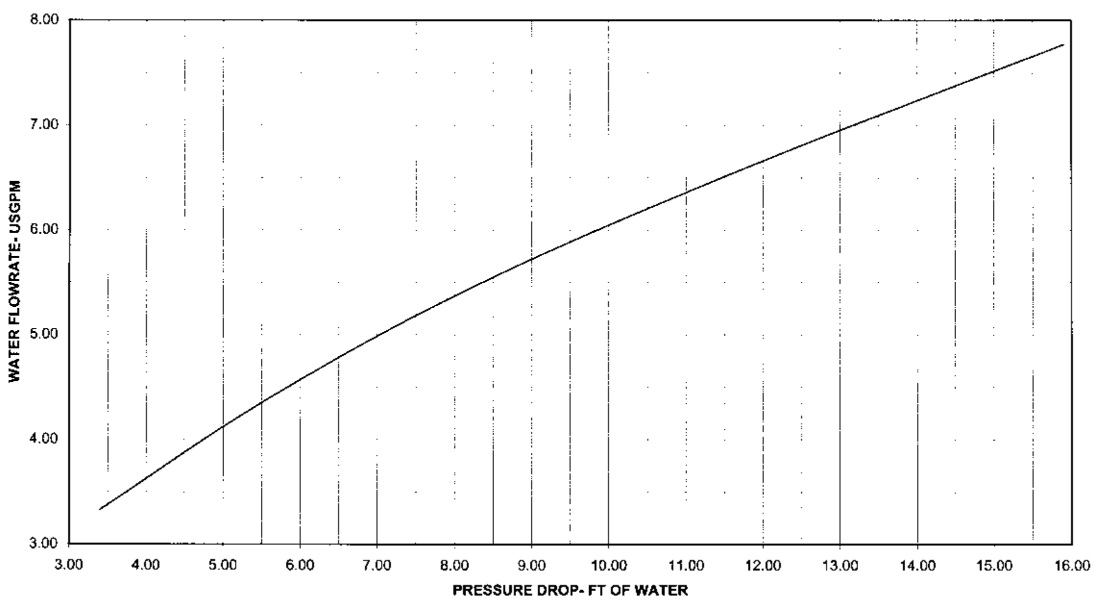
D941 (partially open)
The loss for the D941 in partially open positions may be calculated by adding the signals generated by the D901 and the D920 (see D930 graph) at the required flowrate.

Fig. 8. Typical calibration chart for 'fixed orifice' device

CE20DW



CE25DW



Note : PRESSURE DROP CORRECTION FACTOR = 1.2947 – 0.0021 * (EWTºF)

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