MEBS6006 Environmental Services I

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Water Side Systems

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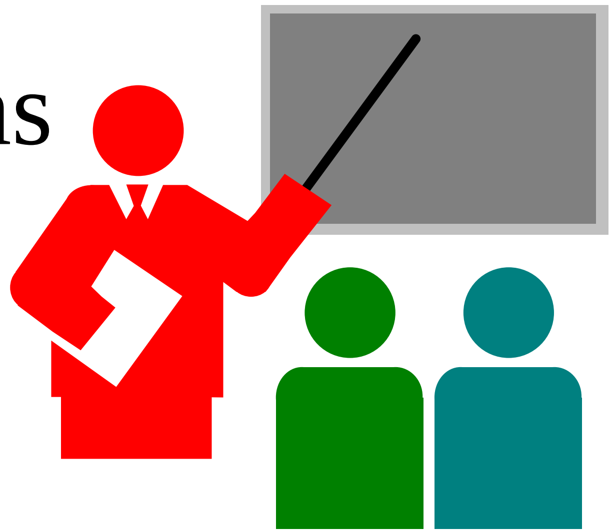
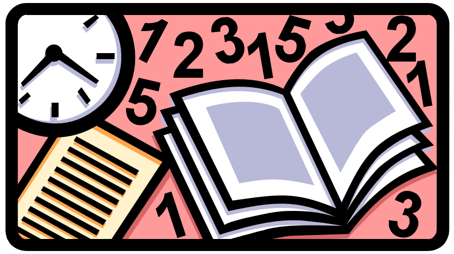
- Types of Water Systems
- Hot & Chilled Water System Arrangements
- Components of Water Systems



Types of Water Systems



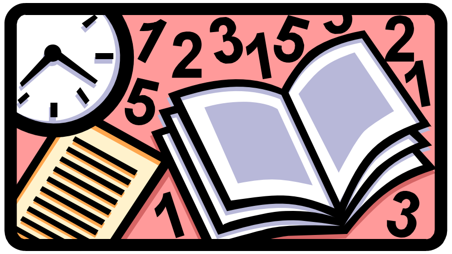
Hydronic systems

- Water systems that convey heat to or from a conditioned space or process with hot or chilled water are frequently called hydronic systems.
- The water flows through piping that connects a boiler, water heater, or chiller to suitable terminal heat transfer units located at the space or process.

Classification of Water systems based on

- Operating temperature,
- Flow generation,
- Pressurization,
- Piping arrangement,
- Pumping arrangement.

Types of Water Systems



Hot Water Systems

Low-temperature hot water (LTHW) system.

- This hydronic heating system operates within the pressure and temperature limits of the ASME *Boiler and Pressure Vessel Code* for low-pressure boilers.
- The maximum allowable temperature limitation of 120°C.
- Steam-to-water or water-to-water heat exchangers are also used for heating low-temperature water.

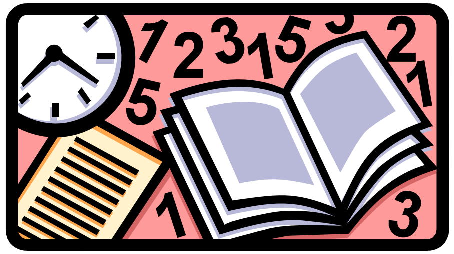
Medium-temperature hot water (MTHW) system.

- This hydronic heating system operates at temperatures between 120 and 175°C.
- The usual design supply temperature is approximately 120 to 160°C.

High-temperature hot water (HTHW) system.

- This hydronic heating system operates at temperatures over 175°C
- The maximum design supply water temperature is usually about 200°C.

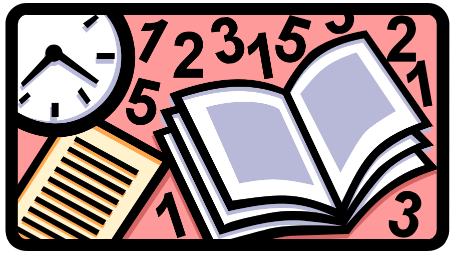
Types of Water Systems



Chilled Water System

- Water is first cooled in the water chiller—the evaporator of a reciprocating, screw, or centrifugal refrigeration system located in a centralized plant—to a temperature of 5.6 to 8.3°C .
- It is then pumped to the water cooling coils in AHUs and terminals in which air is cooled and dehumidified.
- After flowing through the coils, the chilled water increases in temperature up to 12 °C to 14°C and then returns to the chiller.

Types of Water Systems



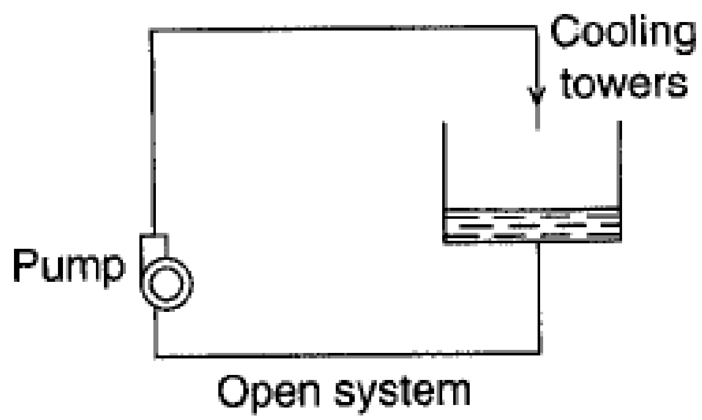
Dual-Temperature Water System

- Chilled water or hot water is supplied to the coils in AHUs and terminals and is returned to the water chiller or boiler mainly through :
  - Separate supply and return main and branch pipes (4 pipe system)
  - Common supply and return mains, branch pipe, and coil for hot and chilled water supply and return (2 pipe system)
- Operate within the pressure and temperature limits of LTHW systems, with usual winter design supply water temperatures of about 38 to 65°C and summer supply water temperatures of 4 to 7°C.
- The changeover from chilled water to hot water and vice versa in a building or a system depends mainly on the space requirements and the temperature of outdoor air.

Types of Water Systems

Condenser Water System

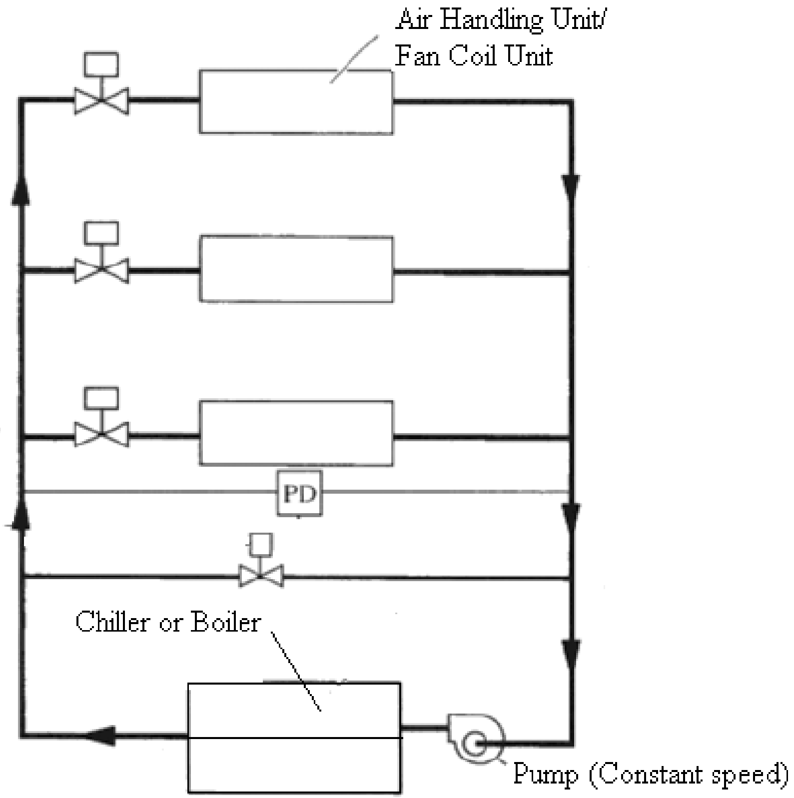
- The latent heat of condensation of the refrigerant in the chiller plant is removed in the condenser by the condenser water.
- This condenser water is either seawater or fresh water from the Water Authority.



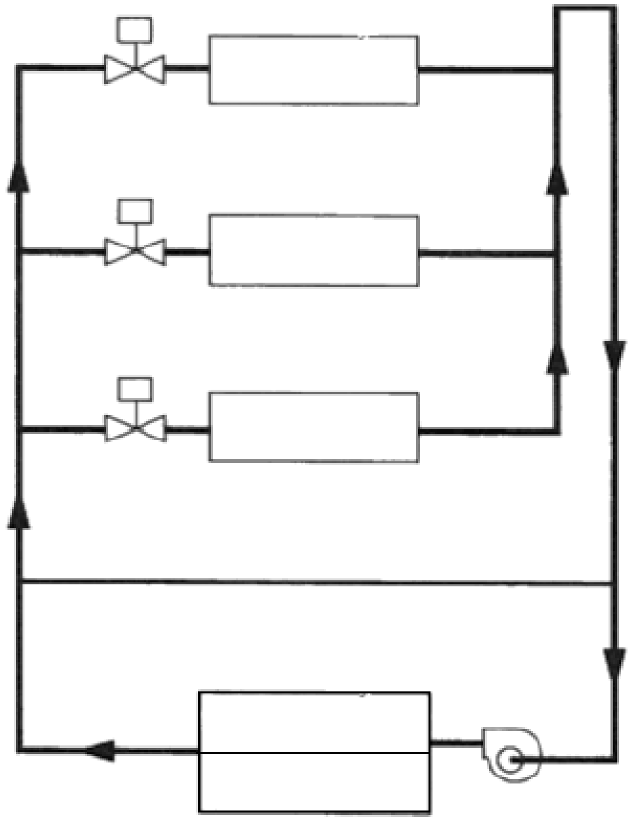
Hot and Chilled Water Systems

Chilled/ Hot water system: Direct Return/ Reverse Return

Compare path resistance of these two systems



Direct Return System

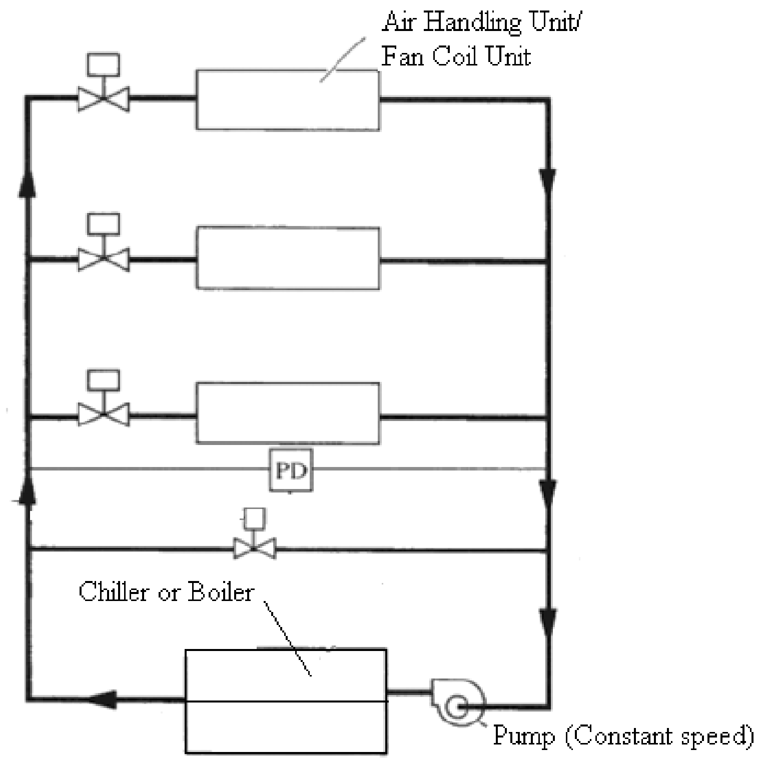


Reverse Return System

Hot and Chilled Water Systems

<u>Direct-return piping</u> : -

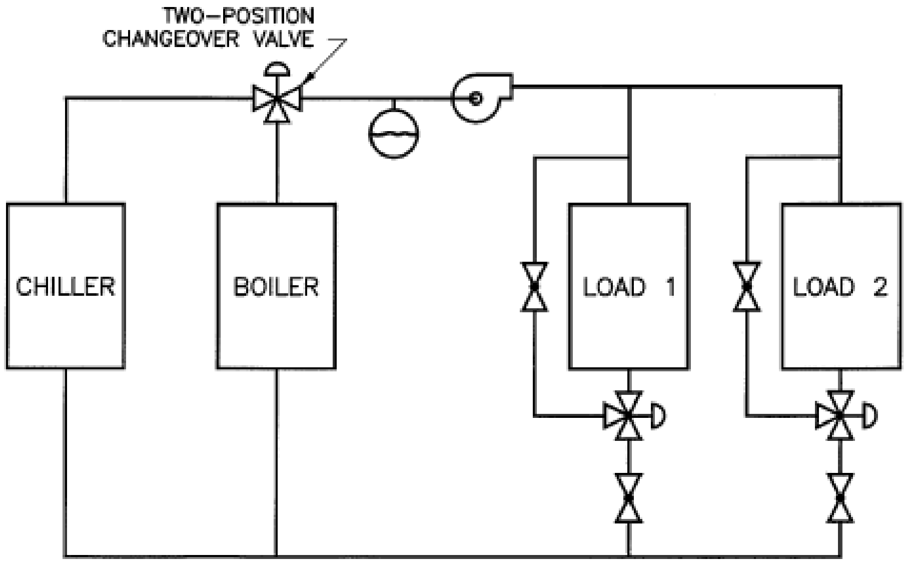
- Applied for subcircuits or terminals that have significant percentages of the total, usually establishing pressure drops for close subcircuits at higher values than those for the far subcircuits
- Including balancing devices and some means of measuring flow at each terminal or branch circuit using control valves with a high pressure loss at the terminals



Hot and Chilled Water Systems

Two-Pipe Systems

- Loads must all require cooling or heating coincidentally; that is, if cooling is required for some loads and heating for other loads at a given time, this type of system should not be used.
- The changeover procedure should be designed such that the chiller evaporator is not exposed to damaging high water temperatures and the boiler is not subjected to damaging low water temperatures.
- If rapid load swings are anticipated, a two-pipe system should not be selected, although it is the least costly of the three options.

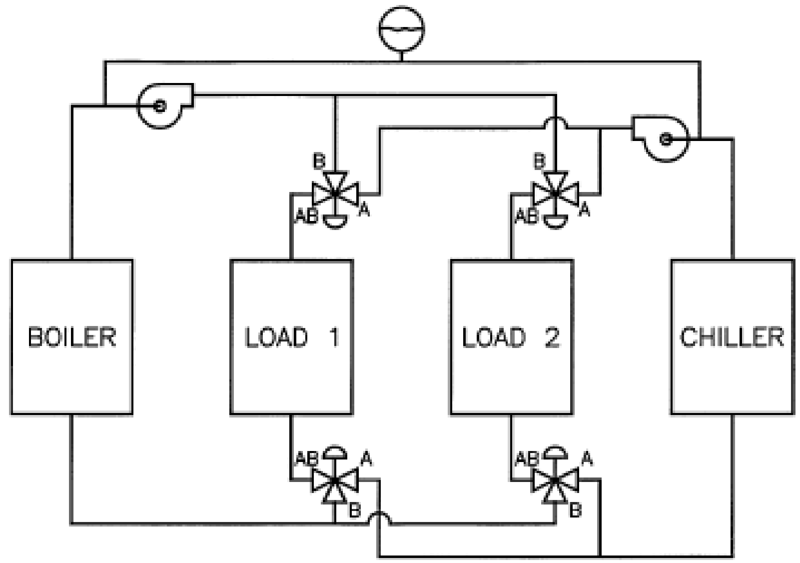


Simplified Diagram of Two-Pipe System

Hot and Chilled Water Systems

Four-Pipe Common Load Systems

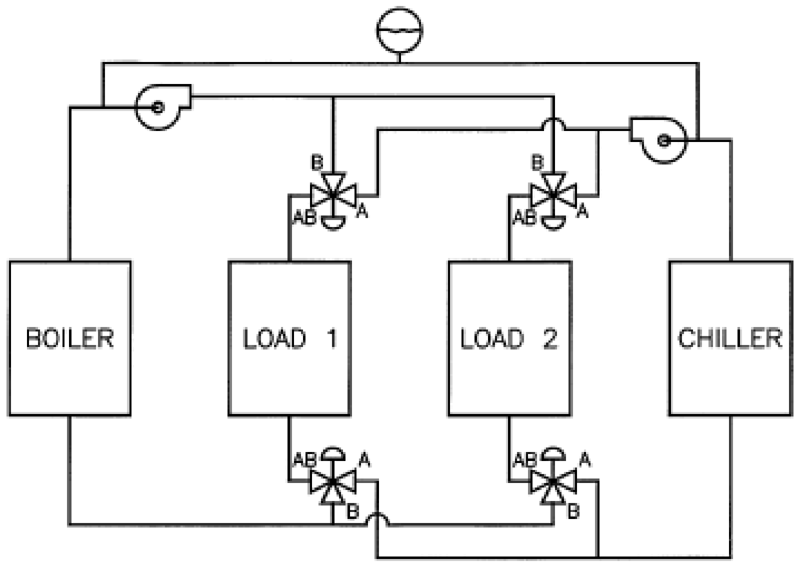
- In the four-pipe common load system, load devices are used for both heating and cooling as in the two-pipe system.
- The four-pipe common load system differs from the two-pipe system in that both heating and cooling are available to each load device, and the changeover from one mode to the other takes place at each individual load device, or grouping of load devices, rather than at the source.
- Thus, some of the load systems can be in the cooling mode while others are in the heating mode.



Four-Pipe Common Load System

Hot and Chilled Water Systems

- Potential problem is the mixing of hot and chilled water.
- Limited to those applications in which there are no independent load circuits (i.e., radiant ceiling panels or induction unit coils).

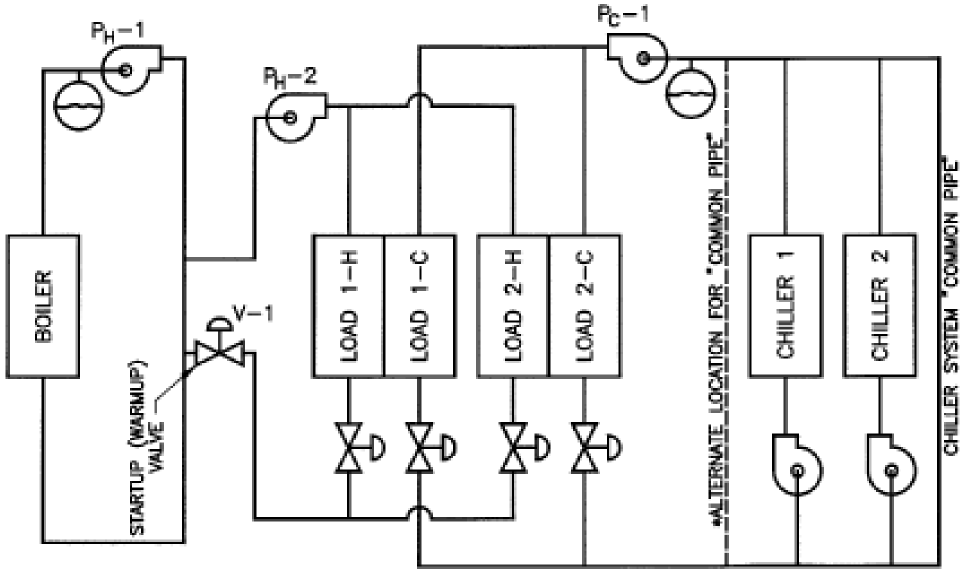


Four-Pipe Common Load System

Hot and Chilled Water Systems

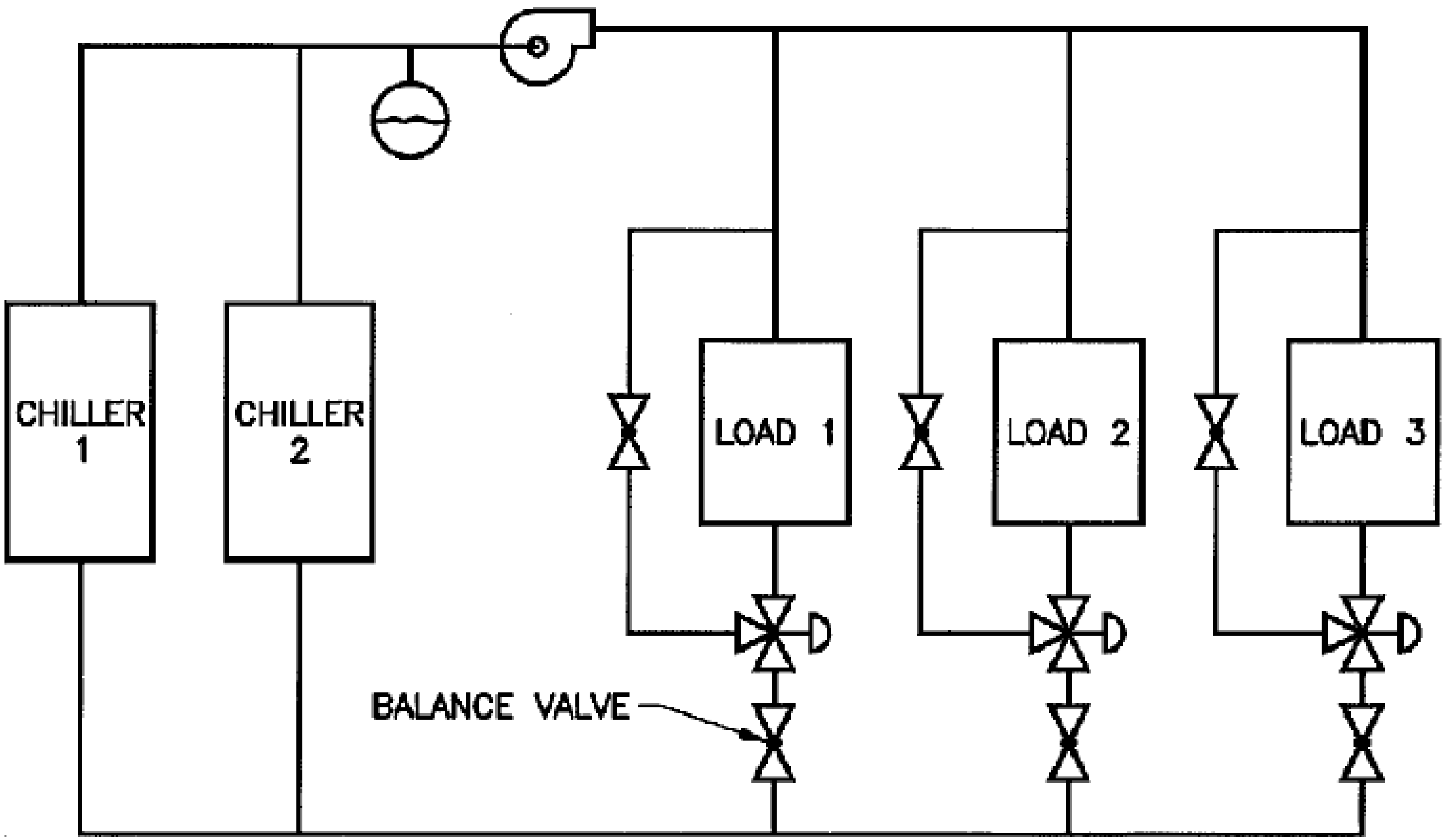
Four-Pipe Independent Load Systems

- The four-pipe independent load system is preferred for those hydronic applications in which some of the loads are in the heating mode while others are in the cooling mode.
- Control is simpler and more reliable than for the common load systems and is less costly to install.
- The flow through the individual loads can be modulated, providing both the control capability for variable capacity and the opportunity for variable flow in either or both circuits.



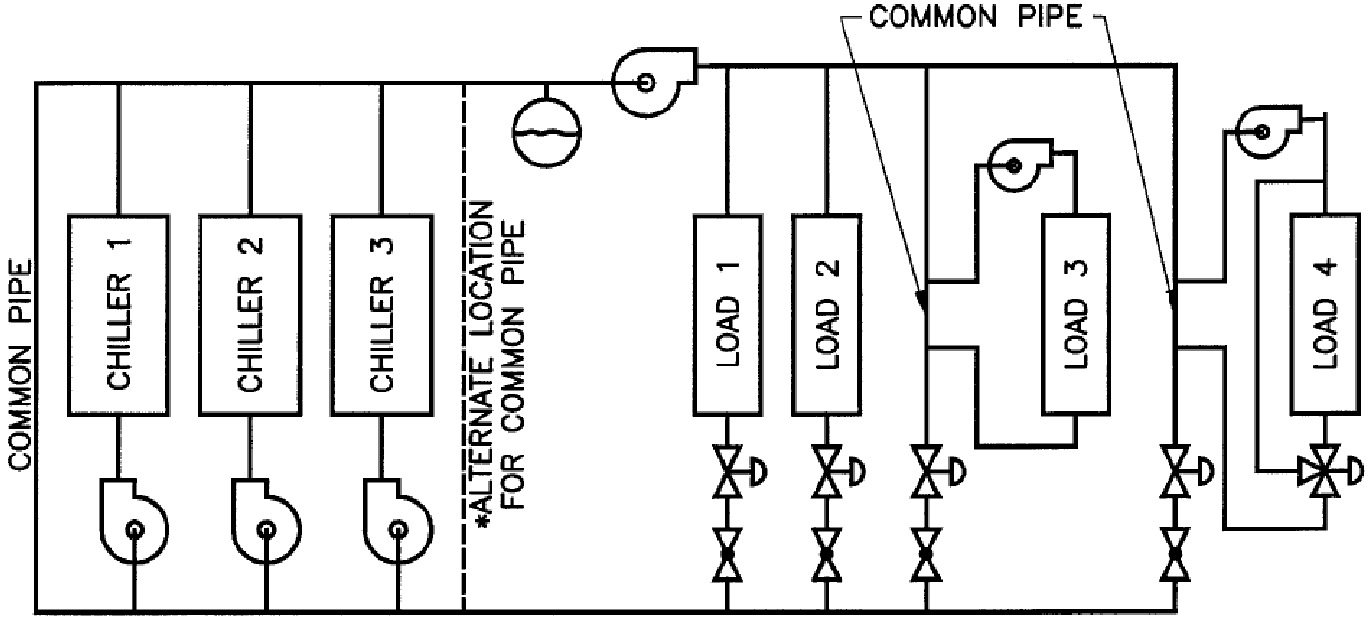
Four-Pipe Independent Load System

Hot and Chilled Water Systems



Constant Flow Chilled Water System

Hot and Chilled Water Systems



Variable Flow Chilled Water System

Hot and Chilled Water Systems

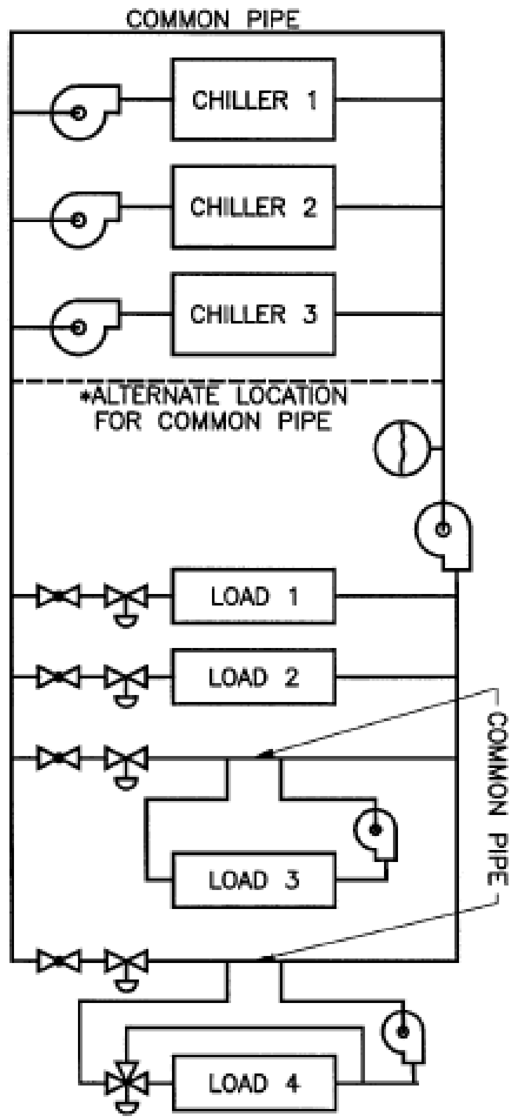
Variable Chilled Water System (Also known as Decoupler System)

Production loop

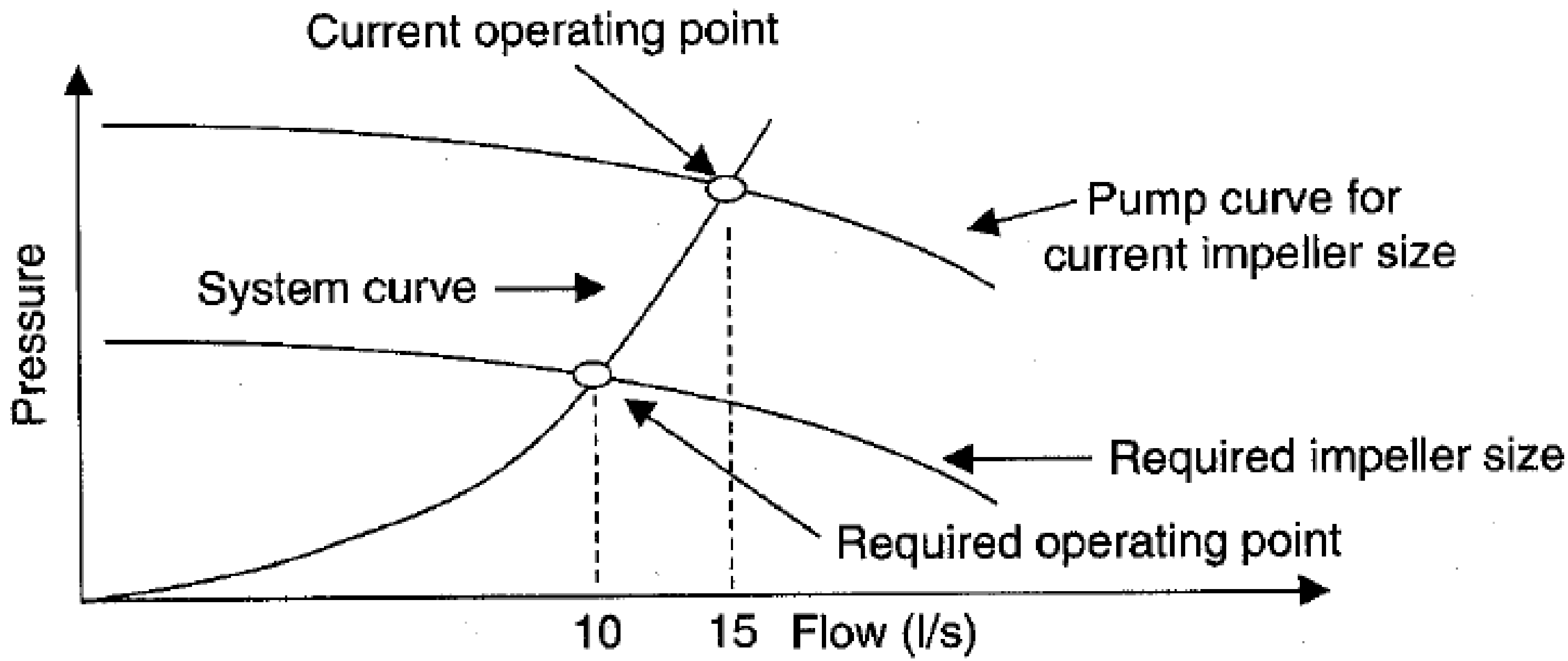
- There would be more than ONE chiller
- Each chiller with one production pump at constant speed
- Distribution pump running at variable speed
- Bypass line with flow meter to measure the flow
- Surplus flow in bypass line leads to stopping of one chiller and production chilled water pump
- Deficit in flow in bypass line leads to starting of chiller and production chilled water pump

Distribution loop

- 2-ways valve close as load reduced & flow resistance increase
- Distribution loop flow changed by change in pumps in operation or speed of distribution pump

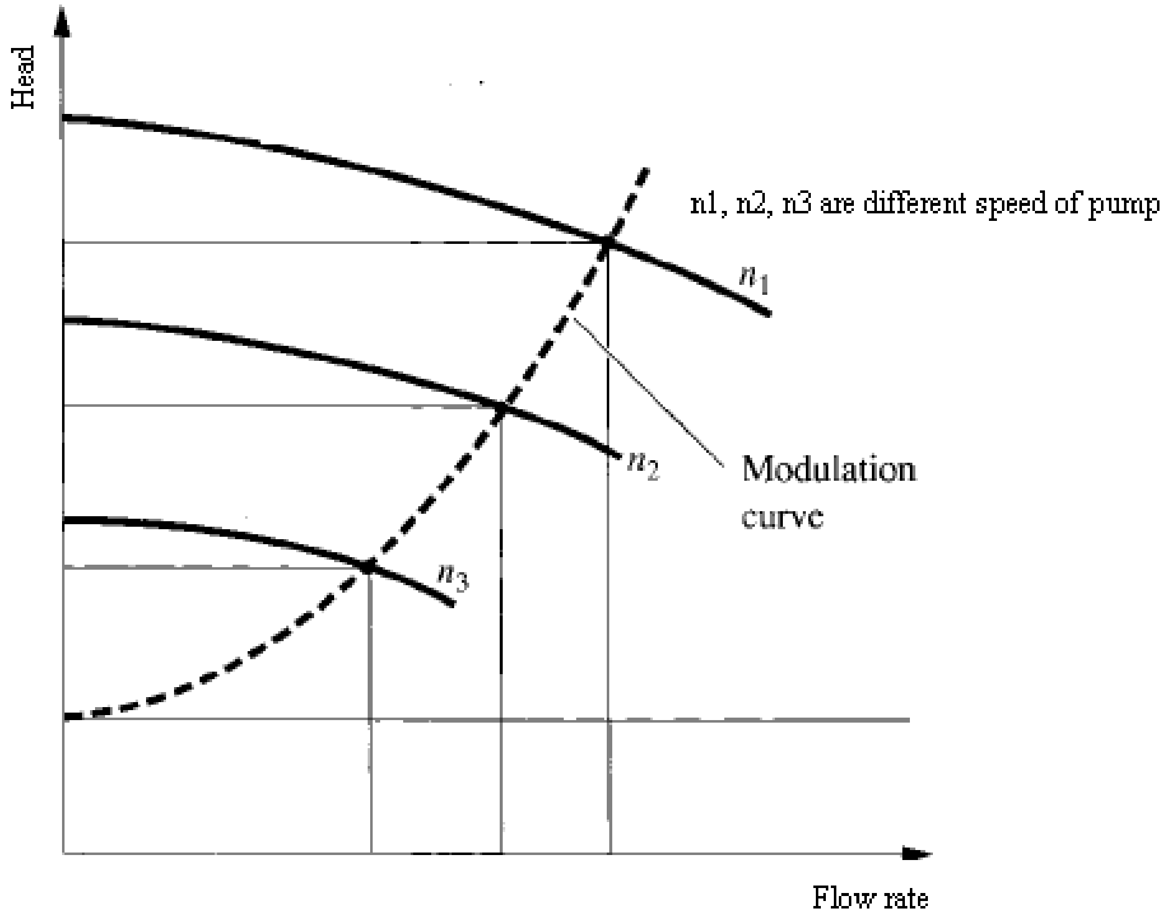


Hot and Chilled Water Systems



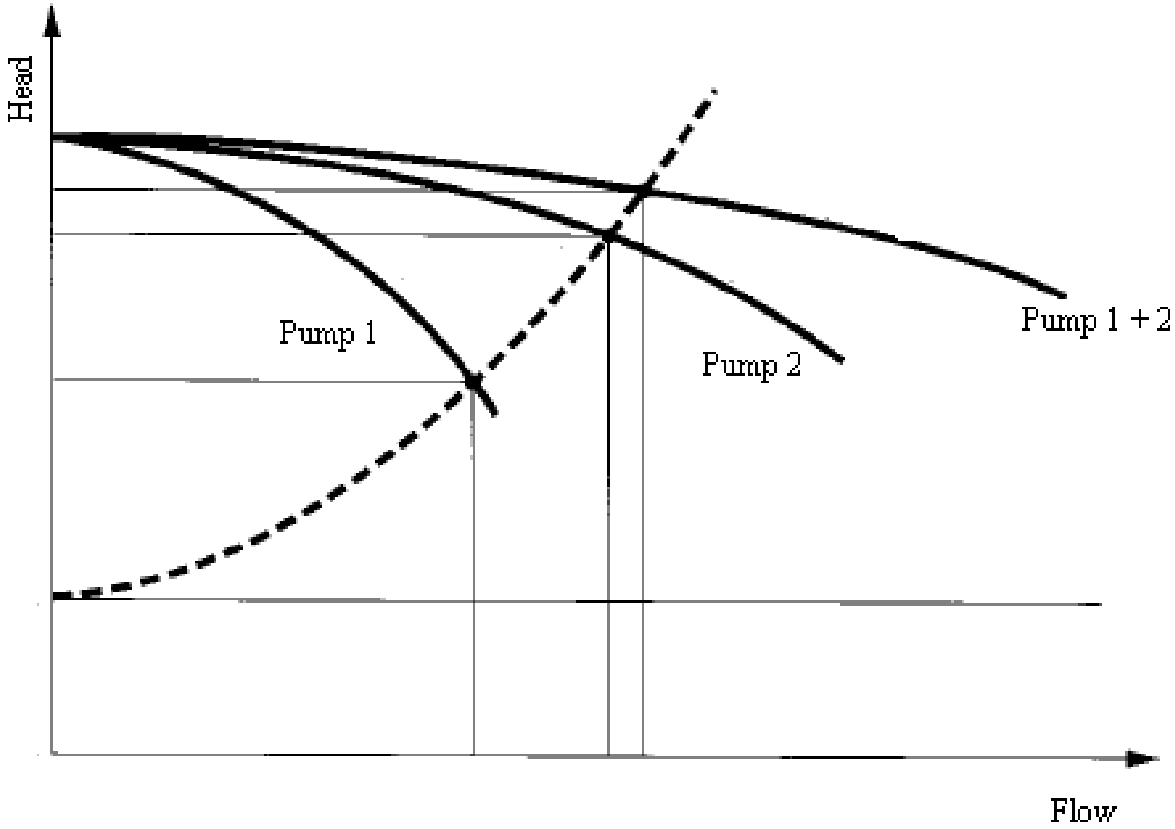
Using pump curves to select a suitable impeller size.

Hot and Chilled Water Systems



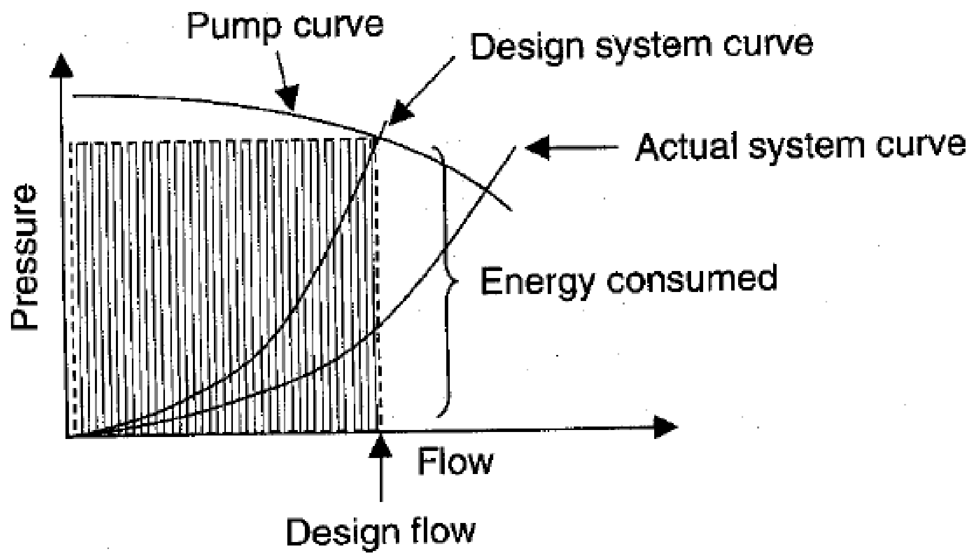
Variable pump speed to control the flow

Hot and Chilled Water Systems

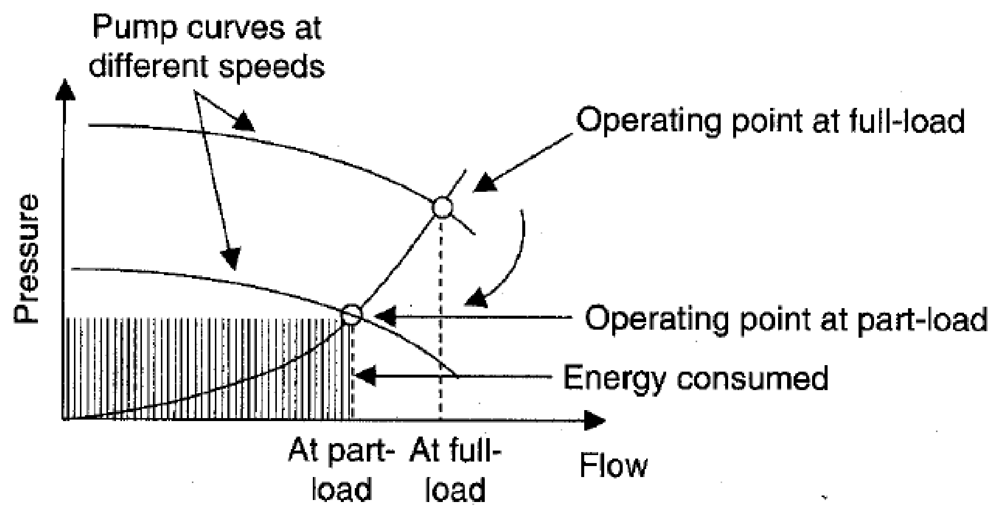


Change in numbers of pump to control the flow

Hot and Chilled Water Systems



Energy consumed by pump that is "throttled" to give the design flow.



Pump operating point for system with 2-way valves and variable speed pumping (pump control).

Hot and Chilled Water Systems

EMSD Code of Practice on Pumping System

- Variable Flow Pumping systems shall be designed for variable flow of reducing system flow to 50% of design flow or less.
  - Exceptions: are systems where a minimum flow greater than 50% of the design flow is required for the proper operation of equipment served by the system, such as chillers.
- Friction Loss
  The friction loss of a piping system shall not exceed 400 Pa/m.
- The designer shall also consider lower friction loss for noise or erosion control.

Hot and Chilled Water Systems

Use variable speed drives to vary the water flow :-

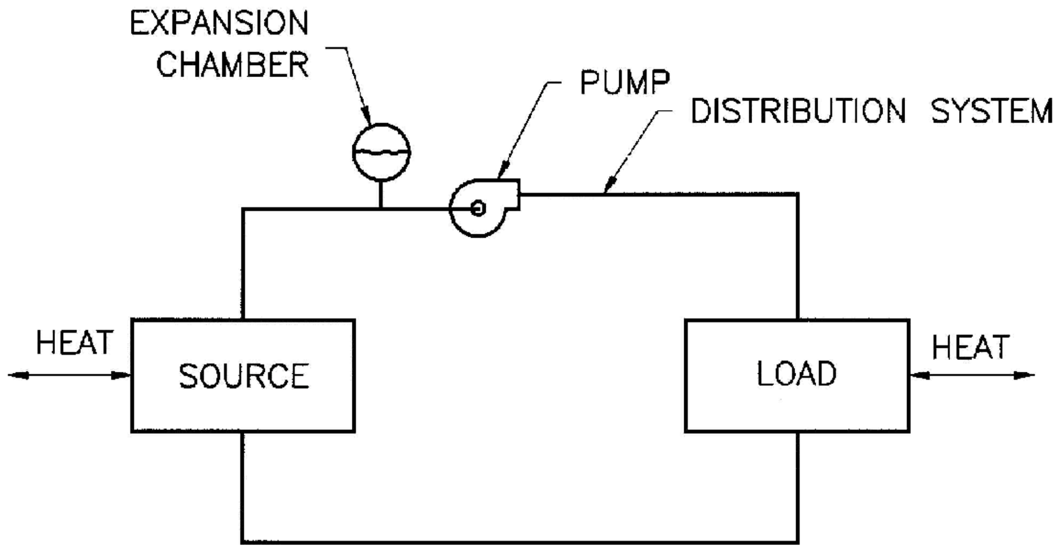
- Reducing the water flow from full flow to 80% flow by turning the valves only reduces energy consumption by about 3%.
- Use variable speed drives to change the speed of the pump/motor to deliver 80% flow, the energy consumption is 1/2 as it is proportional to the third power of speed.
- Variable speed drives or frequency inverters, are sensitive to phase imbalance or difference in phase loads and usually induce harmonic currents due to their non-linear nature.
- Phase differences are no more than 10% on circuits incorporating these devices and the system do not give rise to excessive harmonic contents.

Components of Water Systems

Basic System

These fundamental components are

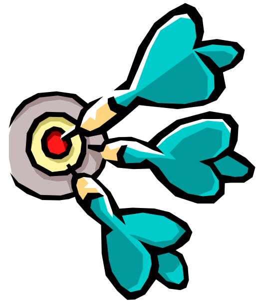
- Loads
- Source
- Expansion chamber
- Pump
- Distribution system



Hydronic System

Actual systems : valves, vents, regulators.

Components of Water Systems



Volume Flow and Temperature Difference

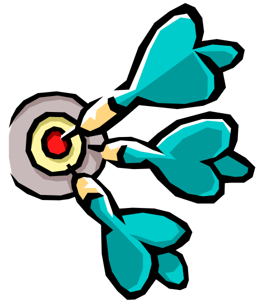
The heating and cooling capacity of water when it flows through a coil: -

$$Q_w = \dot{V}_w \rho_w c_{pw} (T_{we} - T_{wl})$$

Where

$\dot{V}_w$	=	Volume flow rate of water (m^3/s)
ρ_w	=	Density of water (kg/m^3)
c_{pw}	=	Specific heat of water (J.kg. ^oC)
T_{we}, T_{wl}	=	Temperature of water entering and leaving the coil (^oC)
ΔT_w	=	Temperature drop or rise of water after flowing through the coil(^oC)

Components of Water Systems



Volume Flow and Temperature Difference

The temperature of water leaving the water chiller should be no lower than 2.8°C to prevent freezing.

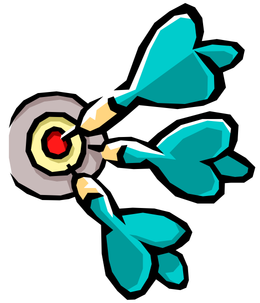
Performance of a chilled water system is closely related to : -

- The temperature of water entering the coil (*Twe*),
- The temperature of water leaving the coil (*Twl*), and
- The difference differential (*Twl-Twe*)

Note also that: -

- Temperature *Twe* directly affects the power consumption in the compressor.
- The temperature differential is closely related to the volume flow of chilled water and thus the size of the water pipes and pumping power.

Components of Water Systems



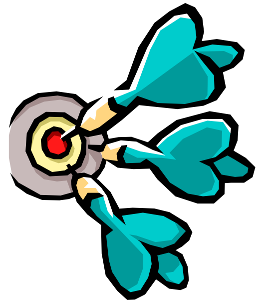
Cooling load devices

- Coils in central units
- Fan-coil units
- Induction unit coils
- Radiant cooling panels
- Water-to-water heat exchangers

Heating load devices

- Preheat coils in central units
- Heating coils in central units
- Finned-tube radiators
- Convectors
- Unit heaters
- Fan-coil units
- Water-to-water heat exchangers
- Radiant heating panels

Components of Water Systems



Cooling source devices

- Electric compression chiller
- Thermal absorption chiller
- Heat pump evaporator
- Air-to-water heat exchanger
- Water-to-water heat exchanger

Heating source devices

- Hot water generator or boiler
- Steam-to-water heat exchanger
- Water-to-water heat exchanger
- Solar heating panels
- Heat recovery or salvage heat device

(e.g., water jacket of an internal combustion engine)

Exhaust gas heat exchanger Incinerator heat exchanger

Heat pump condenser

- Air-to-water heat exchanger

Components of Water Systems

Piping Design - Water Velocity and Pressure Drop

The maximum water velocity in pipes is governed mainly by

- Pressure drop
- Pipe erosion
- Noise
- Water hammer

Components of Water Systems

Erosion of water pipes

- The impingement of rapidly moving water containing air bubbles and impurities on the inner surface of the pipes and fittings
- Erosion occurs only if solid matter is contained in water flowing at high velocity.

Velocity-dependent noise in pipes results from

- Flow turbulence
- Cavitation
- Release of entrained air

Water hammer

- The transient pressure impact on a sudden closed valve.

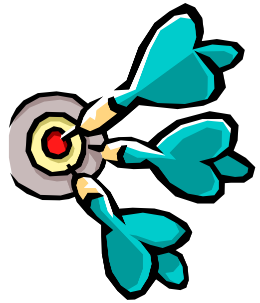
Components of Water Systems

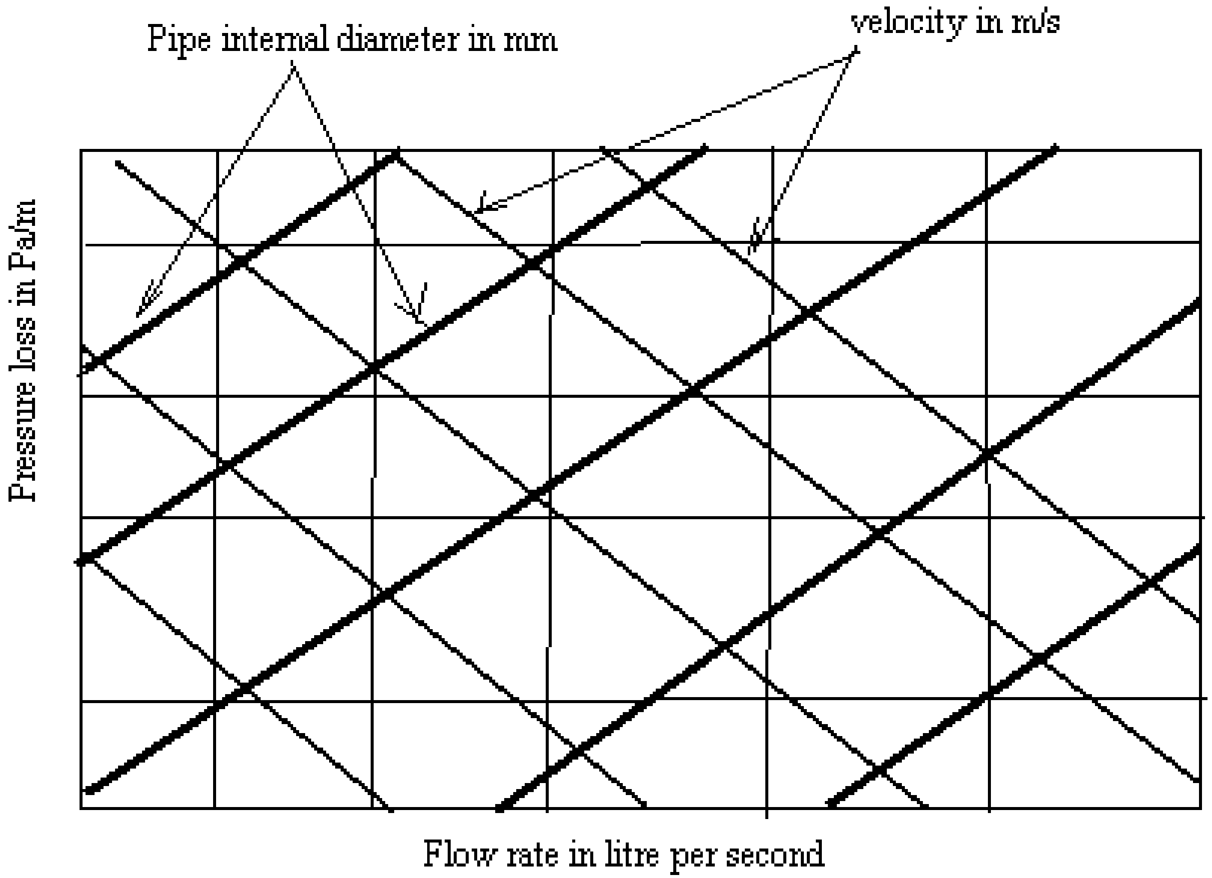
Design Criteria for chilled water system

- **Water velocity > or = 0.6 m/s** Transport the entrained air to air vents
- **100 to 400 Pa/m** Compromise:energy costs, investments, age corrsion
- **< 250 Pa/m** Pipe diameter is 50mm or less
- **200 Pa/m** Closed water systems
- **135 Pa/m** Open water systems.

From friction chart, with the aforesaid criteria, the pipe diameter could be read out

Components of Water Systems





Friction Chart

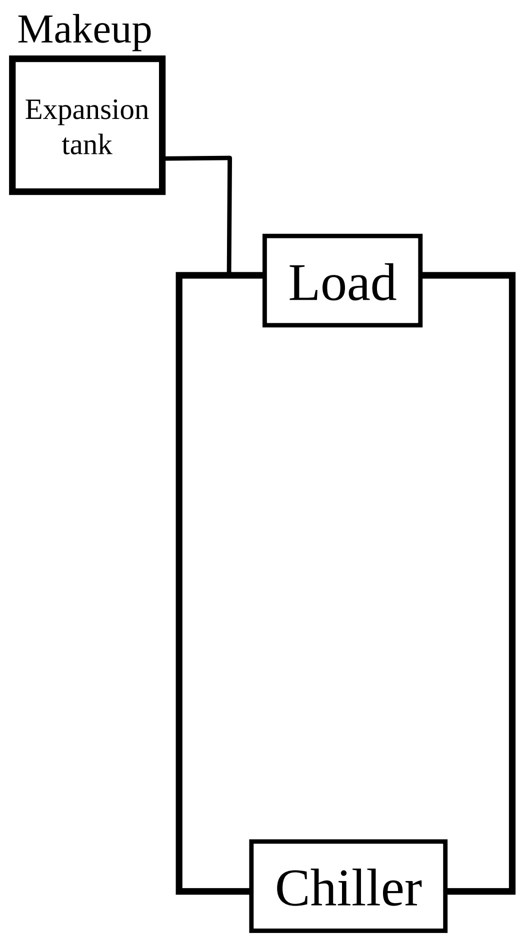
Friction Charts can easily be obtained from Guidebooks like CIBSE Guide

Components of Water Systems

Makeup and Fill Water Systems

- Generally, a hydronic system is filled with water through a valved connection to a water source.

- Because the expansion chamber is the reference pressure point in the system, the water makeup point is usually located at or near the expansion chamber.



Components of Water Systems

Air Elimination

- If air and other gases are not eliminated from the flow circuit, they may slow or stop the flow through the terminal heat transfer elements and cause corrosion, noise, reduced pumping capacity, and loss of hydraulic stability

- Air in the system can be removed by an elimination valve installed at the point of lowest solubility.

- Manual vents should be installed at high points to remove all air trapped during initial operation.

- Shutoff valves should be installed on any automatic air removal device to permit servicing without draining the system.

Components of Water Systems

Drain and Shutoff

- All low points should have drains.

- Separate shutoff and draining of individual equipment and circuits should be possible so that the entire system does not have to be drained to service a particular item.

- Whenever a device or section of the system is isolated, and the water in that section or device could increase in temperature following isolation, overpressure safety relief protection must be provided

Components of Water Systems

Water Treatment

Water treatment aims to evaluate the following parameters in the chilled water system:

PH value

Turbidity

Total iron increment

Total copper increment

Total dissolved solid

Nitrite

Bacteria count

Components of Water Systems

Piping Material

For water systems, the piping materials most widely used is :

- Black Steel pipe - chilled and hot system
- Galvanized(zinc-coated) – condensate drain system

Pipe Joints

- Black Steel pipes by welded joints (except flange joint for large pipe with valves, etc)
- Galvanized pipe (e.g. condensate pipe) with threaded fitting

Components of Water Systems

Working Pressure and Temperature

In a water system,

- *Maximum allowable working pressure and*
- *Maximum allowable temperature*

A proper choice for pipes, joints, pipe fittings, valves, etc.

Components of Water Systems

Safety Relief Valves

- Safety relief valves should be installed at any point at which pressures can be expected to exceed the safe limits of the system components.

- Causes of excessive pressures include :-
  - Over pressurization from fill system
  - Pressure increases due to thermal expansion
  - Surges caused by momentum changes (shock or water hammer)

Components of Water Systems

Piping Insulation

External pipe insulation should be provided to chilled and hot water system for the sake of

- Energy saving,
- Prevention of surface condensation, and
- High-temperature safety protection.

The optimum thickness of the insulation of pipes depends mainly on the operating temperature of the inside water, the pipe diameter, and the types of service.

Table(8.1) : Minimum Insulation Thickness for Indoor Chilled Water Pipe

Indoor				
Minimum Thickness of Insulation for Chilled Water Pipe Installations (mm)				
	Thermal Conductivity(2), λ - W/(m °C)			
	0.024		0.04	
	Indoor Conditions (still air)		Indoor Conditions (still air)	
Nominal size of Pipe(mm)(1)	28°C, 80% RH	30°C, 95% RH	28°C, 80% RH	30°C, 95% RH
	h(3)=5.7	h(3)=10	h(3)=5.7	h(3)=10
15	15	35	22	51
20	15	36	23	54
25	16	38	24	57
32	17	40	25	60
40	17	41	26	61
50	18	43	27	64
65	18	45	28	68
80	19	47	29	70
100	19	49	30	73
125	19	50	30	76
150	20	52	30	79
200	20	54	32	83
250	20	55	32	85
300	21	56	33	88
350	21	57	33	89
400	21	57	33	90

Notes : (1) The above table assumes pipes to be steel pipe of BS1387 or BS3600. For other metal pipes, same insulation thickness is applied to comparable outer diameters.

(2) The insulation thickness in above table is based on thermal conductivity rated at 20°C mean for fluid operating temperature of 5°C.

(3) The surface coefficient h=5.7 is assumed for bright metal surfaces and h=10 for cement or black matt surfaces at indoor still air condition.

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Table(8.2) : Minimum Insulation Thickness for Outdoor Chilled Water Pipe

Outdoor				
Minimum Thickness of Insulation for Chilled Water Pipe Installations (mm)				
	Thermal Conductivity[2], λ - W/(m·°C)			
	0.024		0.04	
	Outdoor Conditions (wind speed = 1m/s)		Outdoor Conditions (wind speed = 1m/s)	
Nominal size of Pipe(mm)[1]	35°C, 95% RH	35°C, 95% RH	35°C, 95% RH	35°C, 95% RH
	h[3]=9	h[3]=13.5	h[3]=9	h[3]=13.5
15	43	32	64	47
20	46	33	67	49
25	48	35	71	52
32	50	37	75	55
40	52	38	77	57
50	54	40	81	59
65	57	41	85	62
80	59	42	88	64
100	62	44	93	67
125	64	46	97	70
150	66	47	100	72
200	69	49	105	75
250	71	50	109	78
300	72	51	112	80
350	73	51	114	81
400	74	52	116	82

Notes : (1) The above table assumes pipes to be steel pipe of BS1387 or BS3600. For other metal pipes, same insulation thickness is applied to comparable outer diameters.

(2) The insulation thickness in above table is based on thermal conductivity rated at 20°C mean for fluid operating temperature of 5°C.

(3) The surface coefficient h=9 is assumed for bright metal surfaces and h=13.5 for cement or black matt surfaces at outdoor condition with a wind speed of 1m/s.

EMSD COP

Components of Water Systems

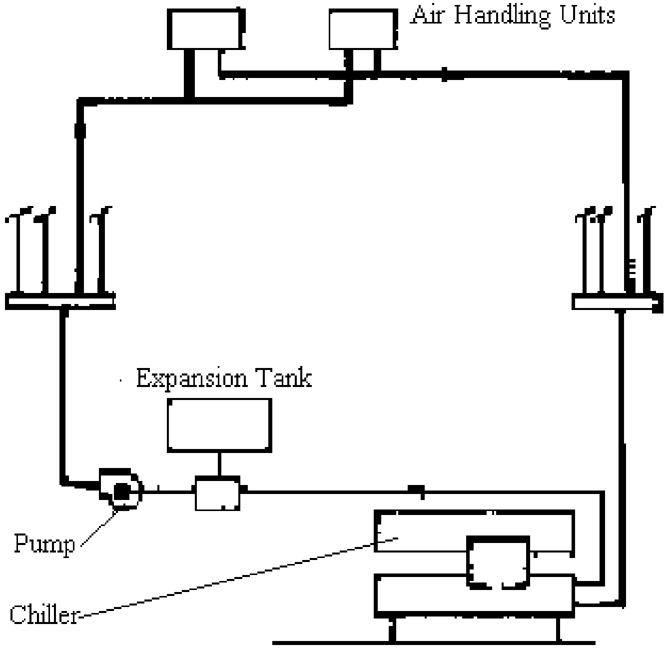
Expansion Tank

- The expansion tank provides a space into which the **non-compressible liquid** can expand or from which it can contract as the liquid undergoes **volumetric changes** with **changes in** temperature.
- To allow for this expansion or contraction, the expansion tank provides an interface point between the system fluid and a compressible gas.

Expansion tanks are of TWO basic configurations:

- An open tank (i.e., a tank open to the atmosphere); and
- A diaphragm tank, in which a flexible membrane is inserted between the air and the water (another configuration of a diaphragm tank is the bladder tank).

Components of Water Systems



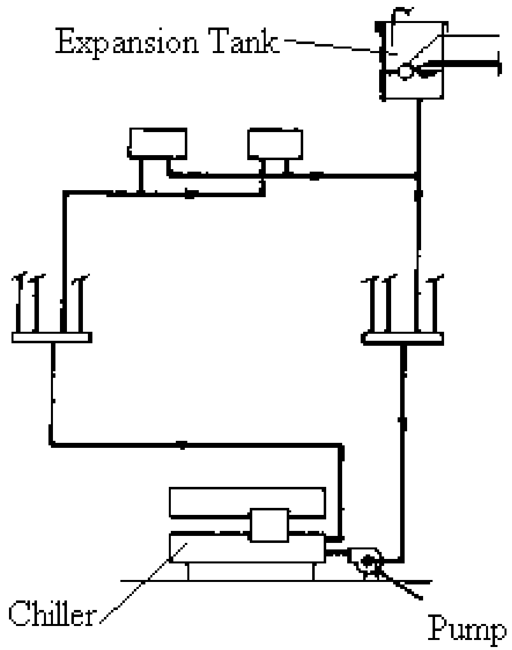
Sizing the expansion tank

For diaphragm tanks,

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

V_t = volume of expansion tank, m^3
V_s = volume of water in system, m^3
t_1 = lower temperature, °C
t_2 = higher temperature, °C
P_a = atmospheric pressure, kPa
P_1 = pressure at lower temperature, kPa
P_2 = pressure at higher temperature, kPa
v_1 = specific volume of water at lower temperature, m^3/kg
v_2 = specific volume of water at higher temperature, m^3/kg
α = linear coefficient of thermal expansion, m/(m·K)
= 11.7×10^{-6} m/(m·K) for steel
= 17.1×10^{-6} m/(m·K) for copper
Δt = $(t_2 - t_1)$, K

Components of Water Systems



Open Tank System

Sizing the expansion tank

For open tanks with air/water interface,

$$V_t = 2V_s\left[\left(\frac{v_2}{v_1} - 1\right) - 3\alpha\Delta t\right]$$

V_t = volume of expansion tank, m^3
V_s = volume of water in system, m^3
t_1 = lower temperature, °C
t_2 = higher temperature, °C
P_a = atmospheric pressure, kPa
P_1 = pressure at lower temperature, kPa
P_2 = pressure at higher temperature, kPa
v_1 = specific volume of water at lower temperature, m^3/kg
v_2 = specific volume of water at higher temperature, m^3/kg
α = linear coefficient of thermal expansion, $m/(m \cdot K)$
= 11.7×10^{-6} $m/(m \cdot K)$ for steel
= 17.1×10^{-6} $m/(m \cdot K)$ for copper
Δt = $(t_2 - t_1)$, K

Components of Water Systems

Types of Valve

Valves are used to regulate or stop the water flow in pipes

Manually

- Hand-operated valves are used to stop or isolate flow, to regulate flow, to prevent reverse flow,and to regulate water pressure.

Automatic control systems

- Valves used in automatic control systems are called control valves

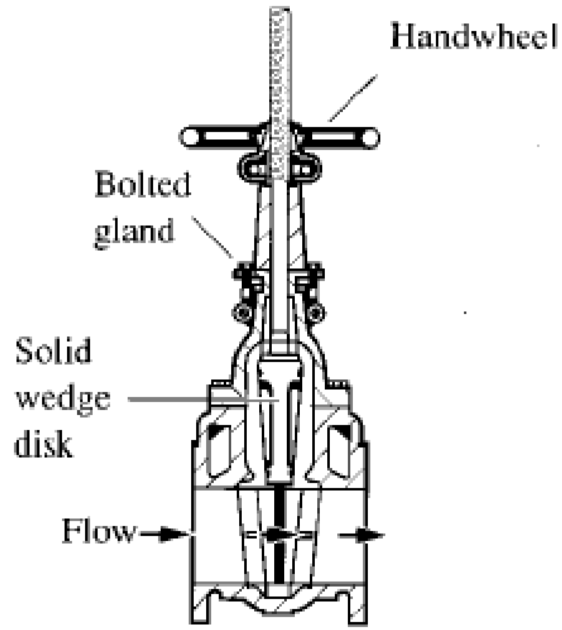
The basic construction of a valve:

- A disk to open or close the water flow;
- A valve body to seat the disk and provide the flow passage;
- A stem to lift or rotate the disk, with a handwheel or a handle

Components of Water Systems

Gate Valves.

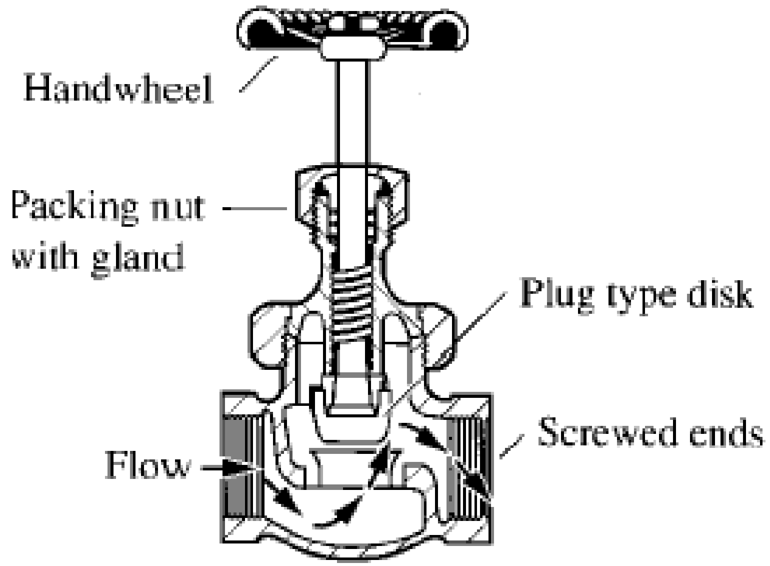
- The disk of a gate valve is in the shape of a “gate” or wedge.
- When the wedge is raised at the open position, a gate valve does not add much flow resistance.
- Gate valves are used either fully opened or closed, an on/off arrangement.
- They are often used as isolating valves for pieces of equipment or key components, such as control valves, for service during maintenance and repair.



Components of Water Systems

Globe Valves.

- **A** round disk or plug-type disk seated against a round port.
- Globe valves have high flow resistances..
- Globe valves are used to throttle and to regulate the flow.
- They are sometimes called balancing valves.



Components of Water Systems

Check Valves.

Use to prevent, or check, reverse flow.

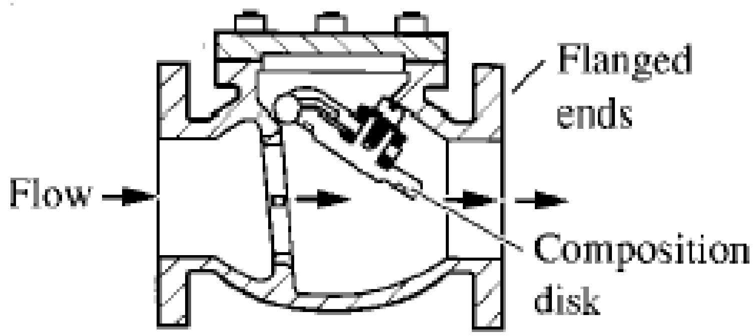
Swing check valve

- It has a hinged disk. When the water flow reverses, water pressure pushes the disk and closes the valve.

Lift check valve

- In a lift check valve, upward regular flow raises the disk and opens the valve, and reverse flow pushes the disk down to its seat and stops the backflow.

- Install at the discharge of pump, etc

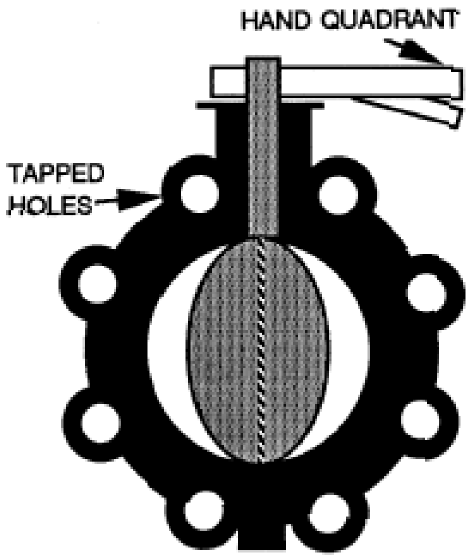


Swing check valve

Components of Water Systems

Butterfly Valves.

- A butterfly valve has a thin rotating disk.
- It varies within a quarter-turn from fully open to fully closed.
- Exhibits low flow resistance when it is fully opened.
- With an actuator a butterfly valve used for control purposes..
- May be used for throttling purposes in addition to on/off control.
- Used in large pipes.



Components of Water Systems

WATER CONTROL VALVES AND VALVE ACTUATORS

Valves

- Water valves are used to regulate or stop water flow in a pipe either manually or by means of automatic control systems.

- Water control valves adopted in water systems can modulate water flow rates by means of automatic control systems.

Valve Actuators

- An actuator is a device which receives an electric or pneumatic analog control signal from the controller.

- It then closes or opens a valve, modulating the associated process plant, and causes the controlled variable to change toward its set point.

- Valve actuators are used to position control valves.

Components of Water Systems

Solenoid Actuators.

These use a magnetic coil to move a movable plunger connected with the valve stem.

- For on and off control
- For small valves.

Electric Actuators

These move the valve stem by means of a gear train and linkage.

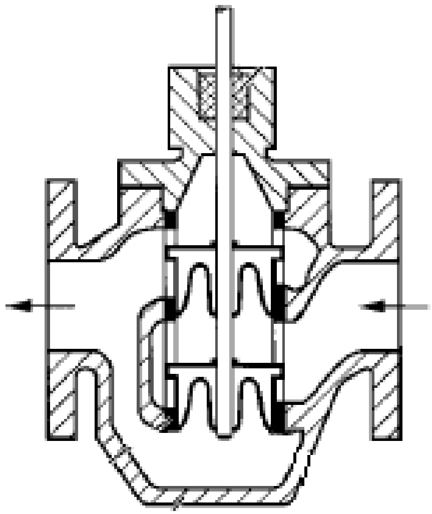
- *On/off mode*. motor moves the valve in one direction, and when the electric circuit breaks, the spring returns the valve stem to the top position
- *Modulating mode*. The motor can rotate in both directions, with spring return when the electric circuit breaks.

Components of Water Systems

Water control valves can again be classified as two ways and three ways valves

Two way valves

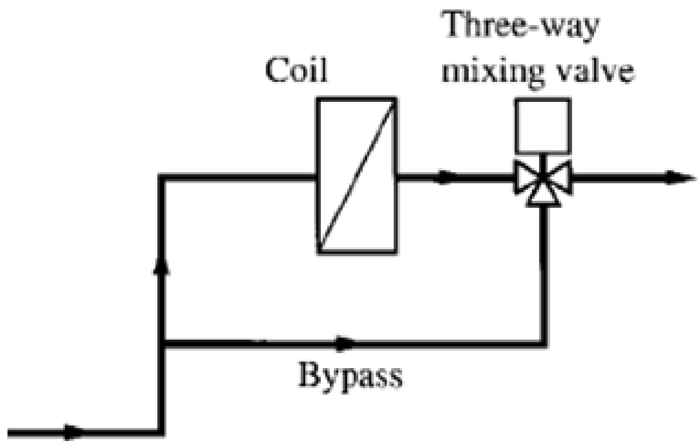
- The two-way valve, Q varies and Δt is fixed
- A two-way valve has one inlet port and one outlet port.
- Water flows straight through the two-way valve along a single passage



Components of Water Systems

Three-way mixing valve

➢ Three-way valve, Δt varies and Q is fixed.

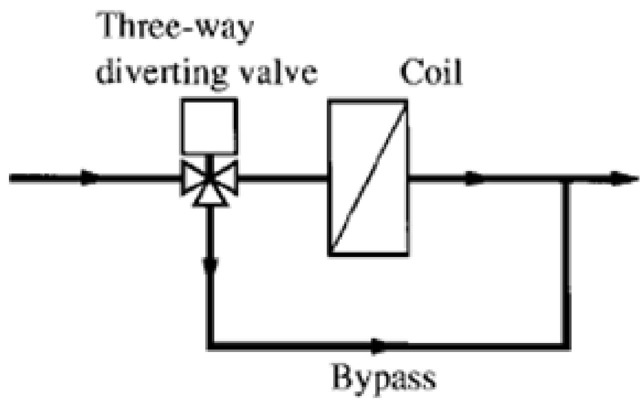


Two inlet ports and one common outlet port

➢ The main water stream flows through the coil or boiler,

➢ The bypass stream mixes with the main stream in the common mixing outlet port.

Three-way diverting valve



One common inlet port and two outlet ports

➢ The supply water stream divides into two streams in the common inlet port.

➢ The main water stream flows through the coil, and the bypass stream mixes with the main water stream after the coil.

Components of Water Systems

Valve Characteristics

- *Equal-percentage valve*
- *Linear valve.*
- *Quick-opening valve.*

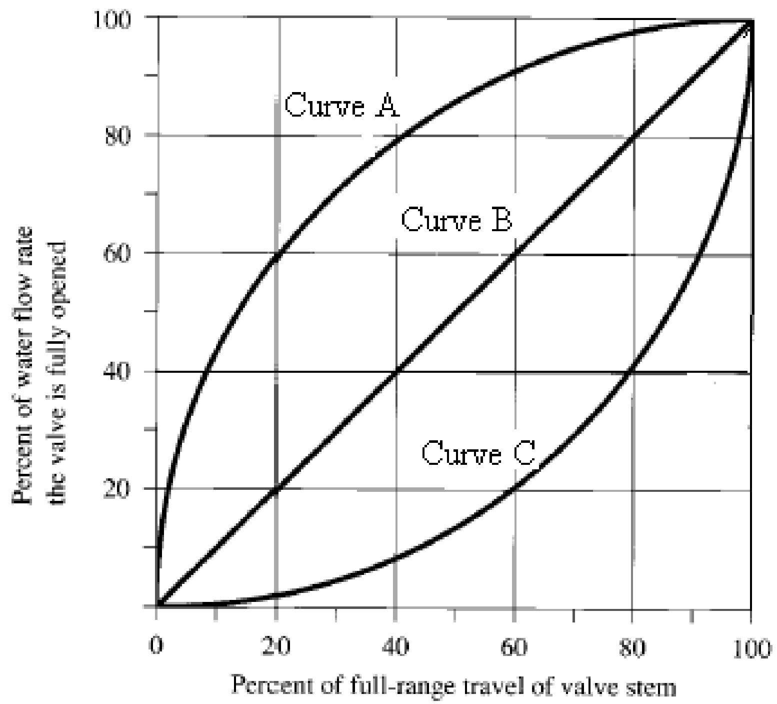
Curve A = Quick Opening

Curve B = Linear

Curve C = Equal %

Valve selection

Equal % of valve + nonlinear output of water coil provide linear control behaviour

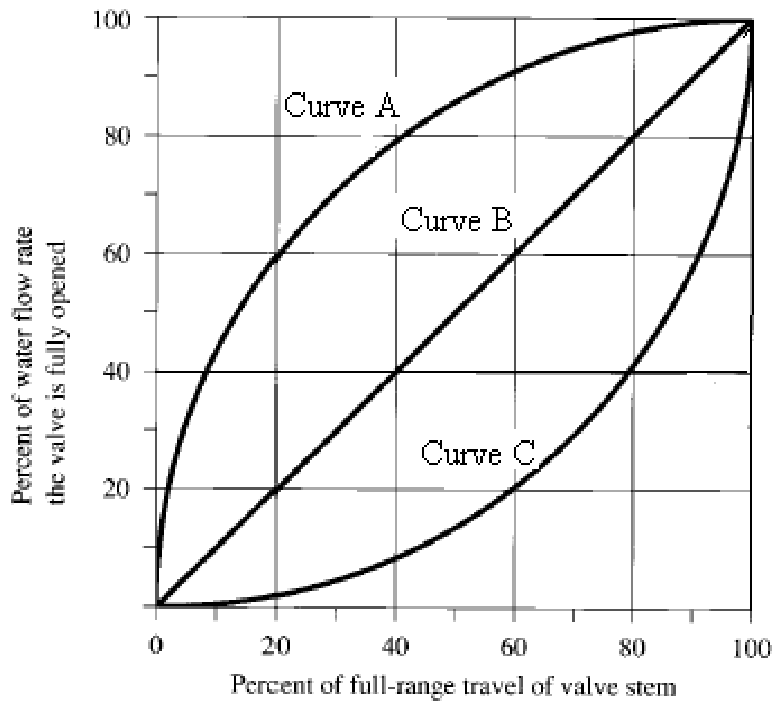


Valve Characteristics Curve

Components of Water Systems

- The Equal Percentage (curve C) characteristic is recommended for proportional control of the load flow for two-way valve;

- The bypass flow port of three-way valves should have the Linear Characteristic (Curve B) to maintain a uniform flow during part-load operation.



Valve Characteristics Curve

Components of Water Systems

Sizing of Control Valve

The size of control valve relates to its water flow rate $\dot{V}$ and pressure drop $\Delta P_{\text{control valve}}$ across the valve.

$$\dot{V} = C_v \sqrt{\Delta P_{\text{control valve}}}$$

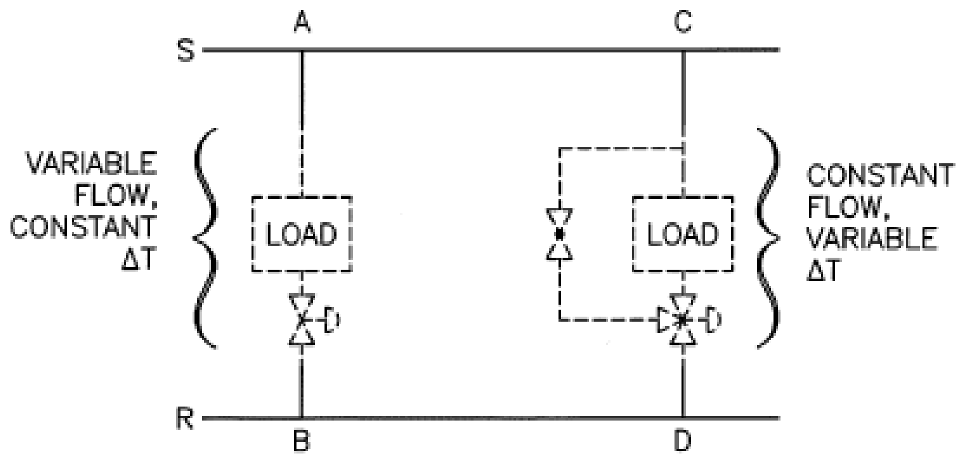
Where C_v is the flow coefficient.

The flow coefficient of control valves can be found in manufacturers' catalogs.

Components of Water Systems

Sizing of Control Valve

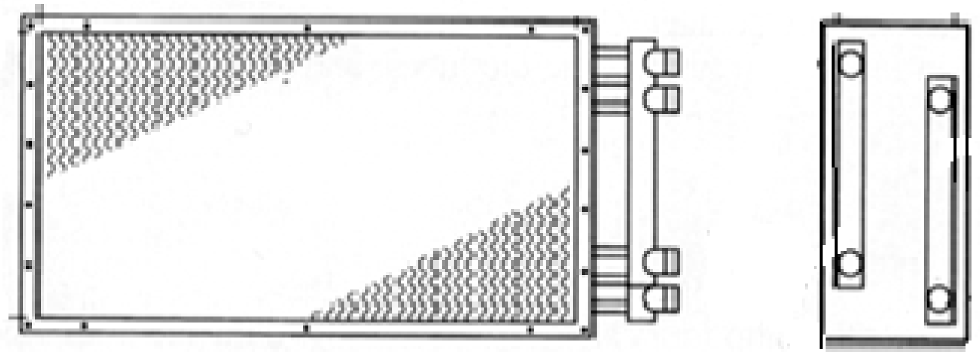
- For stable control, the pressure drop in the control valve at the full-open position should be no less than one-half the pressure drop in the branch.
- The pressure drop at full open position for the two-way valve should equal one-half the pressure drop from A to B
- For three-way valve, the full open pressure drop should be half that from C to D
- The pressure drop in the bypass balancing valve in the three-way valve circuit should be set to equal that in the coil (load)



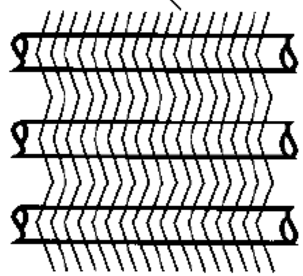
System Flow with Two-Way and Three-Way Valves

Components of Water Systems

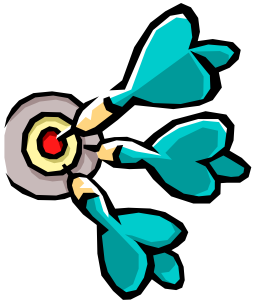
Cooling Coil



Corrugated fins can increase convective heat transfer coefficient and hence higher heat transfer rate



Components of Water Systems

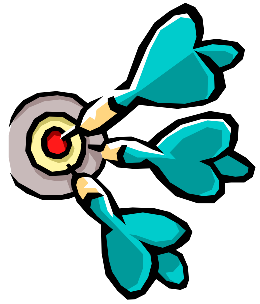


Evaluation of Sensible Cooling Coil – Dry Coils

Definition of some parameters

G_c	=	Mass velocity at free flow area
C_{pa}	=	Specific heat of moisted air
Pr	=	Prandtl number
JP	=	A function of Reynold’s number, total outside surface of coil and tube outer surface area
k	=	Thermal conductivity of water
Di	=	Internal diameter of tubes
A_f	=	Area of the fins
A_o	=	Outer surface area of the coil

Components of Water Systems



1) **Determination of outer surface heat transfer coefficient of coil**

$$\frac{h_o}{G_c C_{pa}} \Pr^{\frac{2}{3}} = 0.00125 + 0.27\,JP$$

where h_o has a unit $W/m^2.K$

2) **Determination of inner surface heat transfer coefficient of coil**

$$h_i = 0.023 \frac{k}{D_i} \mathrm{Re}^{0.8} \Pr^{0.4}$$

where h_o has a unit $W/m^2.K$

Components of Water Systems

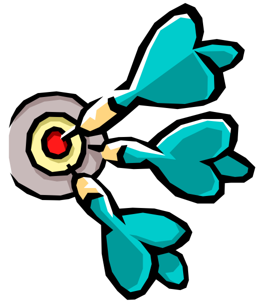
3) Calculation of fin surface efficiency:

R-value of fin (Unit = m^2K/W)

Fin efficiency $\eta_f = \dfrac{1}{1 + h_o R_f}$

Surface fin efficiency $\eta_s = 1 - \left(\dfrac{A_f}{A_o}\right)(1 - \eta_f)$

Components of Water Systems



4) Determination of Heat capacities of air and water

<u>Air</u>

Heat Capacity of air (unit= kW/K) =

Face area of coil x velocity of air x density of air x specific heat of air

(C_{pa}= 1.02kJ/kg.K)

<u>Water</u>

Heat Capacity of water (unit= kW/K)=

Flow rate of water x density of water x specific heat of water

(specific heat of water C_{pw} = 4.2kJ/kg.K)

5) Determination on heat capacity value

$C = \frac{C_a}{C_w}$ if $C_w > C_a$ or $C = \frac{C_w}{C_a}$ $C_w < C_a$

Components of Water Systems

6) Determine the overall heat transfer value: -

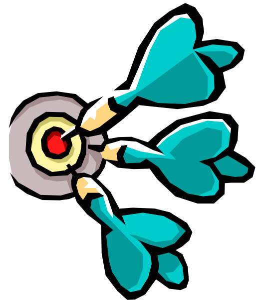
$$\frac{1}{U_o A_o} = \frac{1}{\eta_s h_o A_o} + \frac{1}{h_i A_i}$$

Hence, $U_o A_o$ could be determined

7) Determine Number of Transfer Unit

Number of transfer unit, NTU= $\dfrac{U_o A_o}{C_a}$

Components of Water Systems



8) Determine Dry coil effectiveness

Dry coil effectiveness $$\varepsilon = \frac{1 - e^{[-NTU(1-C)]}}{1 - Ce^{[-NTU(1-C)]}}$$

9) Calculate Sensible Cooling Coil's load

$$q_{cs} = \dot{m}_a C_{pa} (t_{ae} - t_{we}) \varepsilon$$

10) Evaluation of air leaving temperature:

As $$\varepsilon = \frac{T_{ae} - T_{al}}{T_{ae} - T_{we}}$$

Hence, T_{al} could be determined

Components of Water Systems

CENTRIFUGAL PUMPS

- Centrifugal pumps are the most widely for transporting chilled water, hot water, and condenser water because of their high efficiency and reliable operation.

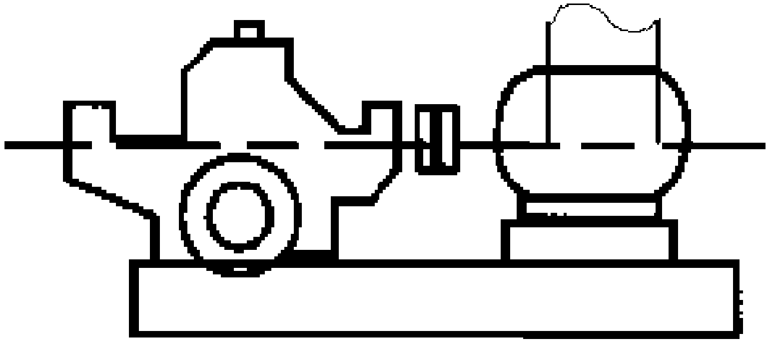
- Centrifugal pumps accelerate liquid and convert the velocity of the liquid to static head.

- A typical centrifugal pump consists of an impeller rotating inside a spiral casing, a shaft, mechanical seals and bearings on both ends of the shaft, suction inlets, and a discharge outlet

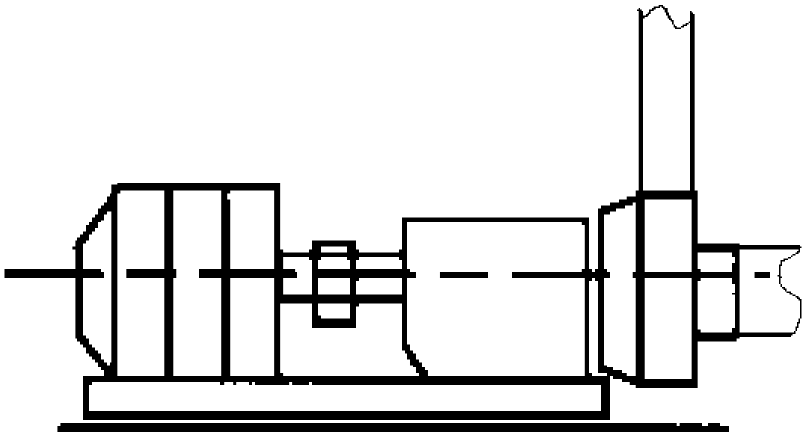
Components of Water Systems

Types of Pumps

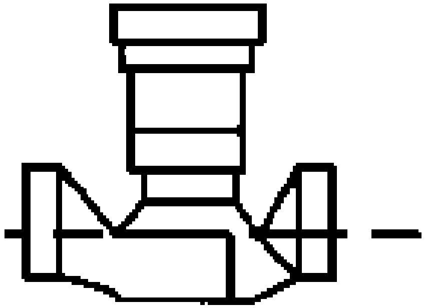
- End Suction
- Horizontal Split-casing
- Vertical Inline



Horizontal Split-casing Pump

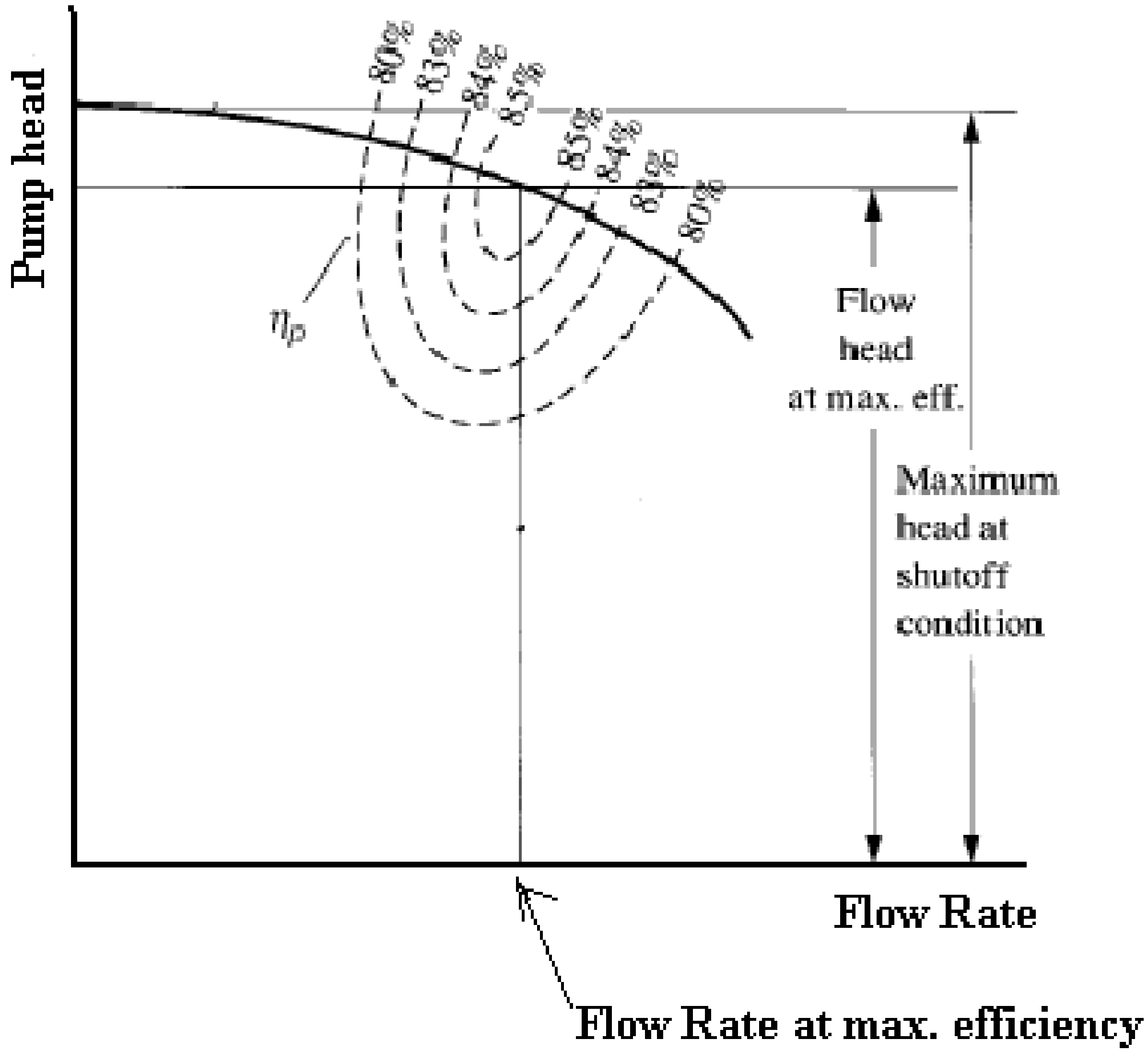


End Suction Pump

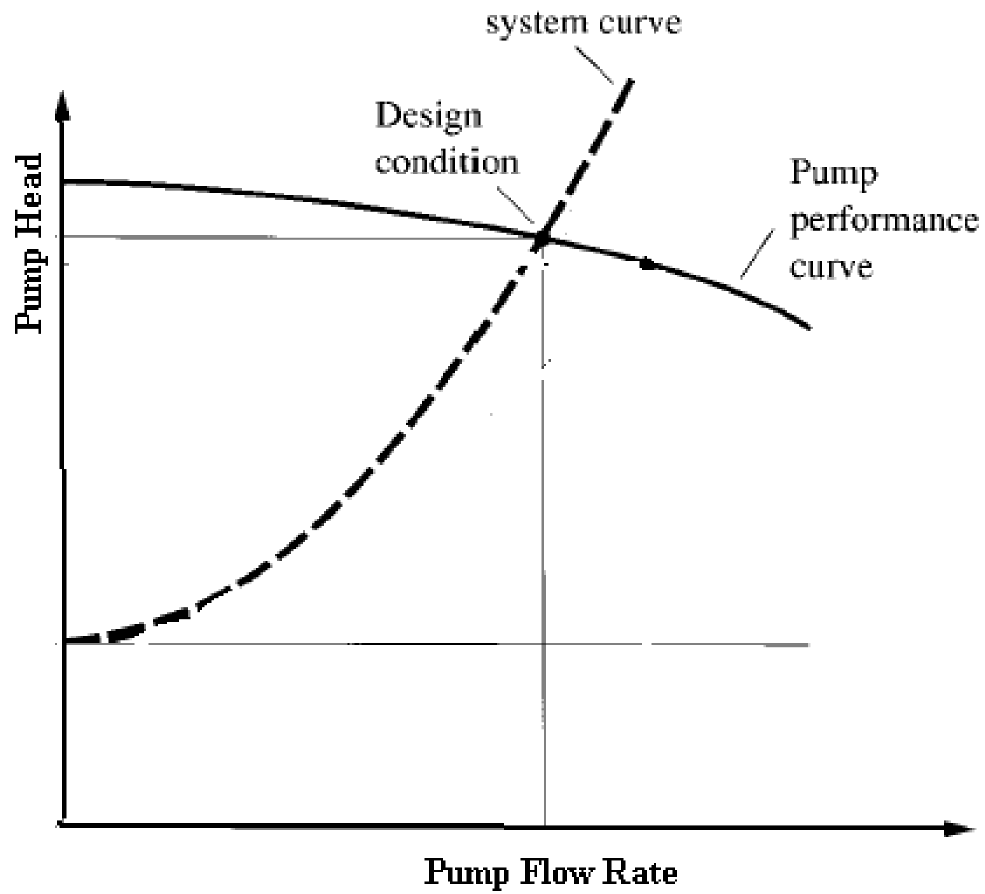


Vertical Inline Pump

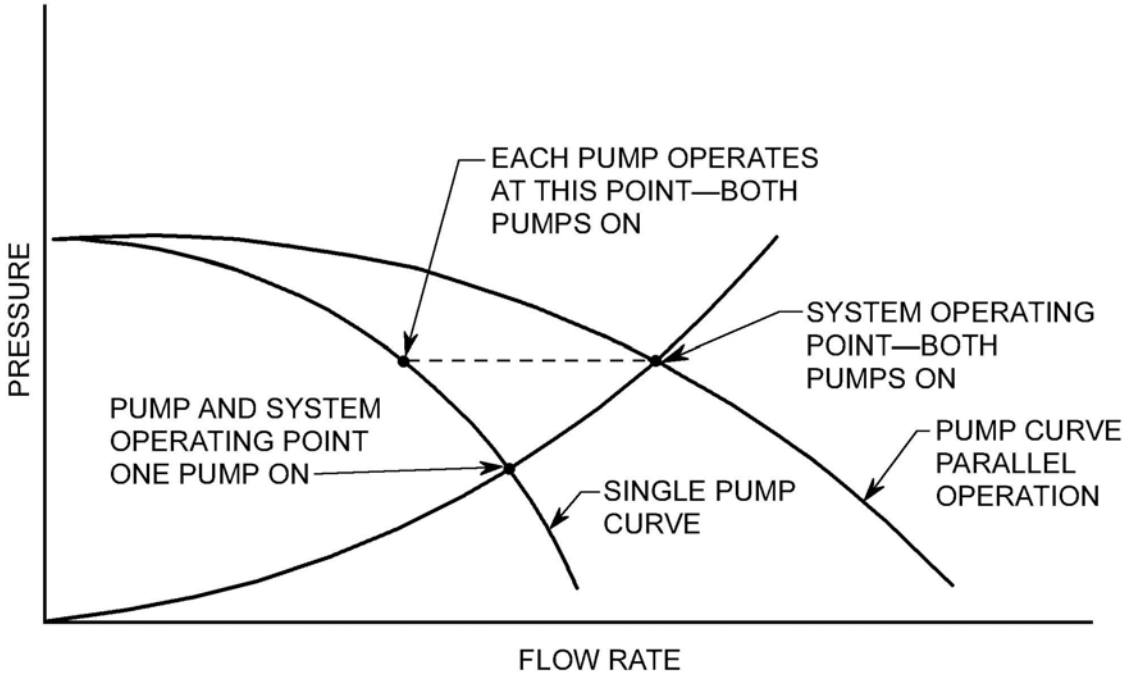
Components of Water Systems

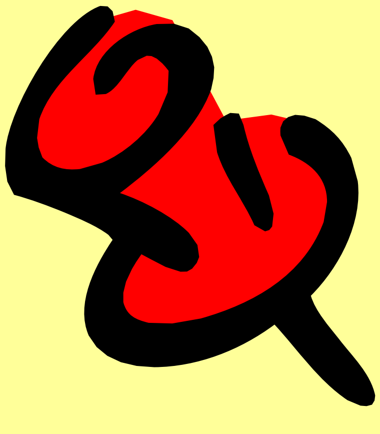


Components of Water Systems



Components of Water Systems





Q & A