•••POWER ENGINEERING

Fourth Class

Edition 3.5

Plant Auxiliary Systems

Part B

Unit B-8

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4th Class Edition 3.5 • Part B

UNIT B-8

PLANT AUXILIARY SYSTEMS

Unit Introduction

This unit introduces the various auxiliary support systems for building and power plant operators.

Consider what would happen if a building or plant lost its lighting. Would the occupants need to be evacuated? How would they leave safely?

Next, consider potable water. How can a plant or building water supply become contaminated and unfit to drink? What would happen to workers on site?

Next, consider that much of the water used in a building or plant must be disposed of. Could a plant or building continue to operate without a functioning waste disposal system?

Finally, consider rainwater systems. What could happen if water is not effectively drained away from plant process buildings?

Power Engineers must have a thorough knowledge of these systems, because:

a) The safe operation of these systems affects the health and welfare of all the building or plant occupants.
b) The availability of these systems directly affects the operation of power plant equipment, such as boilers, compressors, and refrigeration systems.

Unit Rationale

The importance of lighting, water supply, and drainage systems are essential in the day-to-day responsibilities of a Power Engineer. These auxiliary building systems support all the activities within a building or power plant.

In order for the systems to be safe they must be properly designed, installed, and maintained. Otherwise, they will cause the plant or building owners to incur additional repair, re-work and environmental costs.

Power Engineers, as they advance in the field, may be tasked with overseeing the proper design, operation, and maintenance of these facilities. It is therefore essential to have a good understanding of these auxiliary building systems.

CHAPTER 1

Lighting Systems

Learning Outcome

When you complete this chapter you should be able to:

Explain the various lighting systems and some of the basic design considerations for lighting a space.

Learning Objectives

Here is what you should be able to do when you complete each objective:

1. *Describe the common types of lighting equipment and systems.*
2. *Discuss the different types of artificial light sources.*
3. *Explain the various methods of lighting control.*
4. *Describe the general requirements and criteria for emergency lighting in buildings.*
5. *Discuss the interrelationship between lighting, air conditioning, and energy conservation in buildings.*

Chapter Introduction

Lighting design for buildings under construction is usually done by engineering specialists on the architectural design team. However, facility operators are sometimes asked to assist when existing lighting needs to be modified. In some cases (particularly in small companies), operators may interact with subcontractors in the design and installation of lighting systems. Almost all Power Engineers are involved in the operation and maintenance of lighting systems.

It is, therefore, useful for Power Engineers to have some idea of the factors that determine the design of the lighting systems they operate, maintain, or have installed. For most Power Engineers, it is important to develop an overall understanding of design terminology, but not to understand the detailed design process. Some material on design is provided as reference. It can used if there is a need to become involved in lighting design for troubleshooting or in a retrofit situation.

OBJECTIVE 1

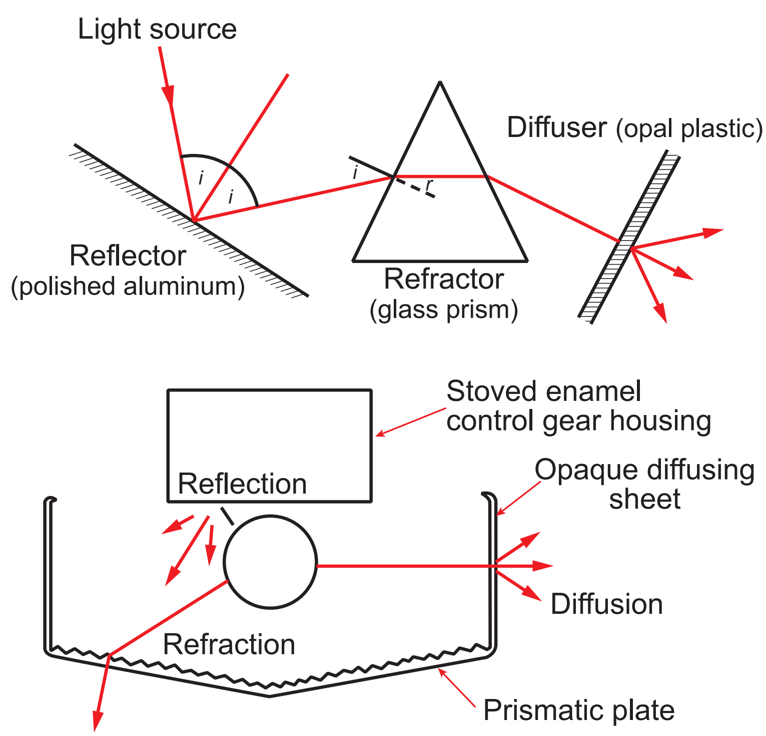
Describe the common types of lighting equipment and systems.

LUMINAIRES

A **luminaire** is a complete lighting unit, including the lamp, a voltage controlling device or ballast and the means of light control (reflector and refractor).

It is the function of the luminaire to direct or control the light produced by the lamp. This function can be accomplished by the use of transparent, translucent, or opaque surfaces that refract, reflect, or absorb light, thereby directing it to where it is required (Figure 1).

Figure 1 – Light Control in a Fluorescent Fitting



Types of Luminaires

There are many luminaires on the market. They provide either direct or indirect lighting or a combination of the two. These include:

- Recessed **troffers**
- Surface-mounted **wraparounds**
- Open reflectors
- Structural lighting

Recessed Troffers

Recessed troffers are rectangular light fixtures that fit in the grids of recessed ceilings. They have prismatic panels (acrylic or glass) that distribute light.

These are commonly used for general lighting in offices and commercial interiors. Because of the numerous troffers required in a large installation, the system can sometimes appear excessively bright.

Ceiling Mount Wraparounds

Ceiling mount wraparounds are fluorescent fixtures that are mounted directly on the ceiling or wall surface. These fixtures have clear prismatic plastic covers that surround the lamps. They give a broad light distribution and are relatively inexpensive and efficient. However, they may appear too bright in many installations.

Open Reflectors

Open reflectors serve as shields to partially screen the lamps from view. They are typically used for industrial installations or in storage areas of commercial buildings.

Structural Lighting

Lamps are fitted into architectural components of a room, such as coves, cornices, valances, and wall brackets. Desks and furniture may have built-in task lighting, to supplement ambient lighting. Each of these is an example of structural lighting.

The use of special lenses, baffles, and louvres is an effective means of controlling excessive brightness. These reduce efficiency and usually add cost to the system. However, the added comfort that is achieved may offset the added costs.

Types of Illumination

There are three main types of illumination:

1. General (uniform)
2. Local (supplementary)
3. Combined general/local

General (Uniform)

A general (or "uniform") lighting system is designed to provide a uniform illumination level throughout an area. Most offices have uniform lighting since it is difficult to predict the location of work stations (which require more lighting) and areas where less lighting would suffice. Also, if work stations are moved, uniform lighting systems can still provide adequate illumination in the new locations. In this type of installation, luminaires are spaced at regular intervals.

Local or Supplementary

Local (or "supplementary") lighting is used to illuminate work areas or displays regardless of the overall uniform ambient light. An example would be track lighting that illuminates wall displays.

Combined General/Local (Non-Uniform or Task Lighting)

A combined general/local lighting system provides a reasonable lighting level. In addition, an effort is made to identify specific work areas to increase their illumination levels. This type of system requires more design work, but it will be more energy efficient than a uniform system.

A small office is an example where non-uniform lighting is effective. The location of desks, filing cabinets, and video display terminals are usually known in advance. This makes it possible to position luminaires so they provide higher lighting levels for critical tasks and lower levels for other areas. Displays, charts, and pictures can be highlighted by using accent lighting from supplementary luminaires or systems (i.e., wall-washers, valances, coves, wall brackets, or spotlights).

The use of task or non-uniform lighting should be encouraged as much as possible. Not only is it more energy efficient, but it also creates a more attractive and interesting space.

Compared to a uniform system, a non-uniform installation creates higher task visibility, reduces initial costs, and lowers operating costs. However, it is difficult to alter the lighting system if the room is rearranged.

The design of an energy efficient lighting system can have a tremendous impact on costs. The initial cost, as well as, the operating and maintenance expenses should always be considered when deciding on which lighting system to install. A system with a low initial cost could be much more expensive to operate and maintain over its service life than a system with a higher initial cost.

Direct and Indirect Lighting

Ambient light can be improved by direct or indirect lighting, or by using a combination of the two.

With **direct lighting**, all or most of the luminous intensity is directed down, toward the work area.

With **indirect lighting**, all or most of the luminous intensity is directed up, at the ceiling. Light, reflected off the ceiling, arrives at the work area indirectly.

The advantages and disadvantages of the two systems are listed in Tables 1 and 2.

Table 1 – Analysis of Direct Lighting

Advantages	Disadvantages
More energy efficient	Harsh shadows
Low initial cost	Greater potential for direct glare
Lower floor to ceiling height possible	Greater potential for veiling reflections and reflected glare
Easier to control and direct	Excessive luminance and glare

Table 2 – Analysis of Indirect Lighting

Advantages	Disadvantages
Potential for maximum visual comfort	Less energy efficient
Greater direct glare control	Requires a uniform, unobstructed diffuse reflecting ceiling surface
Blends in with the environment	Increase in building cost, due to increased floor-to-ceiling height for good lighting uniformity
Produces uniform, shadow-free light	Electrical installation may be more expensive

A common misconception about indirect lighting is that it makes better use of energy. In truth, an indirect system can never be as energy efficient as a direct system. However, because an indirect system usually gives a low brightness installation, it provides less glare and more comfort.

Objective 2

Discuss the different types of artificial light sources.

Types of Commonly Used Artificial Light Sources

Incandescent

Incandescent light is one of the oldest commercially developed light sources. Electrical current passes through a wire filament inside a glass bulb or globe. The filament glows and emits visible light (incandescence).

General Service Incandescent Light Bulbs

An incandescent light bulb is a sealed glass bulb or globe. It contains a filament made of tungsten, through which electrical current passes, and generates light and heat. The metal base of the bulb conducts electric current to the contact wires connected to the filament.

The bulb may contain a vacuum or be filled with an inert gas such as argon, nitrogen, krypton, xenon, or hydrogen. This prolongs the life of the filament, reduces evaporation, and prevents oxidation of the filament.

The glass bulb can be either clear or coated. The main reason for the coated glass is to distribute the light evenly. The coating can also be coloured for decorative purposes.

Halogen Lamp

The halogen lamp is also known as a quartz-halogen lamp, and is a type of incandescent light. The bulb is filled with a halogen gas to prolong the life of the filament. In addition, the halogen provides a brighter light emission than the typical general service incandescent lights. However, the halogen lamp operates at a higher temperature than the typical general service incandescent light.

The incandescent light bulb has a simple design. It is manufactured for many applications and in various sizes at low cost. However, it has a low ratio of energy to light emission efficiency (**luminous efficacy**), which means most of the energy supplied to produce the light is converted to heat. For energy conservation reasons, many are phasing out the production and use of incandescent light bulbs.

Fluorescent

Fluorescent lights are a type of "gas-discharge" light source. They are filled with mercury vapour. An electrical current is applied to the gas, producing ultraviolet (UV) light. The UV light then causes the phosphor coating inside the tube to glow white.

Fluorescent lights consume less energy compared to the general service incandescent light, for the equivalent light emission. Because fluorescent lights are filled with mercury vapour, they are classified as hazardous waste, and must be carefully disposed of when no longer in use. Disposal must be in compliance with local jurisdictional regulations.

Straight Tube Fluorescent

Straight tube fluorescent lamps come in different diameters and lengths for different applications. They all require external ballasts to work.

Compact Fluorescent

Compact fluorescent lights operate the same way as straight tube fluorescent lights. There are two types of CFL: screw-in and plug-in.

The screw-in type has an integrated ballast. It simply screws into existing electrical sockets.

The plug-in type requires a ballast and a socket that corresponds to a specific base configuration (for example, 2 or 4 pins).

In recent years, CFL bulbs have largely replaced incandescent bulbs in most developed countries. The screw-in type of CFL bulbs have been particularly popular since they are self ballasted and are easily placed into the same socket used by the incandescent light bulbs.

High-Intensity Discharge (HID)

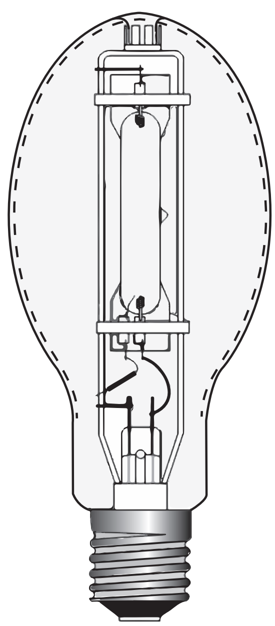
An HID light is a type of electric gas-discharge light. It produces light when an arc passes between two tungsten electrodes inside a transparent quartz tube filled with both metal salts and gas. The gas is used to assist the formation of an arc. The arc heats the metal salts that evaporate and form plasma. This greatly intensifies the light produced by the arc without using additional energy. Therefore, an HID can emit a large amount of light with relatively low energy consumption.

HID bulbs require ballasts to supply adequate starting current. Ballasts also regulate the power during normal operation. HIDs are primary used for high ceiling applications including gymnasiums, warehouses, sports stadiums, and street lights. Some HID bulbs require extended warm up time and are not suitable for interrupted services where lights are turned on or off frequently.

Mercury Vapour

A mercury vapour light bulb (Figure 2) is a type of HID light. An electric current passes between two electrodes and forms an arc. The arc ignites the vapourized mercury inside a pressurized glass tube to produce a bright intensive light. The glass tube is generally clear or coated with phosphor, similar to the incandescent and fluorescent bulbs. As its name implies, the bulb is filled with mercury vapour. Because of this, these bulbs are classified as hazardous waste, and must be carefully disposed of when no longer in use. Disposal must be in compliance with local jurisdictional regulations.

Figure 2 – Mercury Vapour Light Bulb



Sodium Vapour

The Sodium vapour light is a type of gas-discharge light. The basic principles of operation are similar to the mercury vapour bulb. An electric current passes between two electrodes and forms an arc. The arc ignites the sodium gas inside a pressurized glass tube to produce light. There are two general types of sodium vapour lights: low pressure and high pressure.

Low Pressure Sodium (LPS)

Low pressure sodium vapour lights have a glass arc tube coated with solid sodium. The glass tube contains a small amount of neon and argon gas in a mixture to aid with start up. LPS lights are highly energy efficient light sources. However, their use is limited to mostly street and yard lighting, where intensive lighting is not required.

High Pressure Sodium (HPS)

High pressure sodium vapour lights have a glass tube that is typically made of semi transparent aluminum oxide. Xenon gas is used to start up the gas discharge. Like the LPS, the HPS lights are often limited to outdoor lower light intensity applications.

Figure 3 shows high and low pressure sodium light bulbs.

Figure 3 – High and Low Pressure Sodium Light Bulbs

High pressure sodium light bulb

Low pressure sodium light bulb

Light-Emitting Diode (LED)

A diode is a semi-conductor device that allows electric current to flow in one direction only. A light-emitting diode (LED) emits light when a suitable amount of electricity is applied across the leads. Diodes embedded with different compounds can be made to emit infrared, red/green/blue (RGB), and white light.

LEDs have gained popularity in recent years among environmentally conscious consumers, including government agencies. They have been steadily replacing other artificial light sources. Below are some of the positive features of LEDs available today.

a) Low energy cost with the high ratio of energy to light emission efficiency (luminous efficacy)

b) Long service life expectancy

c) Little maintenance requirements

d) Do not contain mercury

e) Bulbs are made of rugged, break-resistant material

f) Instant light up without warm up period

g) Not affected by cold temperature

h) Cool to touch

i) Do not generate heat

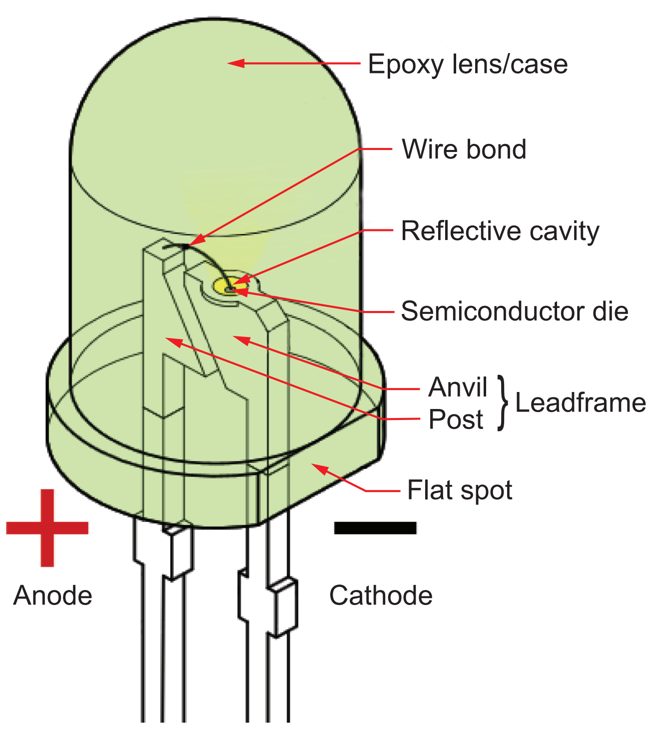
j) Permit dimming and change of colour

k) Can be made very compact

The only disadvantage of LEDs is the initial purchase cost.

Figure 4 shows a single LED and its basic components.

Figure 4 – Light Emitting Diode (LED)



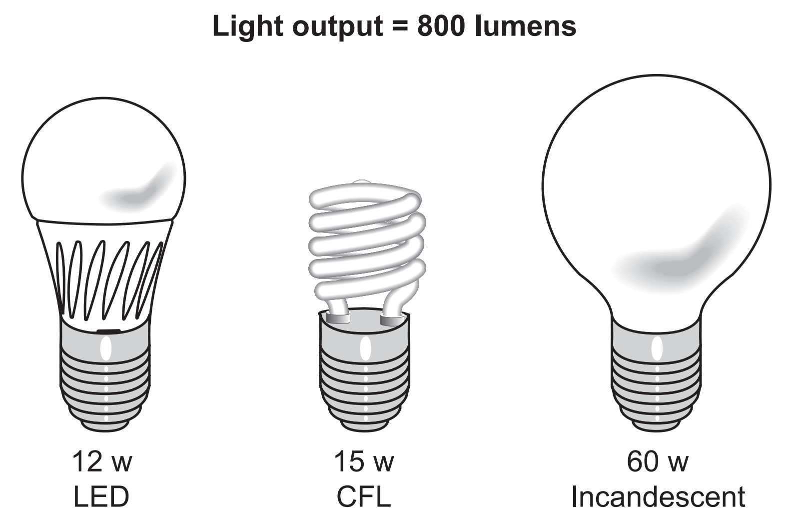
Basic Lighting Measurement Units

Watt – The wattage stated on the lamp is the amount of electrical energy consumed by the lamp to produce light.

Lumens – A Lumen is the metric unit (luminous flux) for the total quantity of light emitted by a light source. The more lumens emitted by a light source, the brighter the light.

Figure 5 shows the relationship between Lumens and Watts for various styles of lamps.

Figure 5 – Lumens and Watts Comparison



Light colour is measured in units of absolute temperature (Kelvin). Lower temperature light is more yellow. Higher temperature light is bluer. Figure 6 shows the relationship between light colour and temperature in Kelvin.

Table 3 shows the most suitable range of light temperatures for various applications. When purchasing lamps for new installation, replacement or retrofit, the most appropriate colour temperature should be selected. Lamp manufacturers include lamp colour temperature directly on the lamp or on the lamp packaging.

Figure 6 – Light Appearance Comparison

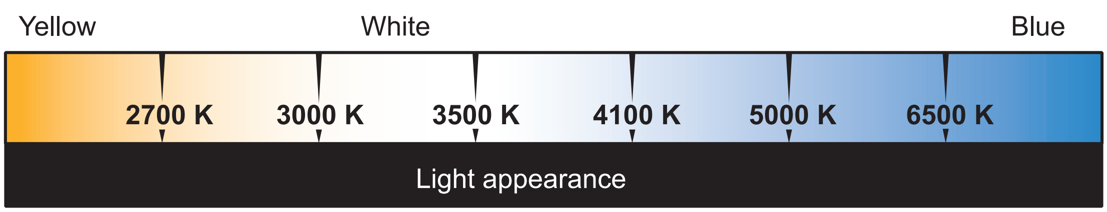


Table 3 – Light Colour Application Guide

Light Colour	Kelvin (K) Number	Applications
Warm White	2700K to 3000K	Comparable to standard colour of incandescent light bulbs
Bright White	3500K to 4100K	Office and Work Spaces
Daylight	5000K to 6500K	Reading

Objective 3

Explain the various methods of lighting control.

Lighting Controls

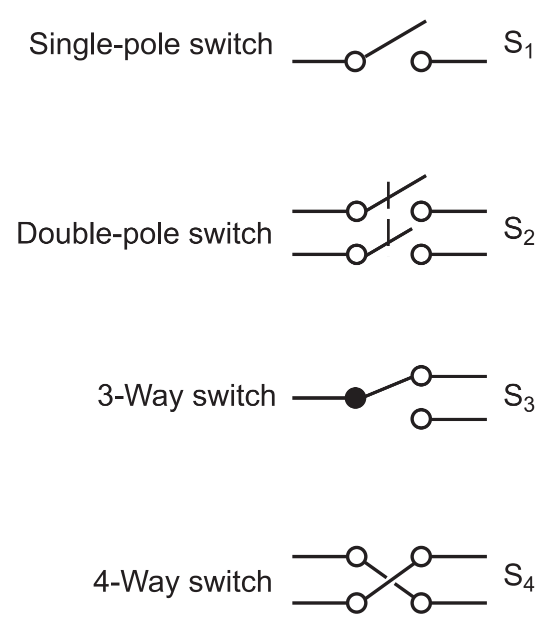
The flow of electric current in the various lighting circuits within a building must be controlled. This is accomplished with the use of a variety of switches capable of opening and closing the circuits.

On-Off Controls

Types of Switches (On-Off Control)

Normal methods of switch construction include single-pole, double-pole, 3-way, 4-way and momentary contact. Switch types and how they function were covered under the electrical unit. Some of the switch symbols are shown in Figure 7.

Figure 7 – Switch Wiring Symbols



A line-voltage lighting system only uses line-voltage rated controls and wiring. To control lighting, it requires the use of 3-way and 4-way switches. A lighting system can be operated from two locations using only two 3-way switches. If additional control locations are required, the additional switches must be 4-way. For example, to control a light from 4 locations, two 3-way and two 4-way switches are required.

Low-Voltage Switching

The previous discussion on switches dealt with line-voltage switches, placed directly in the circuit to supply current to the lights. Figure 8 shows an alternative system. It uses light duty switches, small gauge wiring, and low-voltage relays to control lighting from multiple locations.

A low voltage switching system has many advantages that include:

a) Local and remote control of lights. This allows for centralization of control points and increased flexibility.

b) A reduction in installation cost, due to the use of light gauge, low cost, and low voltage (24 V) control wiring. The line voltage circuitry is shortened. It runs only between the lights and the relays. This reduces the quantity of more expensive wiring. As well, less conduit is installed, which further reduces costs.

c) Higher voltage lighting (208 V and 347 V) can be controlled by operating a 24 V switch, which is safer.

d) Alteration work, such as moving switch locations, is simpler and more economical.

e) Low voltage lighting relays can be operated by programmed distributed control systems. Lights can be controlled by occupancy schedules, detected activity, or other control criteria.

Figure 8 – Low Voltage Switching Control

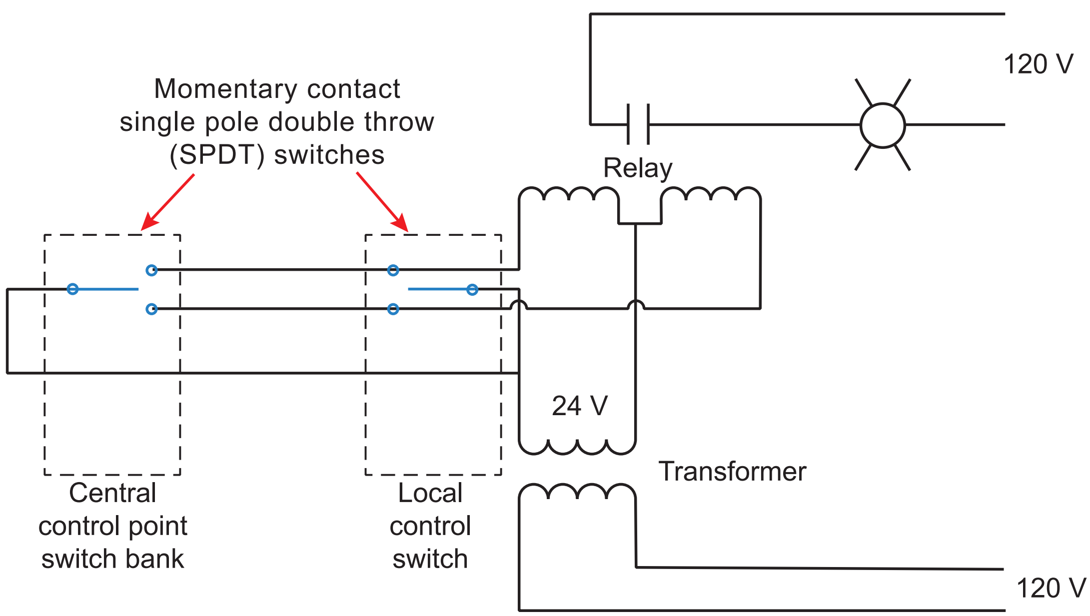
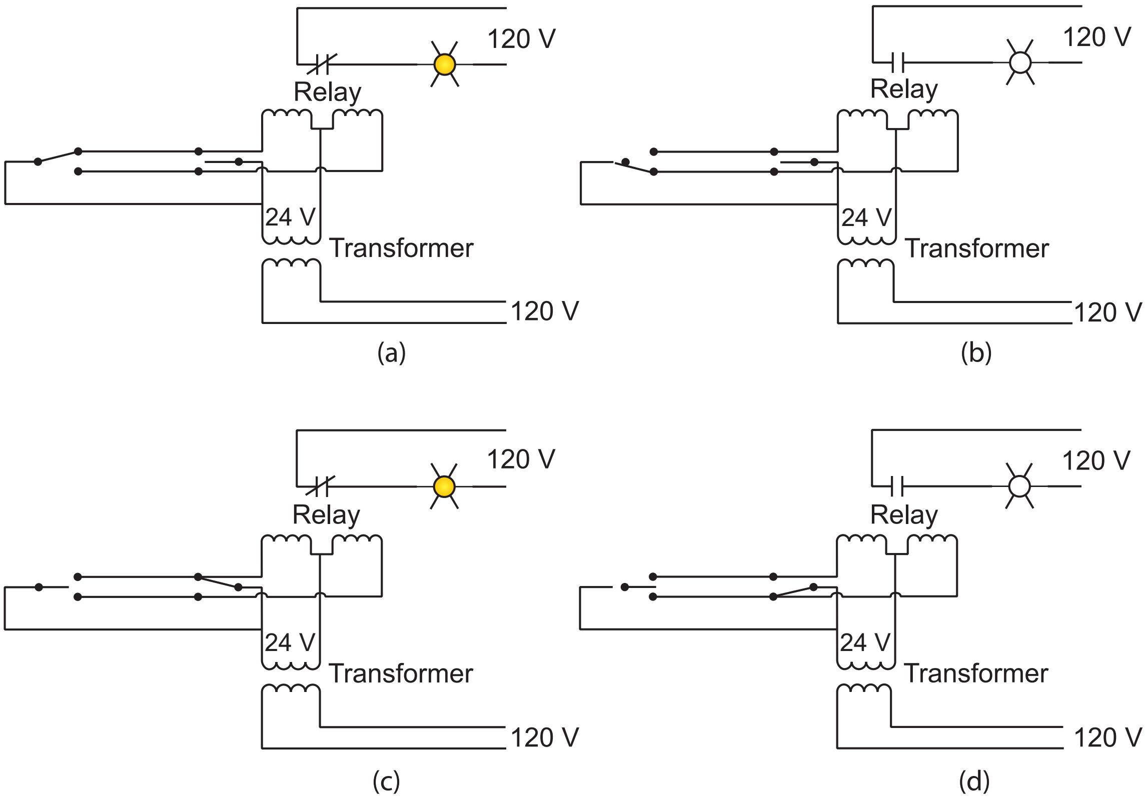


Figure 9 – Low Voltage Switching Control



Refer Figure 9(a). When the momentary contact (SPDT) switch in the central control facility is operated in one direction, half of the relay coil is energized. This causes the relay contact to close, which turns on the lamp. The lamp stays on until the central control switch is operated in the opposite direction (Figure 9(b)) to energize the other half of the relay. This causes the relay contact to open, which turns off the lamp.

As Figures 9(c) and (d) show, the light can be operated on or off from a local switch. The central control switch can also be operated a programmed distributed control system.

Commercial applications of low-voltage switching include hospitals, schools, shopping malls, and industrial facilities. In these situations, centralized control is desirable, without the inconvenience of switching at only one location. The combination of local and centralized control is of great importance in energy conservation. It permits lights to be controlled without physically going to each switch point, while retaining local control at the same time.

Circuit Breaker Switching

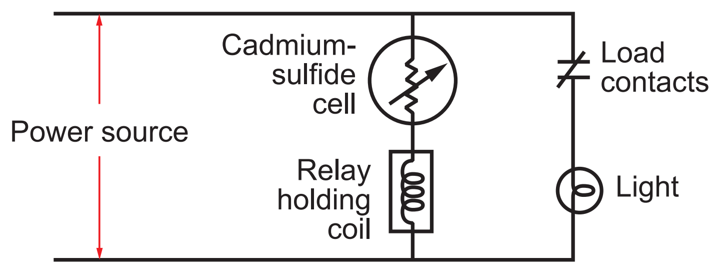
The **Canadian Electrical Code** requires all branch circuits to have circuit protection. This is normally done with circuit breakers. Circuit breakers can be used to switch lighting loads, at an initial saving of a switch leg (circuit to a control device). However, breakers should never be used to replace switches. Using circuit breakers as switches weakens the springs and heater elements. The circuit breaker relies on these components to detect and open overloaded circuits. Using breakers as switches may cause them to trip prematurely or, in worst cases, prevent breakers from tripping when they should. If a breaker fails to open an overloaded circuit, a fire is likely to occur.

Photoelectric Controls

Originally, **photocells** were used for automatic light control. More recently, the cadmium-sulfide cell has come into general use. It operates based on the variable resistance of the cadmium-sulfide cell under different light conditions. The cell has a very high (15 mega ohms) resistance. When exposed to light, its resistance drops to less than 1000 ohms. The cell is placed in series with the holding coil of a normally closed relay.

In high lighting levels, the resistance of the cell is low. Sufficient current flows through the relay coil to hold the relay contacts open and keep the light off. As the illumination level drops, the resistance of the cell increases and the current through the relay coil decreases. When the light level reaches the control setting, the relay contacts close and the light is energized. The control circuit for the cadmium-sulfide cell is shown in Figure 10.

Figure 10 – Cadmium-Sulfide Cell Control Circuit



Timers

A timer or time clock is a device that energizes or de-energizes a light at a preset time. Timers may be electro-mechanical or electronic. Electronic timer sales now dominate the market.

Electro-mechanical time clocks have electric clock motors that move a series of adjustable engagement dogs to turn the lights on or off at designated times. Electronic timers use microprocessor controls and switches to achieve the same result. The simplest timers have a single ON and a single OFF time for each 24 hour period.

Seven-day timers are available to allow for different ON and OFF settings for different days. For example, in an office, it may be desirable to set switching times for weekends to be different from work days. Astronomical clocks compensate for seasonal changes at dusk and dawn.

Electro-mechanical time clocks may be equipped with carryover springs. These springs are kept "wound-up" by the electric clock motor. During a temporary power outage, the springs keep the clock operating, so it is not necessary to check and adjust the time clocks after a power failure.

Newer electronic time clocks have the ability to offer multiple on/off times per day and different times for each day of the week. They also have battery backup, in case of a power failure. The battery will not keep the "timed" equipment operating, but will preserve the time of day, the day of the week and the programing.

Occupancy Sensors

Occupancy sensors turn the lights on when people enter a room and off when they leave, after a set time. Occupancy sensors can reduce lighting costs by 20 to 60 percent. With these savings, the sensors can pay for themselves in less than two years. Sensor lighting control is most effective in spaces with transient activities, where the lights are easily forgotten. Some of these areas include:

- Conference and meeting rooms
- Hallways
- Washrooms
- Storage rooms
- Warehouses

Occupancy sensors are automatic switching devices that sense motion. The two most common types are **infrared** and **ultrasonic** detectors.

Infrared motion detectors respond to heat. They sense changes in patterns of heat radiated by objects warmer than their surroundings, such as a person walking across the room. This kind of sensor only receives a signal from within a line of sight.

Ultrasonic motion detectors sense motion with **ultrasound**. These units send out an inaudible tone, capable of bouncing off walls and around corners. The returning tone is compared with the tone sent out. Any change in tone frequency indicates occupancy. Ultrasonic sensors will automatically turn the lights on when motion occurs from any source (person or an object) in the room.

When selecting a sensor, area coverage and beam pattern are important factors to consider. Make sure the sensor coverage area is suitable for the application before purchasing and installing the sensor. There are different beam patterns available such as ellipse, circle, fan shape, and square or rectangle.

False triggering is another factor to consider when choosing the type and location of an occupancy sensor. Infrared devices may consider a mirrored image or daylight as a signal that a space is occupied. An ultrasonic device may be triggered by vibrations, such as the starting of an air conditioning system or direct air motion on the unit.

Occupancy sensors may frequently turn lights on and off in certain areas, such as washrooms. This will shorten the life of fluorescent lamps and increase the lamp replacement cost.

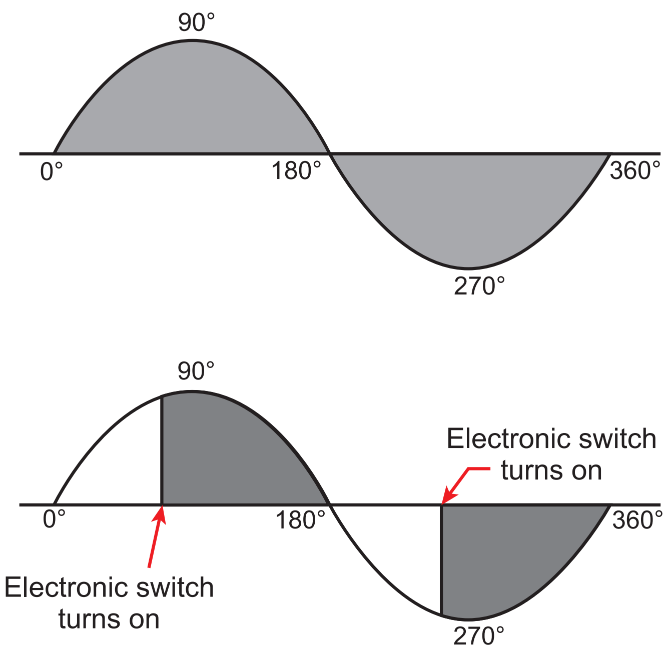
Light Level Control

Dimming

The most effective means of controlling the level of illumination is by use of a dimmer. Originally, dimmers were designed for incandescent lights. This dimmer was a resistance type that diverted some of the current through a variable resistor (rheostat). This type of dimmer cannot save energy since the dimmer itself dissipates the power that is not used by the lamp.

Solid state dimmers now dominate the sales market. The principle of operation is reasonably simple, and the energy consumption of the dimmer itself is low. Solid state dimmers reduce the average voltage across the lamps by turning on or off at a particular instant in each half of the AC wave cycle. The trigger time can be adjusted, thereby varying the average voltage across the lamp (Figure 11).

Figure 11 – Dimmer Characteristics for Alternating Current



Fluorescent and **high intensity discharge (HID)** dimmers require special dimming ballasts and special dimmers. These dimmers are not interchangeable with regular incandescent dimmers. Control from 100% to 0% is not provided, but the lower levels are usually so low that the lamp is assumed to be off. These dimmers are complex and expensive compared to incandescent dimmers, but they may result in energy savings if used properly.

LED lights are also dimmable. Constant voltage (CV) LEDs require different dimming technology than constant current (CC) LEDs. Therefore, ensure the proper dimmer is selected for the particular LED system being used.

Daylight variations demand changes in artificial lighting intensity. Dimmers may be interfaced with photocells and a control station to control the illumination level.

Objective 4

Describe the general requirements and criteria for emergency lighting in buildings.

Emergency Lighting

The **National Fire Protection Association (NFPA 101) Life Safety Code** states:

The emergency lighting system shall be arranged to provide the required illumination automatically in the event of any interruption of normal lighting due to any of the following:

1. *Failure of a public utility or other outside electrical power supply*
2. *Opening of a circuit breaker or fuse*
3. *Manual act(s), including accidental opening of a switch controlling normal lighting facilities*

Occupancies Requiring Emergency Lighting

Since the topic of emergency lighting involves safety, it is covered by several codes, which may or may not be in full agreement. When code requirements differ, clarification can be obtained from the local jurisdictions.

The **NFPA 101 Life Safety Code** lists several types of building occupancies. The occupancies Power Engineers are most likely to encounter are listed below. Definitions are as stated in the NFPA.

1. ***Assembly.*** *An occupancy used for a gathering of 50 or more persons for deliberation, worship, entertainment, eating, drinking, amusement, awaiting transportation, or similar uses.*
2. ***Educational****. An occupancy used for educational purposes through the twelfth grade.*
3. ***Health Care.*** *An occupancy used to provide medical or other treatment or care simultaneously to four or more patients on an inpatient basis, where such patients are mostly incapable of self-preservation due to age, physical or mental disability, or because of security measures not under the occupants' control.*
4. ***Ambulatory Health Care.*** *An occupancy used to provide services or treatment simultaneously to four or more patients that provides, on an outpatient basis, one or more of the following:*
   a) *Treatment for patients that renders the patients incapable of taking action for self-preservation under emergency conditions without the assistance of others*
   b) *Anesthesia that renders the patients incapable of taking action for self-preservation under emergency conditions without the assistance of others*
   c) *Emergency or urgent care for patients who, due to the nature of their injury or illness, are incapable of taking action for self-preservation under emergency conditions without the assistance of others*
5. ***Detention and Correctional.*** *An occupancy used to house one or more persons under varied degrees of restraint or security where such occupants are mostly incapable of self- preservation because of security measures not under the occupants' control.*
6. ***Residential.*** *An occupancy that provides sleeping accommodations for purposes other than health care or detention and correctional.*

7. ***Residential Board and Care.*** *An occupancy used for lodging and boarding of four or more residents, not related by blood or marriage to the owners or operators, for the purpose of providing personal care services.*
8. ***Mercantile.*** *An occupancy used for the display and sale of merchandise.*
9. ***Business.*** *An occupancy used for the transaction of business other than mercantile.*
10. ***Industrial.*** *An occupancy in which products are manufactured or in which processing, assembling, mixing, packaging, finishing, decorating, or repair operations are conducted.*
11. ***Storage.*** *An occupancy used primarily for the storage or sheltering of goods, merchandise, products, or vehicles.*

The **NFPA 101 Life Safety Code** details the specific installation, maintenance, and testing requirements for emergency lighting for all these types of occupancies and others not listed above. Installations usually require all of the following:

a) Illuminated egress paths (including stairwells and vestibules).
b) Illuminated egress signage.
c) Other illuminated areas specific to the type of occupancy.

Emergency lighting must be powered by battery or a stand-by generator. Batteries, battery chargers, and generators must be tested and maintained at regular intervals, as specified in the code.

Emergency lighting designs must provide adequate lighting within a specified maximum amount of time (typically 10 seconds). They must remain on for a minimum specified amount of time (typically 90 minutes).

Objective 5

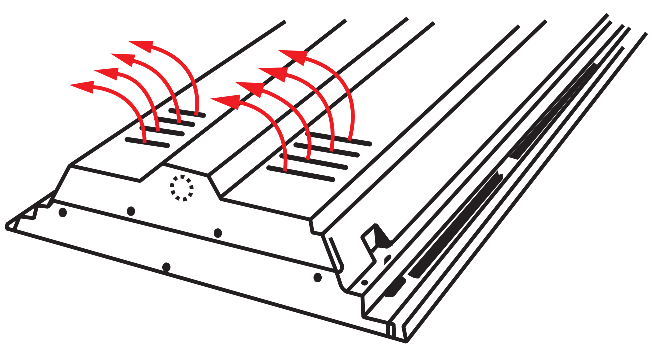
Discuss the interrelationship between lighting, air conditioning, and energy conservation in buildings.

Lighting and Air Conditioning

In cold months, buildings can benefit from heat produced by lights, even if they do not have a specially designed system for heat recovery or heat redistribution. The thermal energy from light fixtures is delivered directly to the occupied space. The lighting system, then, takes the place of the building's heating system by preventing the thermostat from calling for more heat. However, in multi-level buildings, the interior must often be cooled even in winter due to the heat emitted by lighting, people, and equipment.

Heat removal luminaires (Figure 12) remove a large portion of lighting system heat before it enters the occupied space. This reduces cooling and ventilation requirements, improves the lamp efficiency, and extends ballast life. In addition, the lighting system heat which has been removed can be relocated to other areas, or reclaimed for other purposes, thus saving energy. Heat removal luminaires (air supply or air bypass) can improve the ceiling's appearance by eliminating air diffusers and air grills.

Figure 12 – Heat Removal Fixture



Energy Conservation and Lighting Maintenance

The lighting load for industrial-commercial buildings can amount to a substantial portion of the total electrical load. For example, in large office buildings, approximately 60% of the total electrical energy consumption is typically used by the lighting system. As a result, every effort should be made by both the designer and the owner to ensure that energy requirements are minimized. Some steps that can be taken to conserve energy include:

1. Specify the correct level of illumination required.
2. Use efficient light sources.
3. Use luminaires that provide optimum light utilization.
4. Decorate interiors with light reflecting finishes.
5. Maintain lighting systems.
6. Avoid wasting light.

1. Specify the Correct Level of Illumination

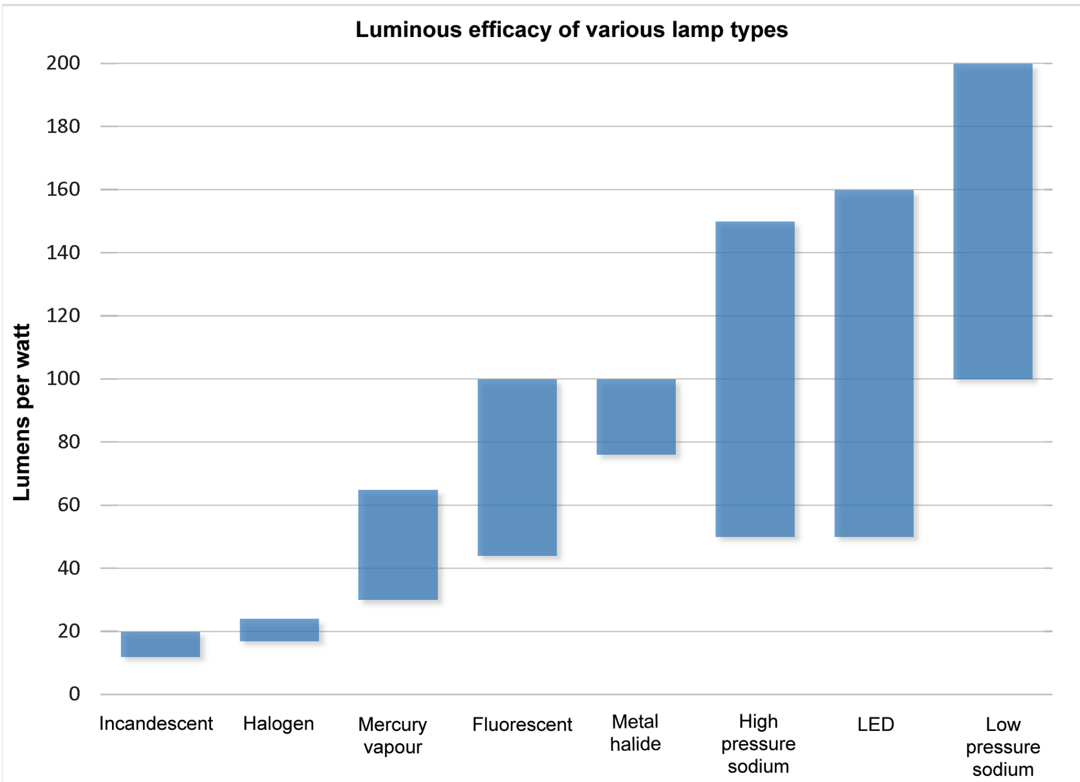
Lighting systems should be designed to provide the user with the right quantity and quality of light for efficient and comfortable vision. Illumination requirements can differ for various tasks. Select the proper level of illumination for a specific task or area. The levels are usually for a specific task, rather than for a general area.

Energy savings can be gained by reducing the illumination levels in areas adjacent to the task areas requiring higher levels of illumination. For example, the areas in offices and banks where people circulate (move around) can be at a lower lighting level than work areas. The concept of task or non-uniform lighting may be a good alternative to general or uniform lighting.

2. Use of Efficient Light Sources

Lamp efficacy is a way to express how much light is given off by a particular luminaire for each watt of electrical power it consumes. Efficacy, then, is expressed in **lumens** per watt. Figure 13 shows the range of efficacies of modern lamp systems (ballast losses included).

Figure 13 – Lamp System Efficacy



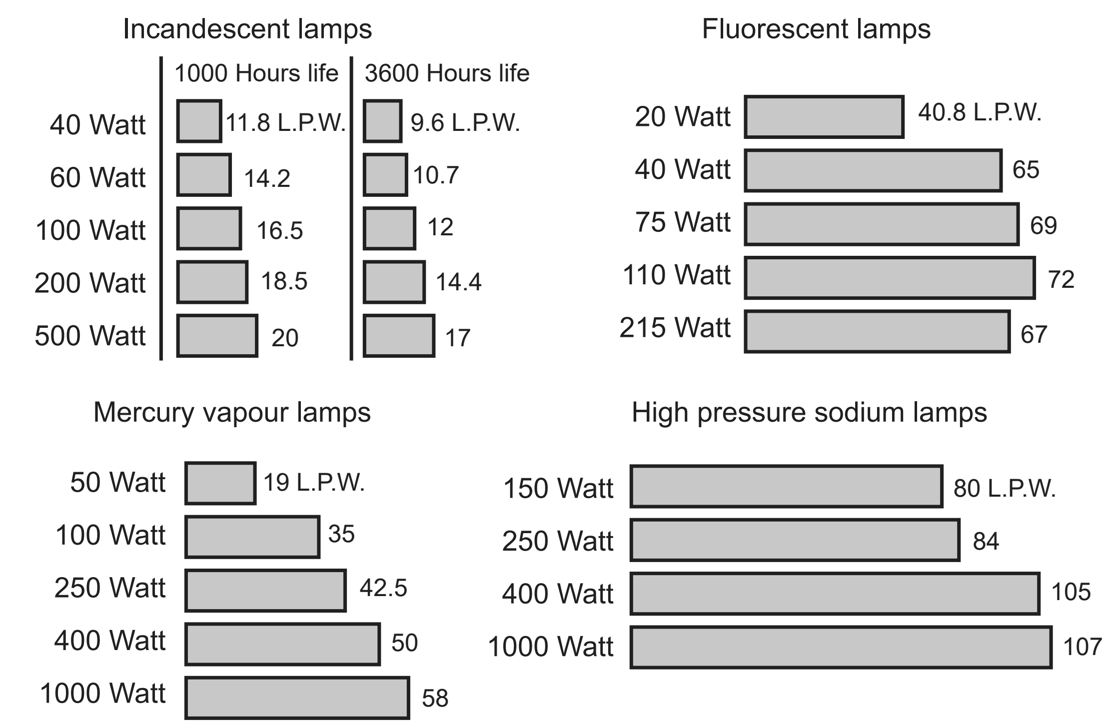
Sometimes, the term **luminous efficiency** is used. Luminous efficiency is the ratio of the luminous power given off by the lamp, in watts, compared to the electrical power it consumes, in watts. Luminous efficiency is therefore a pure ratio, and is expressed in percent.

Efficiency and efficacy are only two of a number of lamp characteristics. The suitability of a lamp for a particular application is influenced by other factors.

- Life expectancy
- Colour rendition
- Cost
- Warm-up time

The efficacy of each type of lamp is affected by its wattage. In general, higher wattage means greater efficacy (Figure 14).

Figure 14 – Luminous Efficacy vs. Lamp Size



Note, however, that energy savings through the use of the largest and most efficient lamp are not the only consideration. Acceptable standards of visual comfort, uniformity, and safety must be met, before energy savings are considered. Some methods that can be used to reduce the consumption of energy include:

- Energy saving lamps
- High efficiency ballasts
- Reduced light output ballasts
- Solid state ballasts

Energy Saving Lamps

To save energy, it is possible to replace existing fluorescent lamps with reduced-wattage alternatives (35 W vs. 40 W), at a slight reduction in lumen output (3000 lumens vs 3150 lumens). In areas with excessive fluorescent light, some of the bulbs can be removed. They are replaced with clear "dummy" bulbs that provide no light, but allow the circuit to function normally with missing bulbs.

As well, fluorescent troffers can be retrofitted with low power consumption LED lamps. These 18 W bulbs replace 32 W T8 fluorescent tubes. The reduction in power costs by these LED retrofits can pay off in 5 to 7 years, depending on the electrical power rates and the number of hours per day the light is on.

High Efficiency Fluorescent Ballasts

High efficiency ballasts can reduce energy consumption by as much as 9%. This is because of the decreased wattage losses within the steel core and copper windings. Due to their lower operating temperature, the average life of these efficient ballasts is two to three times longer than that of their conventional counterparts.

Reduced Light Output Ballasts

Reduced light output ballasts decrease energy consumption by reducing the amount of current to the lamps by as much as 20%. Light output decreases correspondingly; therefore, these ballasts should be used only if the reduced light output is compatible with needs.

Solid State Ballasts

Use of solid state ballasts are rapidly gaining popularity due to their high efficiency. These ballasts use much less power than conventional ballasts. For example, a typical 2-lamp fluorescent luminaire equipped with two 40-watt lamps uses approximately 100 watts of power (80 watts for the two 40-watt lamps, 20 watts for the ballast). The use of a solid state ballast may reduce the power used by this system to 85 watts (80 watts for the 2 lamps, 5 watts for the ballast).

3. Use of Luminaires that Provide Optimum Light Utilization

The **coefficient of utilization (CU)** describes the percentage of light that arrives on the work plane. CU is an important consideration in an energy efficient installation. For example, a typical 2-lamp fluorescent "wrap-around" with a 25 cm prismatic lens has a CU of 0.61 in a particular installation. The same manufacturer can supply a similar luminaire with a 41 cm lens that has a CU of 0.72 in the same installation. This allows an energy saving of 15%.

The CU should not be the only criteria used to determine the effectiveness of a luminaire. The optimum system uses luminaires that are as efficient as possible without adversely affecting the comfort and visibility in the space they are lighting.

4. Decorate Room Interiors with Light-Reflecting Finishes

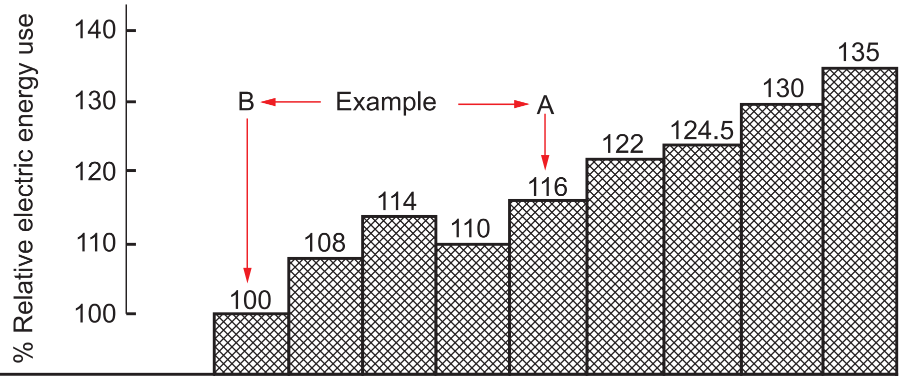
Lighter surfaces reflect more light than darker surfaces. The amount of light that arrives to a work station depends in part on the light reflected from the room surfaces. The higher the reflectance from the ceiling, wall and floor, the more light will reach the task.

While a sterile all-white interior would provide the highest lighting efficiency, it would not be aesthetically pleasing. Using darker, more vibrant finishes on a **small percentage** of the wall areas, provides an interesting and comfortable visual environment. In addition, the average use of light can still be maintained at a relatively high level.

Figure 15 shows the relative energy used for various room reflectances. As interior surfaces become less reflective, the amount of energy required to illuminate a room to a particular level increases. Consider an office space with a ceiling reflectance of 80% and a wall reflectance of 50%. If the same office had darker, less reflective surfaces (50% ceiling reflectance and 30% wall reflectance), it would consume 116% more energy to illuminate to the same level. (Compare arrow "A" to arrow "B" in Figure 15.)

Another way to improve lighting levels and reduce energy consumption with increased surface reflectance is to paint the walls and ceilings of parking garages white.

Figure 15 – Relative Electric Energy Use



% Wall reflectance	50	30	10	50	30	10	50	30	10
% Ceiling reflectance	80			50			10		

5. Maintaining Lighting Systems

The lighting system should be able to provide adequate light, at a minimum cost throughout its year-to-year operation. Without a proper maintenance program, the lighting level will depreciate substantially over time. This can be due to:

a) Dirt collected in luminaires

b) Room surface dirt

c) Lamp lumen reduction

d) Burnouts that are not promptly replaced

Key points to be included in a lighting system maintenance plan include:

- Relamping
- Cleaning

Relamping

In a group relamping plan, all lamps are replaced at a preplanned time in the life of the group of lamps. Group relamping can mean a considerable reduction in labour costs (10%–25%) compared to a plan whereby individual lamps are replaced at burnout. The most economical time to relamp can be predicted on the basis of the known rate of burnouts at a certain point in the life of a group of lamps. Ordinarily, the most economical group relamping period is about 70% of rated life. Loss of light output as lamps age may be a more significant consideration in some situations. In this situation, group relamping may be desirable at as low as 50% of rated life.

Cleaning

Significant light loss will result from dirt accumulation on luminaires. Even in very clean environments, light output can drop 5% per year. In dirtier conditions, light loss is correspondingly higher. Cleaning is usually required no more than once a year, but no less than once every three years. Group relamping with simultaneous cleaning may be the most economical solution.

6. Avoid Wasting Light

One of the most obvious, but most often ignored, methods for saving electrical energy is to switch off lighting systems when they are not required. Good management dictates that both energy use and relamping costs can be reduced by switching off lights when not in use. Inexpensive photoelectric and time-switch controls are readily available for automatic switching of lighting systems. In all cases, the safety of people using the premises must be considered before lighting systems are switched off.

Chapter Summary

When performing their work correctly, Power Engineers help maintain the safety and efficiency of the facilities where they do their work.

Almost all Power Engineers are involved in the operation and maintenance of lighting systems. The lighting systems are crucial to the safety of building inhabitants. This chapter presented specific information on emergency lighting systems, and directed readers to the detailed information found in the **NFPA 101 Life Safety Code.**

Energy efficiency is another primary area of concern for Power Engineers. Specifically, the application, use, and efficiency of lighting systems were addressed. This included direct, indirect, uniform, and task lighting. Energy saving system upgrades were also discussed for ballast and lamp substitution, timer installation, and the use occupancy sensors.

CHAPTER 2

Building Water Systems

Learning Outcome

When you complete this chapter you should be able to:

Explain the various water supply systems used in buildings.

Learning Objectives

Here is what you should be able to do when you complete each objective:

1. *Describe the cold water distribution system in a building.*
2. *Describe the hot water distribution system in a building.*
3. *Describe the construction and operation of building system hot water heaters, including temperature regulation.*
4. *List and describe the construction and operation of water system protective devices in buildings.*
5. *Explain what is meant by "backflow prevention" and describe the common methods used.*
6. *Describe the maintenance requirements for the components in a building water distribution system.*

Chapter Introduction

Water is essential for life. However, contaminated water, and high temperature hot water are hazardous to life.

To ensure the safety of building occupants, Power Engineers must understand water distribution systems in a building. This includes the function of control devices related to the systems.

This chapter covers various water distribution systems found in the following types of buildings.

- Industrial
- Commercial
- Residential
- Public assembly
- Institutional

Some system components, such as heaters, temperature regulators, and mixing devices will be described in detail. The construction, application, operation, and maintenance of specific safety devices – such as temperature and pressure relief valves and backflow preventers – is emphasized.

With this knowledge, Power Engineers will be able to recognize unsafe conditions and system inefficiencies. They will be able to take the necessary proactive steps to protect the interests of all those who may be impacted.

Objective 1

Describe the cold water distribution system in a building.

Cold Water Distribution Systems

Most municipal water systems distribute water at pressures between 350 kPa and 490 kPa. In low-rise buildings, this supply pressure is sufficient to perform all building functions adequately. However, some local regulations require that a higher pressure must be available for fire protection. As well, tall buildings require higher pressure. In these cases, pumps are needed to increase the pressure.

Building codes generally limit the highest pressure permissible in plumbing systems to 560 kPa. It is also recommended that the water pressure, within a building, should not fall below 175 kPa.

Generally, the water demand load for a building plumbing system is determined by adding up the maximum flow rate of the total number of plumbing fixtures used in the system. This ensures that the piping system design will be able to supply sufficient pressure at the most remote points when all fixtures are using water at the same time.

Water may be distributed throughout a building by either:

- **Upfeed systems**
- **Downfeed (gravity) systems**

Upfeed Systems

There are four common upfeed water systems.

a) Direct pressure
b) Tankless constant pressure
c) Constant pressure with a suction tank
d) Constant pressure with a pneumatic tank

Direct Pressure System

With this method, water is obtained directly from a municipal distribution system (often called "**city water**") or from a private supply, at approximately 350 kPa. After entering a building, the water flows through a water meter in the basement and then through a horizontal **water main**. The main supplies a hot water heater and cold water risers to the upper floors. Hot water from the heater is delivered to the upper floors by separate **risers**. Branch lines from both the hot and cold water risers then supply the various plumbing fixtures on each floor. Application of this system is limited to low rise buildings with a small floor area.

Tankless Constant Pressure System

This system is used when either of the conditions below exists.

a) The maximum building demand for water is always less than the maximum flow provided by the local water distribution system.
b) The supply pressure to a high-rise building is too low to provide enough water pressure on the upper floors.

In the system in Figure 1, city water enters the building at 525 kPa. A water meter (WM) causes a 20 kPa pressure drop because it is restrictive. This leaves 505 kPa to supply water to all the floors directly. The pressure must be adequate to maintain a minimum of 175 kPa on the top floor.

Figure 1 – Tankless Constant Pressure Upfeed System for 10-Storey Building

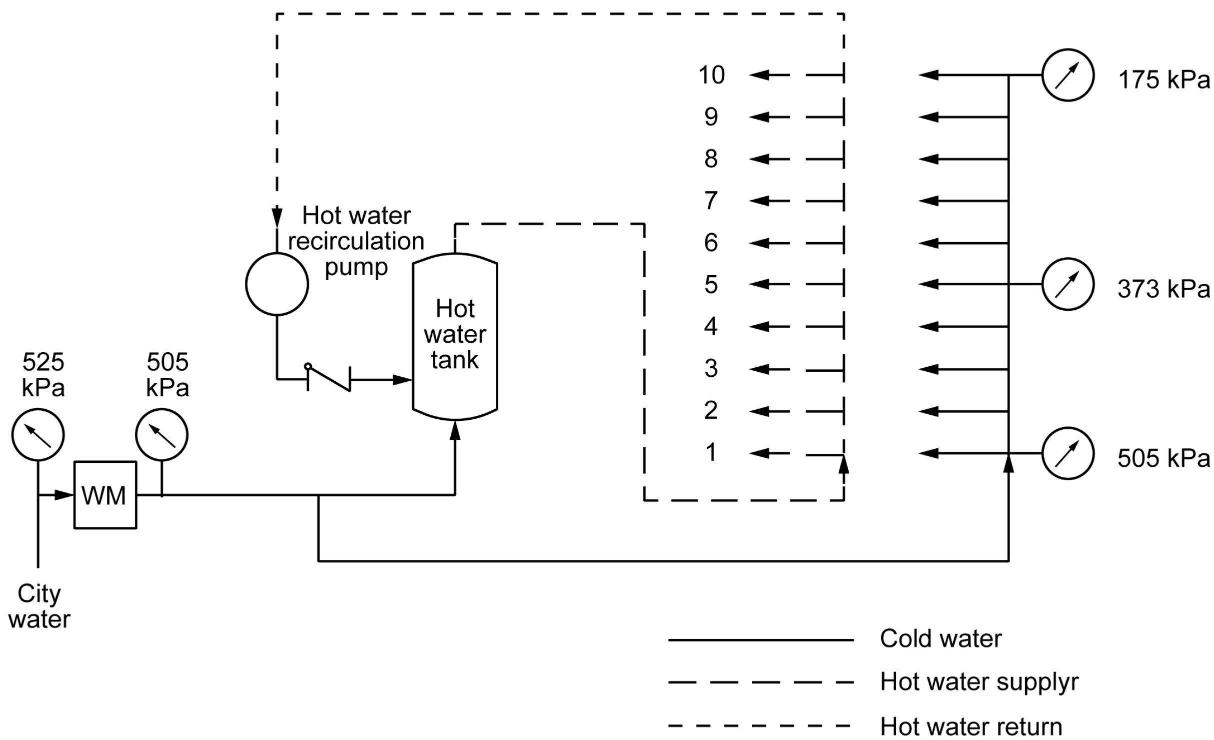
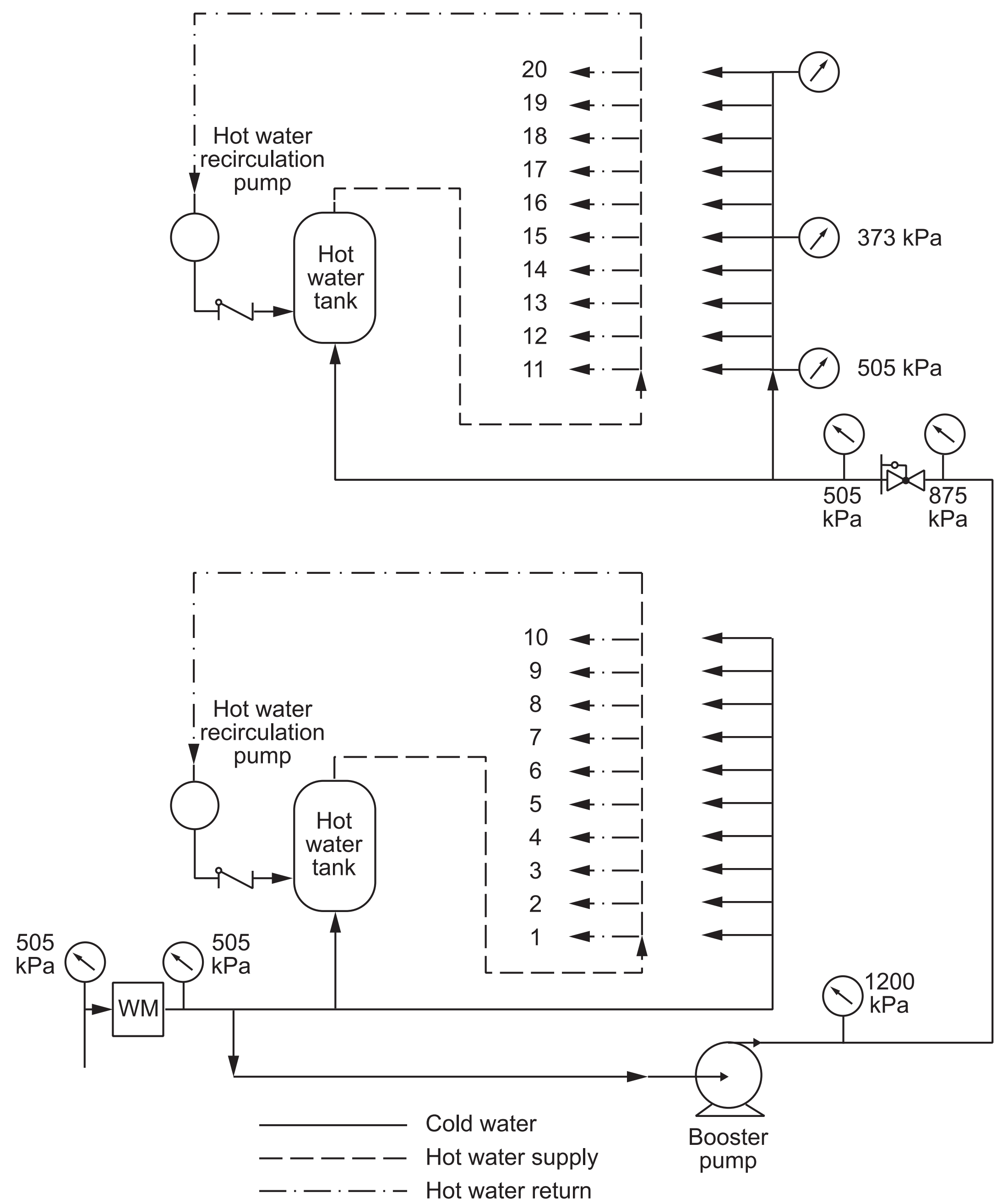


Figure 2 shows a similar system applied to a 20-storey building. Besides directly feeding the first 10 floors, the water supply also feeds the suction of a booster pump whose discharge is connected to a vertical supply main. A pressure-reducing valve (PRV) prevents the pressure on the 11th floor from exceeding 560 kPa. A minimum of 175 kPa is maintained at the 20th floor.

Figure 2 – Tankless Constant Pressure Upfeed System for 20-Storey Building



Water for the building fire system, which includes a fire pump, comes directly from the city water supply, before it reaches the water meter.

Since the inlet pressure from the public water main varies, the booster pump must be designed to maintain the maximum required flow when the suction pressure drops to the lowest anticipated value. When two pumps are used, each pump must be capable of supplying 70% of the maximum flow demand. With a three-pump system, two pumps must each have sufficient capacity to supply 55% of the maximum demand, and the third 25%.

In a two-pump system, one pump is usually in continuous service while the second is on standby. If the water system pressure drops below the acceptable preset value, for example, to respond to an increase water demand. A pressure switch will provide a signal to start the second pump to restore the water system pressure to the acceptable preset value.

In a three-pump system, one 55% pump will be in continuous service. When the water system pressure drops to a preset value, the 25% pump will be activated. Under still further demand for water, the third pump will be placed into service. When the demand for water decreases and the water system pressure increases, the pressure switches will send a signal to stop the two standby pumps in the reverse order.

Constant Pressure System with Suction Tank

A surge or suction tank should be used in either one of the situations below.

a) The water flow from the supply source is not adequate to meet the maximum demand for cold water in a building.

b) The maximum building demand could cause the water pressure in the supply source to drop too low.

Water, coming from the supply source, flows by gravity into a supply tank which connects to a pump suction. In this system, the tank fills up during periods of low water demand. When water demand is higher, or upon temporary loss of water supply, the supply tank is able to provide the water without interruption for a period of time depending on the size of the tank. A level controller, such as a simple float-operated valve, maintains the level in the supply tank.

Typically, more than one pump is used. The pump capacities are similar to those in the system explained previously, with one pump operating continuously. During periods of extremely low demand, a pressure relief device bypasses the flow back into the tank, and prevents the pump from overheating. Generally the pumps are operated under low suction head and must be capable of providing a greater discharge head. This often results in higher electric power consumption.

The pump suction should always be above the bottom of the tank. This prevents sediment from being discharged into the system. Sediment accumulations in the tank should be removed during periods of low building demand. This can be done with intermittent bottom blowoff. Often, the supply tank has a partition that allows one part of the tank to be cleaned, while another section is in service.

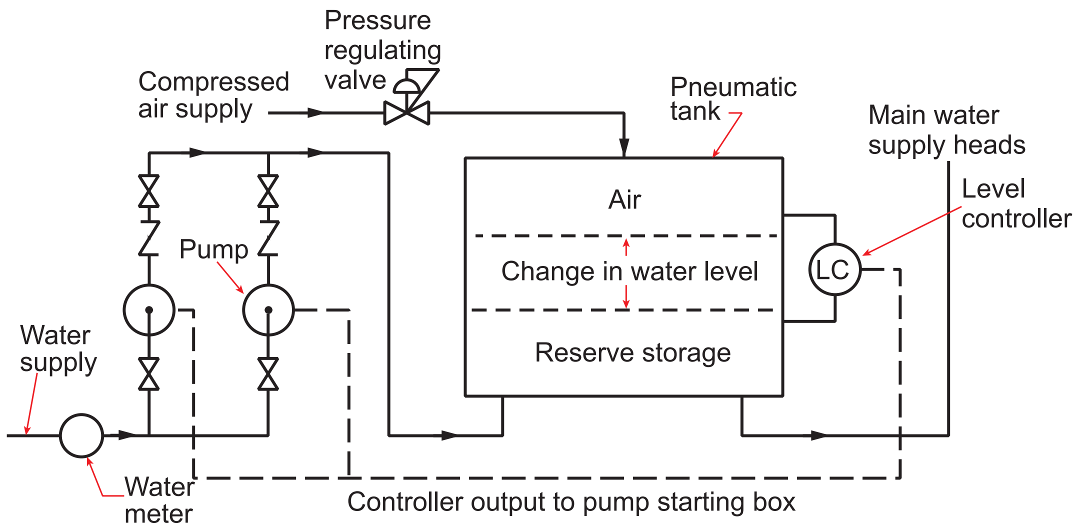
Constant Pressure System with Pneumatic Tank

The constant pressure system with a pneumatic tank (Figure 3) is also used when:

a) The building water demand exceeds the supply from a municipal system.

b) The source pressure is insufficient to supply the required pressure at the most remote point of water demand.

Figure 3 – Hydropneumatic Storage Tank and Intermittent Pump



Water entering the pump suction goes into a pressurized tank, and then flows into the building cold water system. A level controller operates the service pump intermittently to maintain the water level in the tank within preset minimum and maximum limits. The controller does this by measuring the differential pressure between the air space and the point of minimum water level.

The electrical output of the controller operates the pump switching device to start and stop the pump. If the pump in service should fail to maintain the acceptable water level, the controller will automatically start a standby pump.

A pressure regulator maintains a constant pneumatic tank pressure by regulating the amount of compressed air supply to the tank and to replace any air absorbed by the water.

Use of this system is limited to smaller buildings. It becomes quite expensive when higher pressures and larger storage volumes are required in buildings of greater height and larger floor area. Since the water storage tank is a pressure vessel, it must be constructed according to **ASME** and **CSA** codes.

Note: The water system pressure may vary slightly as the water level changes in the tank.

Downfeed or Gravity Systems

These systems have a storage or "**house tank**" above the highest fixture in the building. They provide storage capacity for the **potable** water system in situations where the supply flow may be too low.

The building storage tank supplies a constant pressure to each floor through a downfeed line. Pressure reducing valves are placed on each lower floor where the pressure exceeds 560 kPa. Domestic water is drawn off at the middle of the tank so that a reserve of water is always available for fire protection. Water supply to the heaters is drawn off near the top of the vertical supply line, to maintain a constant pressure at the heater.

Multiple gravity feed tanks located at different intermediate levels are used on high buildings.

A multiple pump system, connected directly to the municipal supply, maintains the proper level of water in the house tank. Suction tanks may also be used. The levels in the suction and house tanks are usually controlled by a float control system, but other control systems may also be used. Float switches are often used to start and stop pumps, as described previously.

Objective 2

Describe the hot water distribution system in a building.

Hot Water Supply Systems

Hot water supply systems for buildings may be of the non-circulating or the circulating type.

Non-Circulating Hot Water System

A **non-circulating hot water system** is normally used in small residential buildings where only short runs of piping are required. It consists of a single pipe through which the heated water passes from a water heater to each fixture in the building.

Since the hot water dead ends at each fixture, the water temperature drops when the fixtures are not used for long periods of time. Consequently, colder stagnant water may need to be flushed out before hot water reaches a fixture, which results in a waste of both water and energy. Most building regulations prohibit single pipe systems over 15 metres in length from a water heater or a hot water recirculating line.

Circulating Hot Water System

Circulating hot water systems have a return line connected near the end of each hot water main leading back to the water heater. This design provides hot water at each fixture with shorter delays, resulting in less waste than the non-recirculating system.

This system can be applied to all types of buildings where the fixtures are a long distance from the central heating source. Circulation of hot water may be moved either by gravity or by the use of pumps.

Many large, new buildings may have individual water heaters for every two to four floors. This conserves energy by reducing heat losses in piping and energy consumption by large circulating pumps.

Principle of Operation of a Hot Water Recirculating System

Water expands and becomes less dense when heated. This causes natural circulation (also known as convection) as shown in Figure 4.

Figure 4 – Water Circulation due to Natural Convection

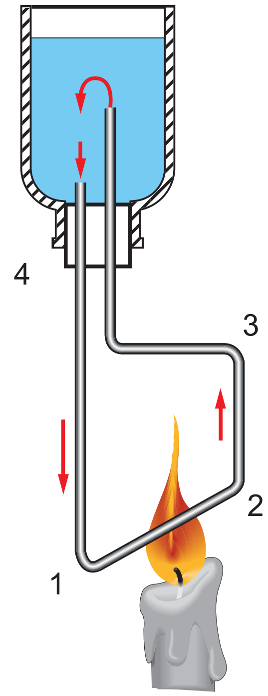


Figure 4 shows a glass tube with both ends connected to a container. Heat is applied to the lower portion of the loop between the points 1 and 2, causing the water between these points to become less dense.

The column of cold water between points 4 and 1 is denser than the hot water between points 1 and 3. The hot water between points 1 and 3 rises and is displaced by the cold water between points 4 and 1. As a result, a natural circulation is set up.

If the height of cold water between points 4 and 1 increases, water circulation in the glass tube will also increase. Likewise, circulation of the water is increased if its temperature between points 1 and 2 is raised. This principle of natural hot water circulation by means of gravity can be applied to all hot water systems.

Any circulating hot water system has all three of the items listed below.

a) A heater (with or without a storage tank).

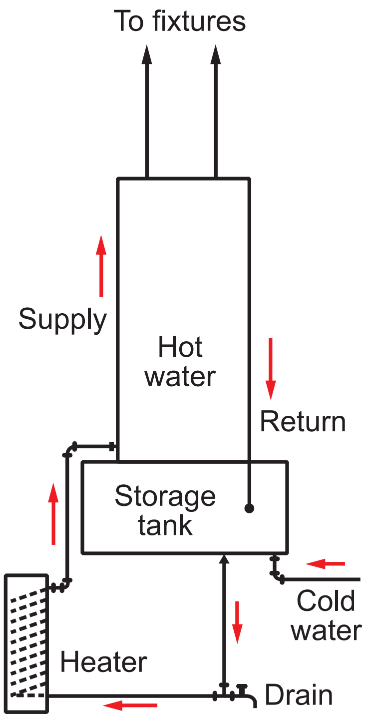
b) Supply piping to carry the hot water to the fixtures.

c) Return piping to return the unused water back to the heater.

A simple system with a storage tank is illustrated in Figure 5.

Circulation is maintained because the water in the return main is cooler and denser; it exerts a greater pressure than the same height of water in the hotter supply main. A check or backflow valve must be installed in the return line. This prevents cold water from entering the hot water lines when there is maximum flow from the fixtures at the end of the hot water supply. Cold water from a municipal distribution system or a domestic storage tank is used to supply the water heater.

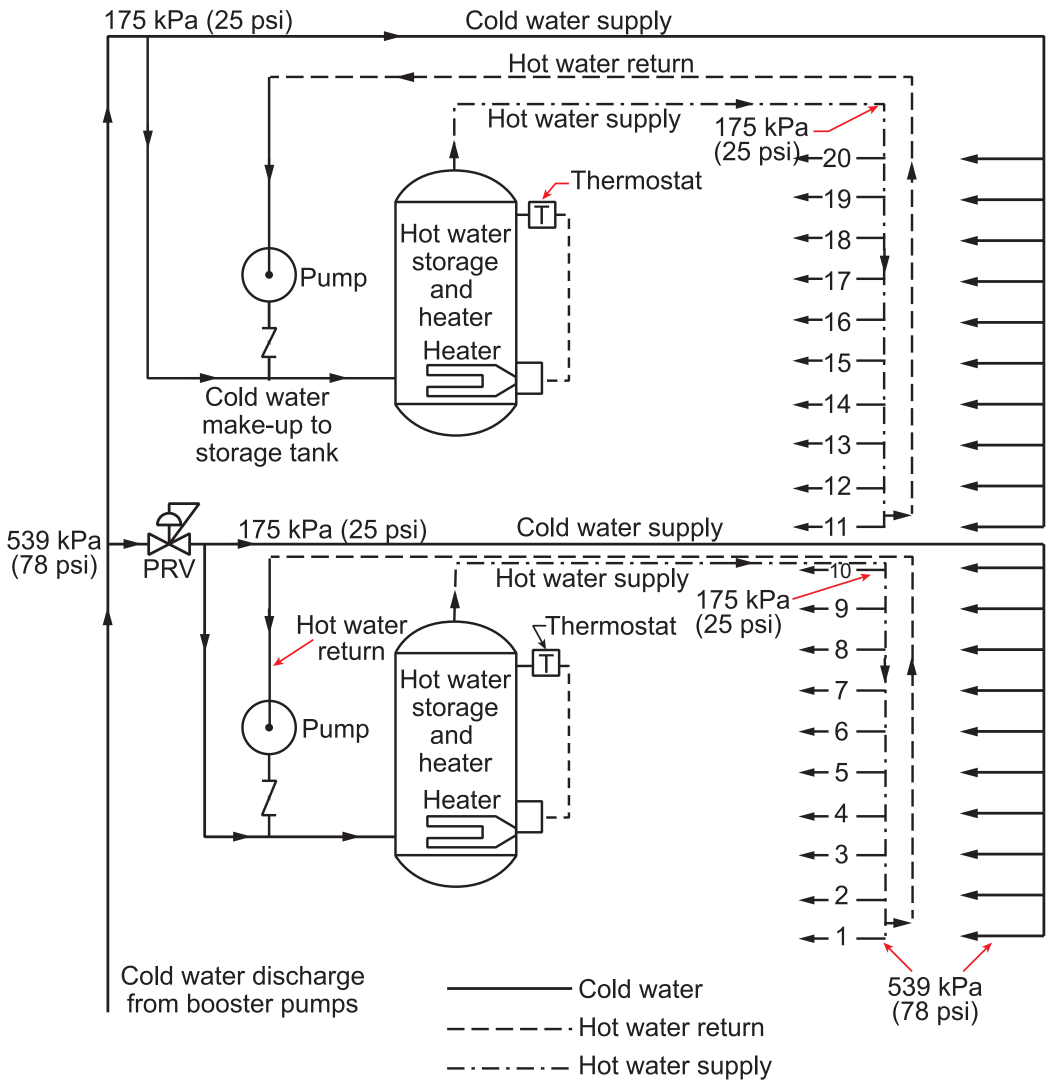
Figure 5 – Simple Hot Water System



In many large hot water systems, it is impossible to develop adequate circulation by means of gravity. Thus, pumps are used to improve circulation. A pump keeps the hot water circulating through the system and back to the heater. Automatic air vents are usually located at the top of hot water risers. The vents remove the air that is released when the water is heated. If the hot water riser ends below the top floor fixtures, the fixtures may be used to vent the air from the system.

Figure 6 illustrates an upfeed cold water distribution system. It has a multiple heater hot water system, and each heater supplies ten floors. This system, used in large, multi storey buildings, limits the maximum pressure in the hot water system and reduces maintenance costs.

Figure 6 – Hot and Cold Water Distribution



In Figure 6, booster pumps supply the total water requirements. A pressure-reducing valve reduces the water pressure from 539 kPa to 175 kPa on the tenth floor. As the water moves from the tenth floor down to the first floor, the supply pressure for both hot and cold water increases again (due to head pressure) to 539 kPa. Pressure-reducing valves may also be used on lower floors where the pressure is excessive.

A hot water circulating pump is used at each heater to maintain a constant hot water temperature at each floor. An electrical water heater with a hot water storage tank is used in this design. However, in other buildings, the water may be heated by steam coils submerged in the hot water storage tank. The water temperature is controlled by a thermostat that operates electrical relays or a thermostatically controlled steam valve.

The hot and cold water supply is taken directly off the booster pump every ten stories of the building. If the building exceeds twenty stories, the discharge pressure from the booster pumps must be increased, to supply a pressure of 175 kPa at the top floor. Higher buildings also have additional water heaters installed. Each heater will have a separate hot water return and a circulating pump.

Objective 3

Describe the construction and operation of building system hot water heaters, including temperature regulation.

Hot Water Heaters

Hot water heaters in commercial buildings may be classified as either direct or indirect. In the former, the water is heated by a burning fuel or an electric element. In the latter, the water is heated by a tube arrangement utilizing the heat energy in steam or high temperature water.

Direct Hot Water Heaters

A common type of direct water heater is an automatic gas-fired storage heater, which features a single tank used for both heating and storing the water. Figure 7 shows a single flue design suitable for small buildings. In this heater, the gas burner is located beneath a centrally located flue. The hot products of combustion pass through the flue to heat the surrounding water. A spiral baffle in the flue increases the heat transfer efficiency. A multiple flue, multiple burner heater is used for larger buildings.

Figure 7 – Single Flue Heater

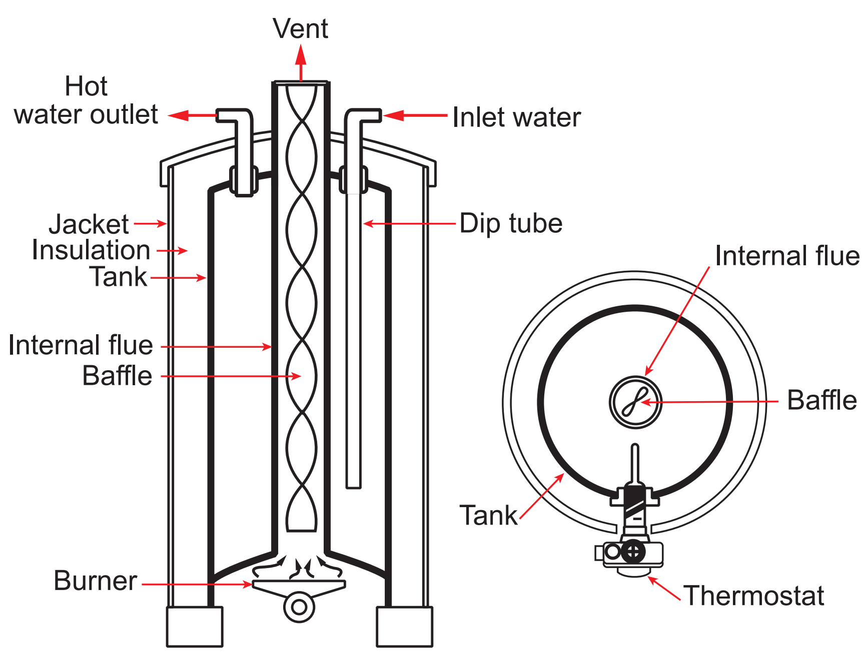
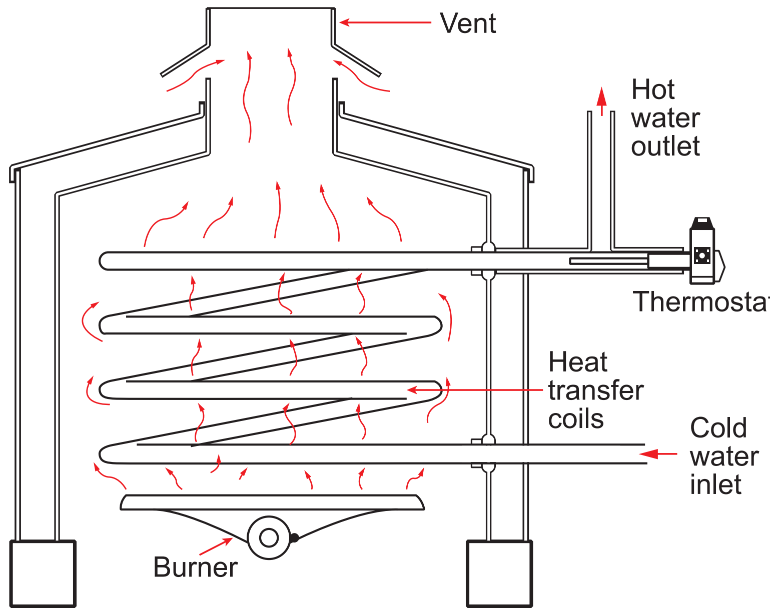


Figure 8 shows a direct-fired heater that does not require a storage tank. This type is known as an **instantaneous water heater** because the water is heated instantaneously as it flows through the tubes. In some applications, the water tubes may be located directly in a boiler to conserve energy.

Figure 8 – Instantaneous Water Heater



Since instantaneous water heaters are used wherever there is a continuous demand for hot water, a circulating pump should be installed at the heater inlet. A thermostatically controlled **mixing valve** should also be used on the hot water outlet. This valve will maintain a safe temperature at the water fixtures to prevent the scalding of anyone using the hot water. The mixing valve reduces the outlet water temperature by mixing recirculating or cold water with the hot water from the heater.

A thermostat is used to control the burner output as water flow increases.

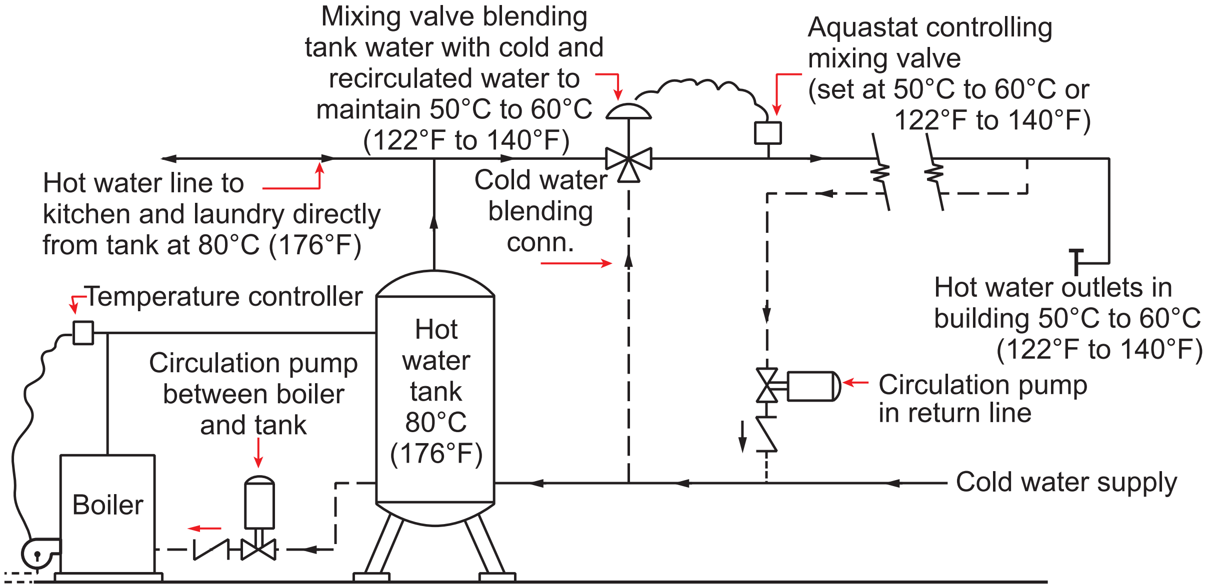
Figure 9 shows a similar hot water heater, connected by piping to a hot water storage tank. This water heating system is adaptable to buildings that require hot water at two different temperatures.

Water, at approximately 80°C, flows from the storage tank directly to a kitchen and laundry, where hot water is required at the higher temperature for sterilization. A three-way mixing valve blends the hot water at 80°C with cooler water from the return and cold water to create supply water between 50°C and 60°C to other fixtures in the building.

A thermostatic controlling device, commonly called an **aqua-stat**, regulates the ratio of the two flows at the mixing valve. The aqua-stat maintains the proper hot water temperature. Another temperature controller regulates the fuel and air supply to the heater. This controller maintains the hot water from the heater at approximately 80°C.

A circulation pump is located at the heater inlet. This pump maintains positive water circulation.

Figure 9 – Hot Water System with Mixing Valve



Indirect Hot Water Heaters

Indirect hot water heaters (the storage or instantaneous type) are heated by steam or high temperature water from a heating system.

Figure 10 shows an indirect heater with a storage tank around the heating coils. Water is heated by means of steam flowing through the tubes. The flow of steam is regulated by a thermostatically controlled valve. This valve increases the steam flow when the water temperature drops below the desired value. As the steam leaves the tubes, its heat transfers to the water, and the steam condenses. A steam trap removes the condensate from the heater.

Figure 10 – Indirect Heater with Storage Tank

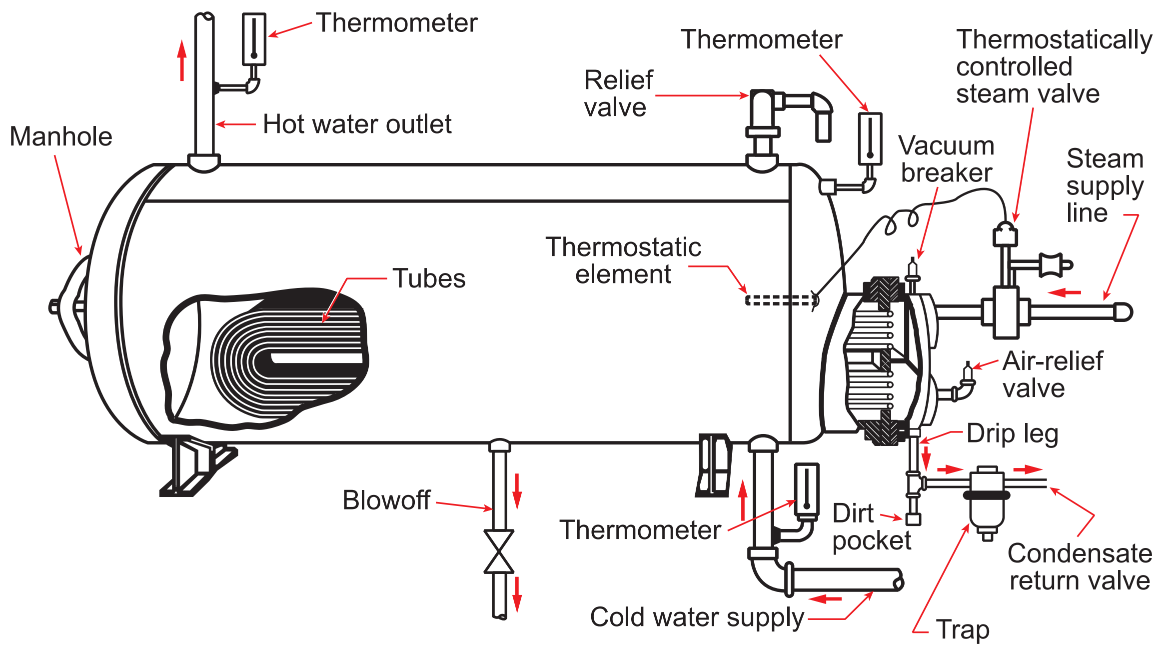
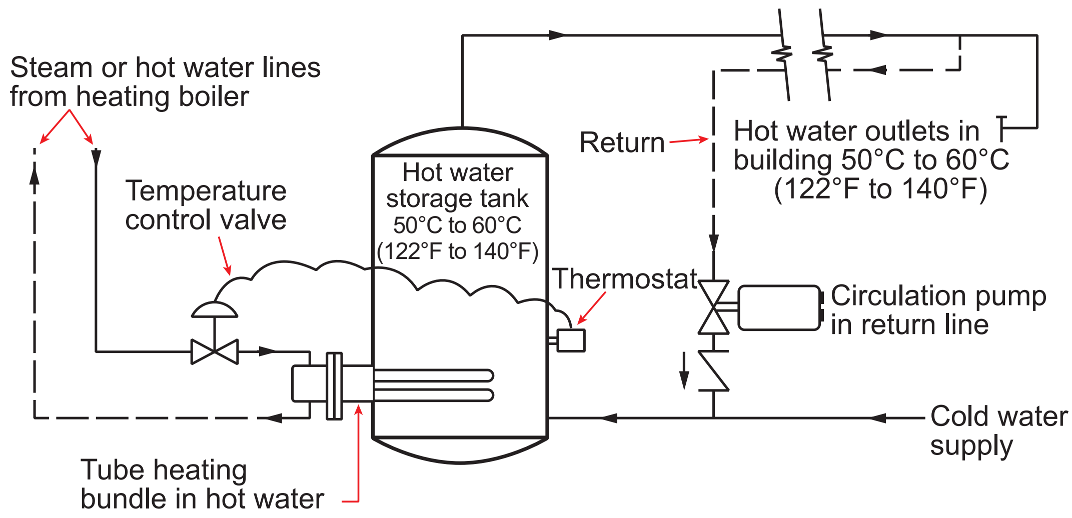


Figure 11 illustrates the general layout of a system using an indirect heater. This system could be applied in the building system shown in Figure 6.

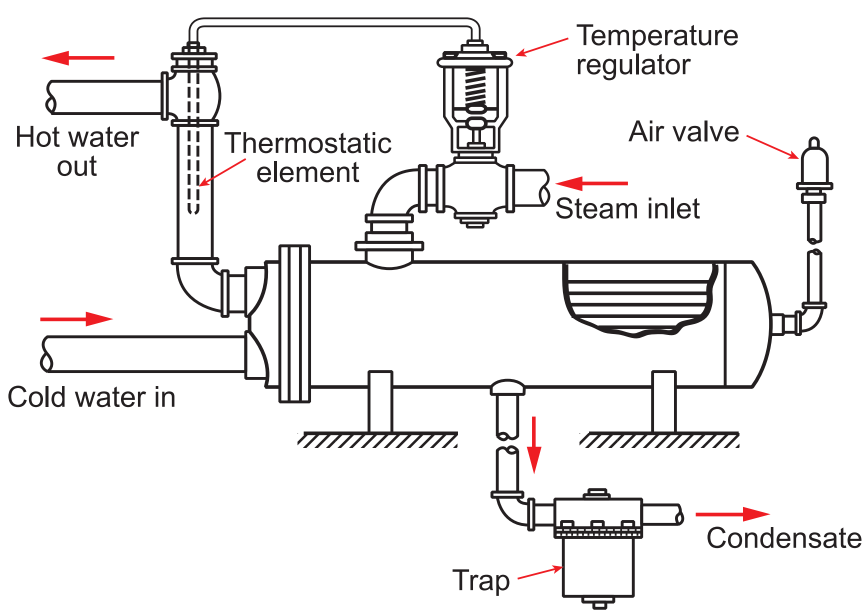
Figure 11 – Indirectly Heated Hot Water System



Temperature and Pressure (T&P) relief valves are installed on the uppermost part of heaters. These relief valves release the water pressure if the temperature of the water becomes too high due to a malfunction of the control system.

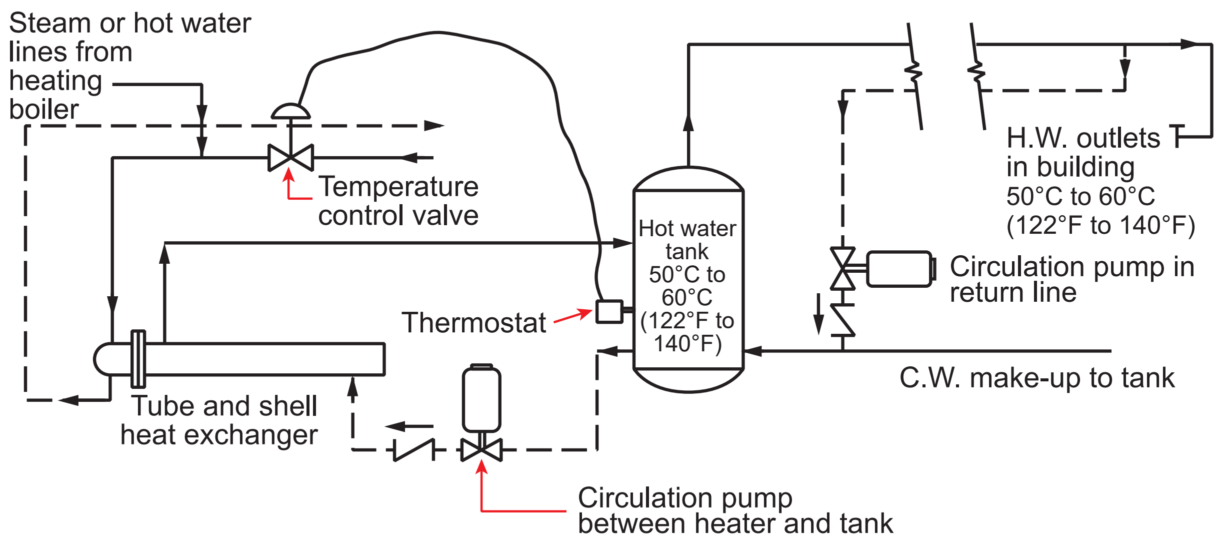
An instantaneous indirect heater, which uses steam to heat the water, is shown in Figure 12. This type has water flowing through tubes surrounded by steam in the tank. The steam flow to the heater is controlled by a thermostatically controlled regulating valve.

Figure 12 – Instantaneous Indirect Heater



Some instantaneous indirect heaters in larger buildings may be connected to a storage tank as shown in Figure 13. A circulation pump is installed between the heater and the storage tank to maintain a positive flow in the proper direction. The flow of steam or hot water to the heat exchanger is controlled by a thermostat and control valve.

Figure 13 – Indirect Instantaneous Heater with Storage Tank



Temperature Regulation

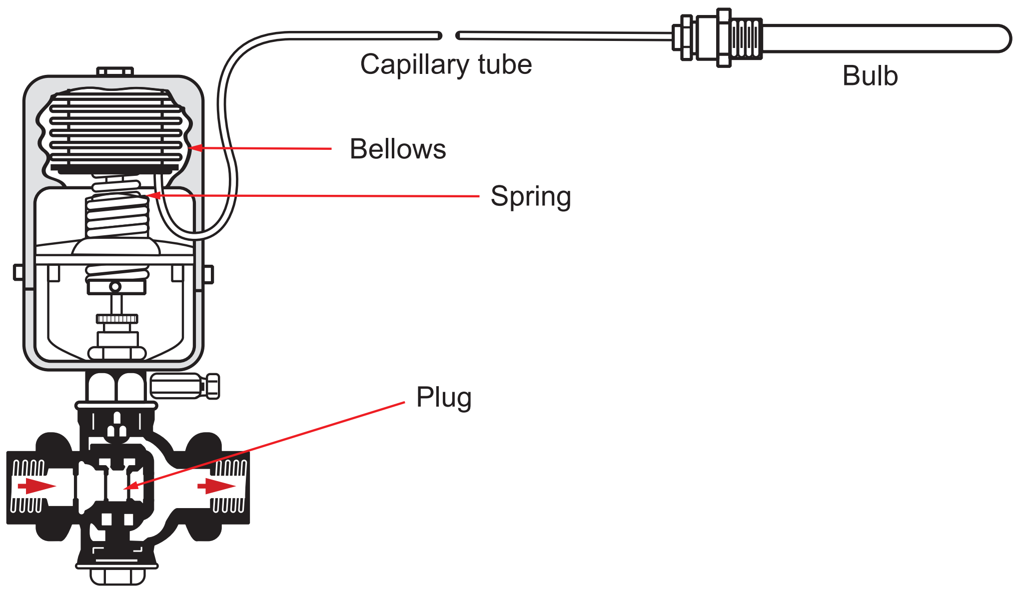
A typical self-operating temperature regulator is illustrated in Figure 14. It consists of a bulb, capillary, and a valve actuating bellows that are filled with a **volatile fluid** (a fluid that readily expands on the application of heat). The bulb can be immersed directly into the hot water tank or into a **thermowell** screwed into a heater. Use of a thermowell permits removal of the bulb without draining the heater.

When the bulb senses changes in hot water temperature, the volatile fluid will either expand or contract. This causes an increase or decrease in pressure in the control system. The bellows will expand or contract to reposition the valve plug and change the heat input to the heater.

With the valve plug in the position shown in Figure 14, the valve is closed, and no steam is permitted to enter the heating coil. This condition occurs only when there is no demand for hot water and the water temperature is at the desired setpoint.

When the bulb senses a decrease in hot water temperature, the pressure of the volatile fluid in the control system also decreases. The decrease causes the upward force of the valve spring to compress the bellows. This pulls the valve plug off the seat to allow more steam or hot water to flow into the heater.

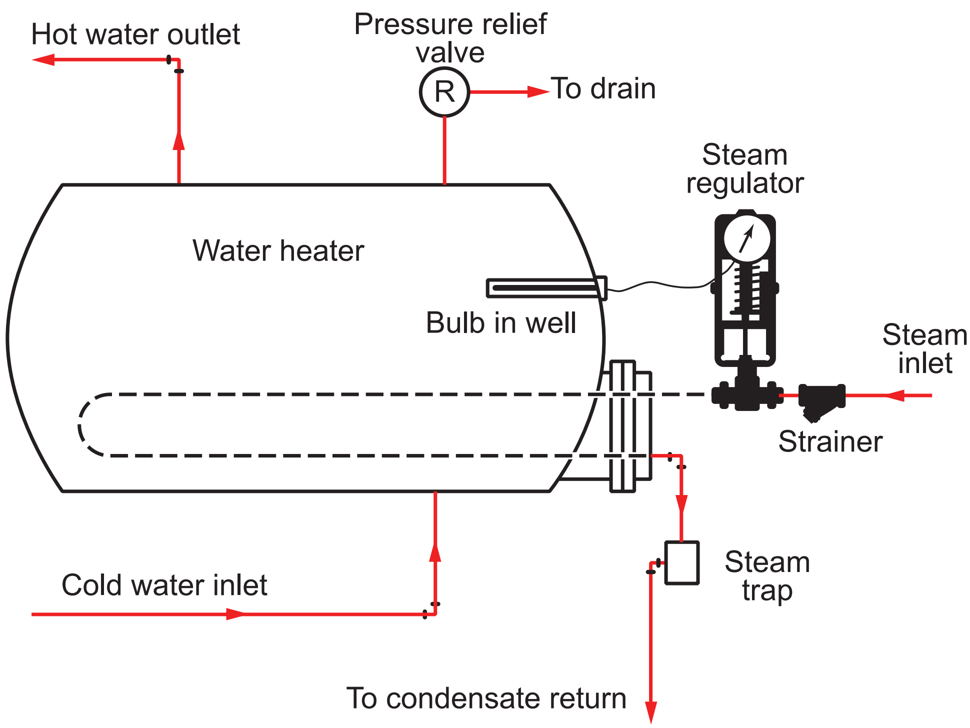
Figure 14 – Self-Powered Temperature Regulation Valve



During normal operation, the valve will always be partially open to maintain sufficient steam flow to heat the water. At peak demand for hot water, the valve will be nearly fully open. Increasing the compression of the spring increases the regulated temperature.

Another common installation is shown in Figure 15. This regulator will keep the hot water at an almost constant temperature. Note that the steam line contains a strainer and the condensate line has a steam trap. Both must be maintained in good working order for correct operation of the heater.

Figure 15 – Heater Temperature Control System



Objective 4

List and describe the construction and operation of water system protective devices in buildings.

Protection Devices

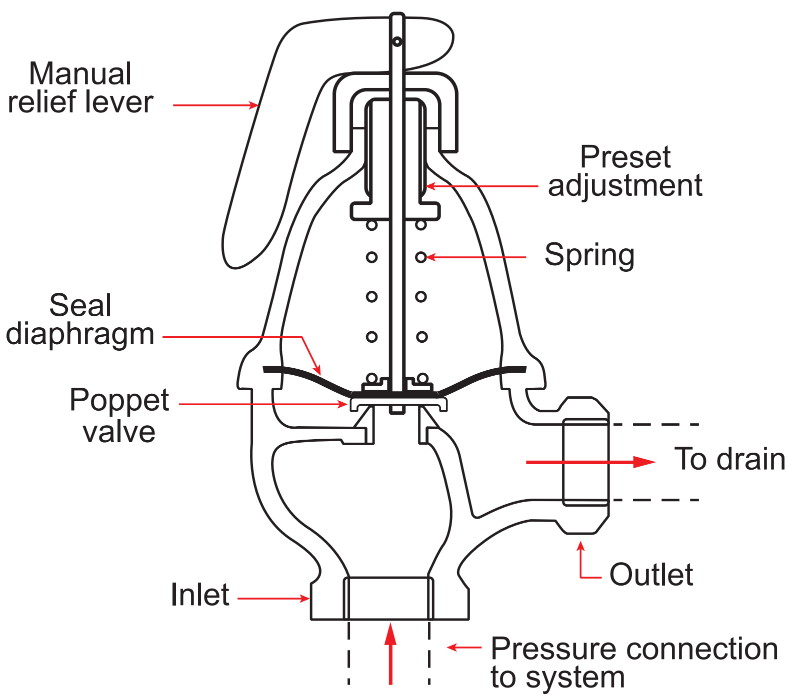
Hot water systems must be provided with safety devices. The safety devices prevent dangerously high pressures and temperatures from developing in the system.

Pressure Relief Valve

When water is heated, it expands and causes an increase in system pressure. If the hot water is able to expand back into the cold water supply pipe, the pressure increase will be relieved. However, if a check valve or a pressure-reducing valve is installed in the cold water supply line, the hot water will not be able to expand and dangerously high pressures could occur. This may result in the bursting of pipes, storage tanks, or other system components. This hazardous condition can be prevented by the installation of a pressure relief valve.

A pressure relief valve (Figure 16), suitable for installation in a hot water system, consists of a poppet valve held down upon its seat by a spring preset to give the required opening pressure (usually about 175 kPa (25 psi) above normal line pressure). If the hot water pressure builds up to the preset pressure, the valve opens, and allows water to escape to relieve the pressure build-up. When the pressure drops below the preset pressure, the valve closes again.

Figure 16 – Pressure Relief Valve



The pressure relief valve may be installed anywhere in the hot water system, reasonably close to the heater or tank. Frequently, the relief valve is installed in the hot water discharge line. There must not be any valve (shut-off, check, or any other type) installed between the relief valve and the heater or tank.

The drain or drip line from the relief valve should be piped to some point over a fixture or floor drain, and kept above the top rim of such a fixture. It must never be connected directly to any drain or vent pipe.

Frequent opening or spilling of the relief valve may be due to any of the following causes.

a) Scale has accumulated on the valve seat and the valve cannot close tightly. If the water is hard, then scale will form if the temperature of the heater goes above 65°C (150°F).

b) Pressure in the supply line varies and at times exceeds the setting of the valve.

c) The relief valve is defective or designed for the wrong pressure range.

If the relief valve does open frequently, then the cause must be found and remedied.

Temperature Relief Device

Pressure relief valves, by themselves, cannot adequately protect potable hot water systems from over-pressurization. If water is heated to above 100°C in a pressurized system (such as a potable water system), it will become a super-saturated liquid. If the water pressure is reduced, the super-saturated water will flash into steam. This steam may burn individuals operating faucets or cause devastating hot water tank explosions, even if a small tank leak should occur.

The formation of high temperatures in the system can be prevented by automatic control of the heat source. However, there is always the possibility of the control apparatus failing to function properly. Therefore, all hot water systems should be equipped with a suitable temperature relief device.

The temperature relief device protects the system from dangerously high water temperatures. These devices open when the water temperature rises to about 99°C. This allows hot water to escape from the system and cold water from the supply to enter. This reduces the water temperature.

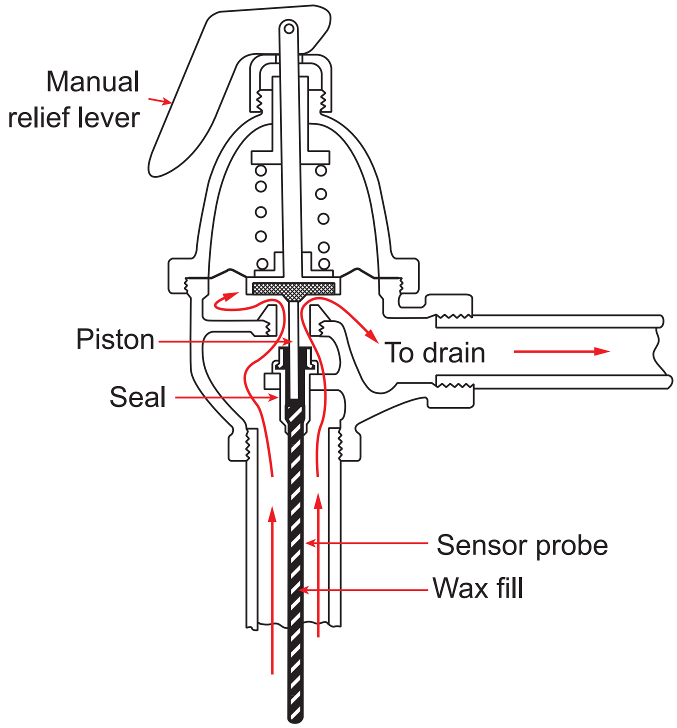
Various types of temperature relief devices are used. On rare occasions, a fusible plug, made of material which melts at 99°C, is used to allow the hot water to escape when the maximum safe temperature is reached. The fusible plug is often an unsatisfactory method because the water continues to flow until a new plug is installed.

Figure 17 illustrates a combination pressure and temperature relief valve. The valve will open when either the maximum allowable working pressure or temperature is exceeded. If the pressure in the system exceeds the maximum allowable working level, the valve plug will be forced off its seat. If the pressure remains normal, but the water temperature rises to 99°C, the wax filled sensor probe expands and opens the valve by means of the piston. When the pressure and/or temperature decreases, the valve closes and normal operation resumes.

If the water in the system is quite hard, scale deposits will form; these may either cause the valve to leak or to be stuck in the closed position. To avoid these conditions, the manual relief lever should be used to periodically open the valve to break loose any scale deposits before they build up.

Pressure relief valves may be located anywhere in the system. However, the temperature relief device and the combination pressure-temperature relief device must be located at the point of maximum water temperature, which is usually at the top of the storage tank or in the hot water outlet from the tank.

Figure 17 – Combination Pressure Temperature Relief Valve



CAUTION

Never plug off the outlet of a pressure relief valve or a temperature and pressure relief valve! This could result in a catastrophic explosion!

If a safety valve or a temperature and pressure relief valve is weeping, it should be replaced with a new valve. The new valve must have the setpoint and capacity recommended by the hot water heater manufacturer.

Storage Tank Drain

If the hot water system includes a hot water storage tank, it will be equipped with a drain valve at the bottom. In order to remove excess scale deposits from the tank, two or three pails of water should be drained out through the drain valve every two or three months.

High Limit Energy Cut-Off

The high limit energy cut-off is a thermostat that shuts off the heat to the water heater when the maximum temperature has been reached.

Objective 5

Explain what is meant by "backflow prevention" and describe the common methods used.

Backflow Prevention

Backflow can be defined as a backwards flow of water (or other liquid, gas, mixture, or other substance) into the distributing pipes of a potable water supply from any source. Either of the situations below may cause backflow.

a) **Back syphonage** (backflow caused by pressure that is below atmospheric in the supply system).

b) **Back pressure** which results from a downstream pressure in the piping system that is higher than the upstream or supply pressure.

A **cross connection** is any actual or potential connection between the potable water supply and any other source or system through which it is possible to introduce contaminants into the potable water system. These contaminants may include used water, industrial fluid, gas, or substances other than potable water. Any temporary or permanent device through which a backflow can or may occur is considered to be a cross connection.

There are five different methods employed to prevent backflow.

a) Air Gap Backflow Prevention

b) Reduced Pressure Principle Device (RPZ)

c) Double Check Valve Device (DCVA)

d) Pressure Vacuum Breaker (PVB)

e) Atmospheric Vacuum Breaker (AVB)

The type used is determined by whether there is back pressure or negative water supply pressure, and by the degree of hazard presented.

Air Gap Backflow Prevention

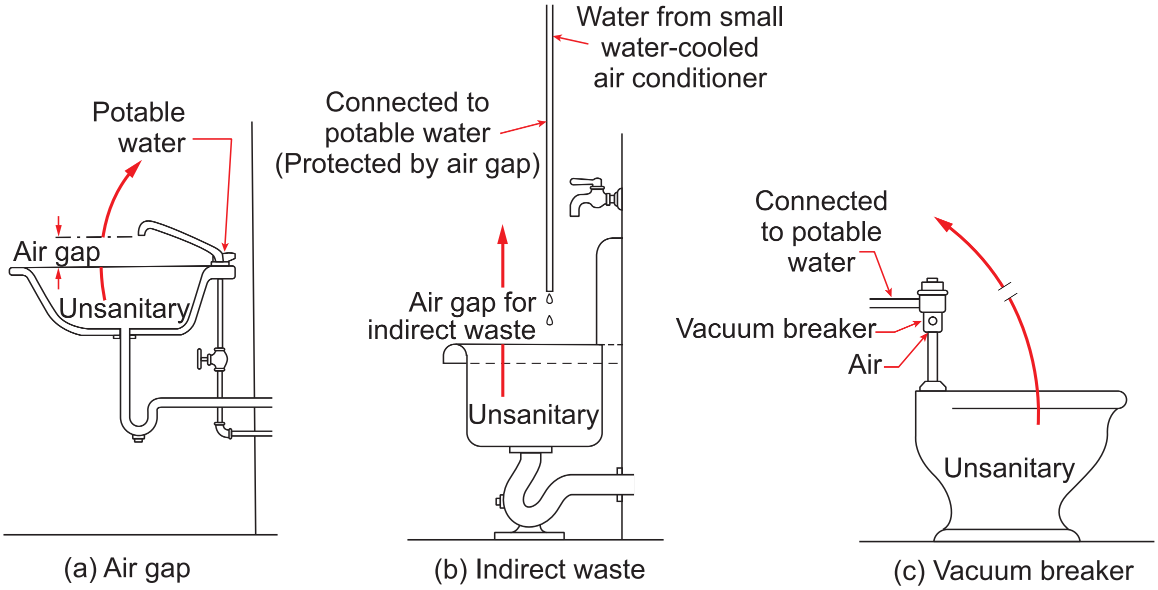
An **air gap** is a physical separation between the free flowing discharge end of a potable water pipe and an open, non-pressurized vessel (such as a sink).

Every plumbing fixture in a building receives pure water and usually discharges it at some lower point. These two points are often close to each other. It is therefore possible for unsanitary water, which is intended for the drain, to be syphoned accidentally into a pipe carrying pure water.

Figure 18(a) and 18(b) show an air gap between supply and drain. The air gap prevents unsanitary water from being syphoned back into a pipe when the system is shut down and opened for repairs.

In the **flushometer** of Figure 18(c), fresh water enters the bowl from below the rim, which is an unsanitary area. To prevent even a small amount of waste flowing back, a **vacuum breaker** is placed immediately below the **flush valve**. The valve is closed by water pressure, but opens to allow entry of air if there is a partial vacuum in the water pipe. This process eliminates syphoning in a similar way that a vent prevents syphoning in a trap.

Figure 18 – Air Gap Backflow Prevention



Reduced Pressure Principle Device (RPZ)

A **reduced pressure device** (also known as an RPZ) consists of two independently acting check valves with an automatic operating pressure differential relief valve located between them. The pressure between the two check valves is kept lower than the supply pressure by the first check valve. If for any reason either check valve leaks, the relief valve will discharge to atmosphere, and will maintain the pressure in the area between the two check valves at lower than the supply pressure.

Double Check Valve Device (DCVA)

Double check valve devices are backflow preventers consisting of two independently acting check valves. The check valves close if the water pressure upstream of the device is less than the pressure downstream.

Pressure Vacuum Breaker (PVB)

Pressure vacuum breakers consist of a single body which contains a spring loaded check valve. The valve opens to admit air whenever the pressure within the body approaches atmospheric pressure.

Atmospheric Vacuum Breaker (AVB)

Atmospheric vacuum breakers have a moving element inside that prevents water from spilling from the device during flow. If the flow should stop, the device drops down to provide a vent opening.

The **CSA Code "B64 Series Backflow Preventers and Vacuum Breakers"** requires most types of backflow preventers to be tested on installation and annually thereafter. Local jurisdictions require certified individuals to install, test, maintain, and replace backflow preventers.

Objective 6

Describe the maintenance requirements for the components in a building water distribution system.

Routine Maintenance

The following discussion is not intended to cover all aspects of the routine maintenance of water distribution system components. The procedures and recommendations provided by the equipment manufacturers must always be followed.

Storage Heater Maintenance

A blowoff connection is provided so that all sediment carried to the heater through the water line may be removed. This can be done while the heater is in service by opening the blowoff valve. Bottom blowoff should be done at least once a month to prevent sediment from building up in the bottom of the heater.

To allow for inspection and maintenance, larger storage heaters are fitted with manholes. Once each year, a heater should be drained, cleaned, and inspected. If corrosion is apparent in the shell, the interior should be painted with a rust preventative. In some installations, permanent protection is assured by lining the shell with cement. The purpose of any type of treatment is to guarantee a supply of clear hot water and to prolong heater life.

CAUTION

Large hot water storage tanks and heaters are confined spaces. They have difficult access and egress, and are not designed for human habitation. Hazards may include hot surfaces, asphyxiation, and drowning. A confined space entry permit must be obtained. All confined space procedures must be followed prior to entering a hot water storage tank. As part of the confined space entry, lockout and tagout procedures must be followed.

The **CSA B51** code permits hot water storage tanks and hot water heaters to be designed in accordance with **ASME IV** or **ASME VIII**.

ASME IV requires water heaters to have officially rated temperature and pressure relief valves or at least one officially rated safety relief valve. The pressure setting shall be less than or equal to the maximum allowable working pressure of the water heater. These valves must be in good working order.

Other fittings usually include a pressure gauge which serves as a check against the relief valve setting, and a thermometer to indicate the temperature of the exiting water. Sometimes a recording device is installed so that temperatures are permanently recorded.

On the steam portion of the heater, the fittings include the temperature regulator, steam trap, air vent, vacuum breaker, and strainers. If these fittings are checked regularly, the heater should operate as designed. Maximum heat transfer from steam to water requires that the trap correctly discharges condensate from the heating element. When condensate is not promptly removed, water hammer could occur, and possibly damage the heater tubes.

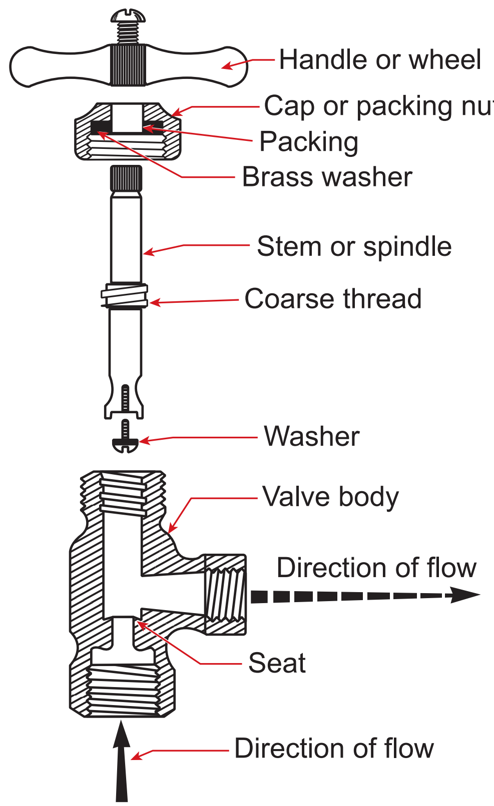
Maintenance should also include checking and patching the insulation on the heater, steam lines, and hot water lines. Otherwise, heat can be lost via radiation.

Repair of Valves and Faucets

Water faucets and valves both serve to control the flow of water. Faucets are used at discharge points over plumbing fixtures, such as sinks, lavatories, and tubs. Valves are used to isolate portions of the plumbing system.

Since faucets and globe valves are very similar in construction, maintenance information applies to both. Faucets or valves may differ somewhat in general design from the valve shown in Figure 19, as both come in a wide variety of styles.

Figure 19 – Globe-Type Angle Valve



Mixing faucets (found on sinks, laundry trays, and bathtubs) are actually two separate valves with a common spout. Each unit is repaired independently.

Almost all faucet leaks are caused by failure to turn the faucet completely off after being used. Eventually, the rubber washer inside the faucet wears out and a leak results.

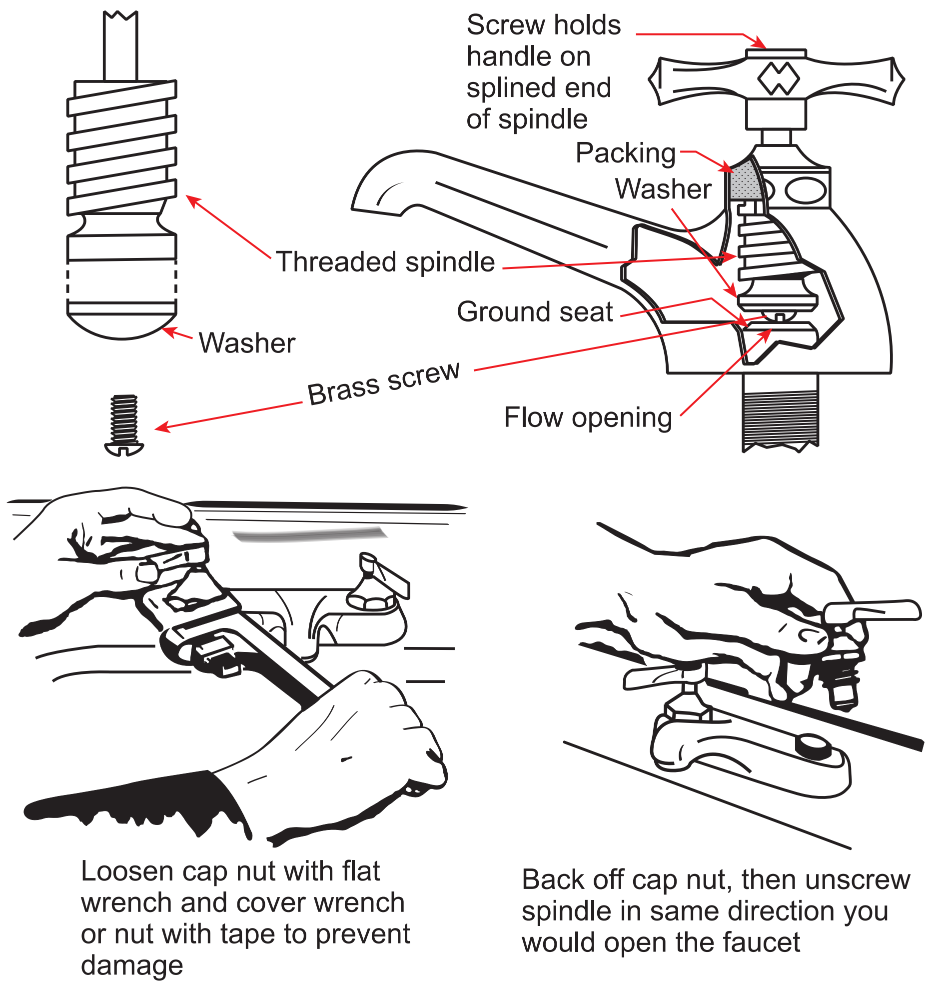
If a faucet drips when closed, or vibrates ("sings" or "flutters") when opened, the trouble is usually a worn washer at the lower end of the spindle. If the faucet leaks around the spindle when opened, new packing is needed.

To replace a washer:

1. Shut off the supply of water at the nearest isolation valve.
2. Unscrew the packing nut and remove the spindle.
3. Remove the washer from the end of the spindle and replace with a new one of the same size.
4. If the valve seat appears to be smooth and serviceable, replace the spindle and tighten the packing nut.

If a faucet leaks for an extended period of time, the faucet seat is likely to be rough. Some faucets have renewable seats with a square opening in the centre into which a seat removal tool may be inserted. If the opening in the seat is round, it is not replaceable and must be refaced. (This procedure requires a special tool and will not be discussed here.)

Figure 20 – Removing a Faucet Valve



Packing in the faucet prevents water from leaking around the stem. Simply tightening the packing nut will stop the leakage in many faucets. However, if a leak persists and the packing appears to be worn and hard, it should be replaced. If packing for a specific valve cannot be obtained, valve stem packing made of cotton, saturated with graphite, can be used. After removing the packing nut, wrap new packing tightly around the stem and re-insert the packing nut. Some newer faucets do not use packing, but instead use a rubber O-ring installed on the spindle.

Other faucet parts may be replaced as necessary.

Complete faucet inserts, in which the washer does not turn on the seat, are available. This feature prolongs washer life indefinitely.

Several new washerless faucet designs aimed at easier operation are now commonplace. They eliminate drip and promote long service life. Repair instructions are available for download from manufacturer websites. Repair kits may be obtained from local dealers.

The following are helpful hints for faucet repairs:

a) Most washrooms will have the same brand and type of faucet throughout. Obtain complete information on that brand from the suppliers.

b) Do not skimp on the quality of repair tools or replacement parts.

c) Never use excessive force when disassembling or reassembling a faucet. Protect chrome parts from tool damage.

d) Keep aerators and screens clean and re-clean them after repair is completed. (These are located on the end of the spout.)

e) When replacing faucet "O" rings or washers, use only the material, size, and type recommended by the manufacturer.

f) Always check the faucet seat before installing a new washer. If not perfectly smooth, reface it or replace it.

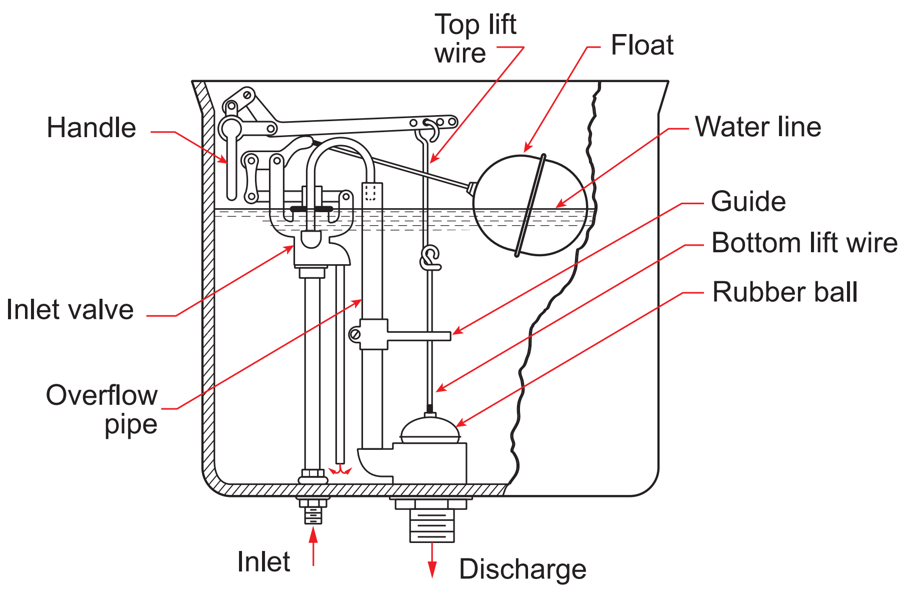
Toilets

A toilet flush tank, shown in Figure 21, operates by means of two valves.

A float-controlled valve (typically a **ball cock**) admits water to the tank. When the float rises, the valve shuts off. On some types, an adjusting screw controls float height to adjust the water level in the tank.

The discharge valve (flush valve) consists of a rubber or plastic flush ball and seat.

Figure 21 – Water Closet Flush Tank



The float-controlled valve may persistently leak and maintain water level at the top of the overflow pipe. Any one of the following may cause this to happen.

a) The float arm rubs against the side of the tank.
b) The float has a small leak, which allows water to enter and "sink" the float sufficiently to partly open the valve.
c) The float rod requires adjustment, so the valve will close when water is at the correct level.
d) The valve washer may be damaged and require replacement,
e) The valve seat may be damaged that the valve cannot be positive shut-off.
f) Sand, grit, or other foreign material may be holding the valve open.

Operation of a ball cock or inlet valve can be checked by raising the float arm to its maximum height. If water still escapes, the ball cock is leaking. The most common fault is a bad washer, which must be replaced. Some ball cocks have **vitreous china** seats to resist the corrosive action of water, giving long life and quiet action. Other ball cocks have metal seats that are easily refaced to remove small imperfections. In large buildings, it is often easier to replace the entire leaking ball cock valve and take it to a maintenance room for repair at a more convenient time.

The float rod should be adjusted so it will close the inlet valve and shut off the water about one inch from the top of the overflow pipe. The float must not contact the sides or the end of the tank.

The filler tube on the ball cock is often called the "**hush tube**." It extends almost to the bottom of the tank and reduces noise by preventing splashing. The "**refill tube**" which extends from the ball cock to the overflow reseals the bowl trap after flushing.

To prevent cross connection, adjust the float rod so the water level does not come above the ball cock. Some newer and better type ball cocks are made with vacuum breakers or back flow preventers.

Older style bowls use 11 to 15 litres of water flush. Many municipal codes now require new installation to be a maximum of 6 litres per flush.

Water may leak from the flush valve for any of the following reasons:

a) The ball could be defective. Often, after long use, the ball can become soft and lose its shape, so it will not seat properly. The bottom lift wire must be turned out of the ball and the ball replaced.
b) There might be dirt on the ball or the seat. Both should be wiped clean of all dirt, rust or other foreign material with a clean cloth.
c) The lift wires could be improperly adjusted. To allow the ball to drop directly into the seat, it may be necessary to adjust the bottom lift wire. Adjust the length of the top lift wire, so there is some slack in the lift wires when the ball is seated.
d) The flush ball might not be seating properly.
e) The flush seat might be corroded or worn.

If alignment and action are correct, remove the flush ball and clean it. Dry the flush valve seat and clean it. Tank balls or flush balls should be replaced every few years, or when badly worn or out of shape. When flush valve seats are badly corroded, replace the seat and overflow.

Objectionable condensation may form on a toilet tank. One of the following may help to solve the problem.

a) Attach a tray under the tank.
b) Install a tank with an inner liner.

Flush Valves (Flushometers)

A flush valve is primarily used to flush toilets and urinals in public and institutional buildings. It provides a means of opening the water supply line to the fixture and permitting a predetermined volume of water to be discharged. The volume of water must be sufficient to cleanse and flush the fixture properly during each operation.

The flush valve is a metering device which, once actuated, will complete its cycle, and shut off automatically. Older flush valves discharge approximately 13.7 L of water in ten seconds. This figure varies with different pressures. To effect a proper flush in a toilet or similar fixture, a sufficient volume of water must be discharged in the shortest time possible. Under new municipal codes, flush volumes have been reduced to between 3.8 L and 6 L.

Flush valves have been in use for over 100 years and the principle of operation has changed very little.

There are two basic types of flush valves:

- Diaphragm
- Piston

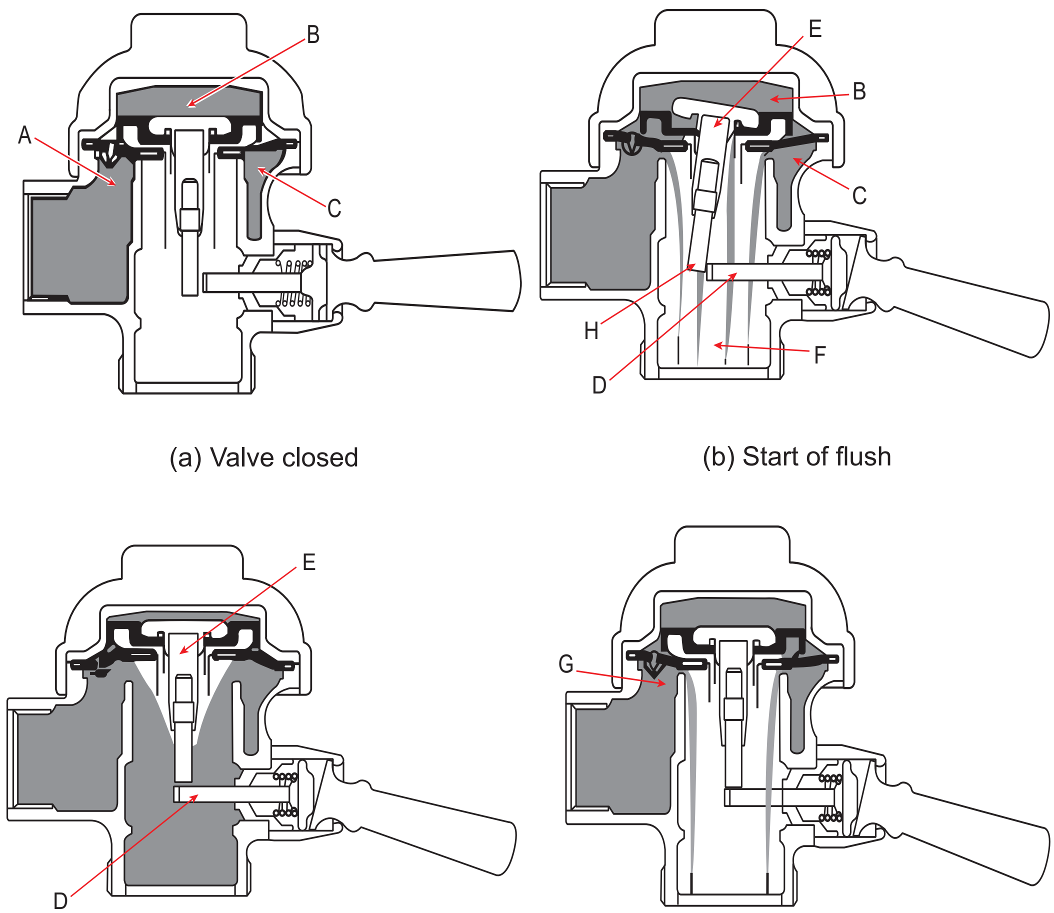
Since two pressure chambers are used in a flush valve, the two different types simply refer to the method used to separate the two pressure chambers. The diaphragm type was in use first. The piston type was developed because of frequently ruptured diaphragms. However, this problem has been solved with the use of synthetic diaphragm materials, such as neoprene.

A flush valve installation differs from a flush tank installation in that water under line pressure flows into the fixture. In a flush tank, the water is first accumulated in the tank and then flows into the fixture due to gravity alone.

Figure 22(a) illustrates a typical flush valve in the closed position. The diaphragm (A) divides the valve into two chambers, the upper (B) and the lower (C), with equal water pressures on both sides of the diaphragm. The greater area exposed to pressure on the top of the diaphragm holds the relief valve closed.

Figure 22(b) illustrates the beginning of the flush operation. When the handle is moved in any direction, the plunger (D) contacts the relief valve stem (H), tilts the relief valve (E), and relieves the pressure in the upper chamber (B). This action allows the pressure in the lower chamber (C), which is now greater, to raise the main operating unit. The water from the supply pipe can now flow through the valve outlet (F) to the fixture to be flushed.

Figure 22 – Flush Valve



(a) Valve closed

(b) Start of flush

(c) Valve fully opened

(d) Valve closing

Referring to Figure 22(c), the operating unit is fully raised, which allows maximum flow of water to the fixture. The relief valve (E) closes when the end of the relief valve stem has risen above the plunger (D).

Figure 22(d) illustrates the closing operation of the valve. After the operating unit has reached its maximum travel and the relief valve has closed, the pressure in the upper chamber is again increased by a slow flow of water through the by-pass opening (G). As the pressure in the upper chamber slowly builds up, the operating unit is forced downward. When the pressure in the upper chamber has again equalized with the pressure in the lower chamber, the diaphragm returns to its seat and closes the valve.

The relief valve is designed to allow the stem (H) to telescope within the relief valve unit and allow the valve to close even if the handle is held in the operating position. When the operating handle is released, the telescoping stem (H) drops down to its normal operating position.

The following troubleshooting guide lists the problems that can occur with flush valves, the possible causes, and the suggested methods of correcting them.

Table 1 – Troubleshooting Guide

Trouble		Possible Causes		Corrective Action
Valve will not flush at all	1.	The water supply valve is shut.	1.	Open the supply valve.
	2.	The valve needs new parts.	2.	Examine and replace worn parts, such as the diaphragm, plunger, or handle.
	3.	Water pressure or volume is insufficient.	3.	Increase pressure or volume by ensuring the supply valve is completely open.
Valve gives too long a flush	1.	The valve needs regulation.	1.	Shorten the flush by regulation (if valve is an adjustable type). For other valves, refer to the manufacturer's instructions.
	2.	The bypass orifice is partially blocked.	2.	Clean out the bypass orifice.
Valve gives too short a flush	1.	The valve needs regulation.	1.	Lengthen the flush by regulation (if valve is an adjustable type). For other valves, refer to the manufacturer's instructions.
	2.	The valve contains an oversized bypass orifice.	2.	Clean out the bypass orifice.
	3.	The diaphragm is damaged.	3.	Replace the diaphragm.
Valve continues to run	1.	The bypass orifice is blocked	1.	Clean out the bypass orifice.
	2.	A foreign object is resting on the auxiliary valve seat or the main valve seat.	2.	Remove foreign objects from the seat. Check adjacent parts to make sure no scoring or pitting has occurred in the interim.
	3.	Wearing or pitting has occurred on the auxiliary valve seat or the main valve seat.	3.	Replace auxiliary valve seat washer or main valve seat (unless the seat is cast integrally, in which case nothing can be done).
Valve will not pass enough water to satisfactorily siphon the bowl.	1.	The water supply valve is not completely open.	1.	Open the water supply valve fully.
	2.	Insufficient volume of water is being supplied to the valve due to low pressure or undersized piping, or both.	2.	Conclusively establish the volume of water available by removing the internal assembly from the flush valve, replacing the cover, and flushing the valve. This converts the valve into a simple elbow. If an adequate flush cannot be obtained under this condition, water pressure or pipe sizes, or both, must be increased.

Clearing Stoppages in Toilet Bowls

A toilet bowl should never become clogged, unless it is misused. Modern toilets drain on a simple syphon principle. However, should a toilet bowl become stopped up so that it drains very slowly or overflows, it is usually possible to remove the obstruction by one of the following methods.

CAUTION

When trying to unclog a toilet, wear safety glasses or face shield and protective elbow length gloves to protect against biological hazards.

a) Try to manually remove any foreign material through the bowl itself.

b) If unsuccessful, try flushing the bowl several times. Perhaps the obstruction can be washed through to the sewer. If an object such as a cake of soap is lodged in the trap, it may soften enough to wash through if left to soak for a period of time.

c) If the bowl is still clogged, the next step is to use a force cup or plunger. This device consists of a bell-shaped rubber cup fastened to a wooden handle. To use it, partly fill the bowl with water, place the cup over the drain opening and work the handle up and down several times, using quick, forcible strokes. The resulting compression and suction is sufficient to clear most stoppages.

d) A stiff wire forced into the opening often works where a force cup fails. Extreme care must be taken not to scratch the glazed surface of the fixture.

e) A flexible **water closet auger** (or toilet auger) may be used to clean traps. Insert the auger in the fixture and turn its handle. This rotates a hook that grabs onto obstructions in the same way a corkscrew operates. Withdraw the auger and the attached obstruction.

f) Chemical solutions can be used to clear stoppages; however, their use is not recommended. These chemicals are usually very strong and must be used with extreme caution. If the chemical does not unclog the toilet, then the toilet may need to be removed and manually cleaned. In this case, residual chemicals can cause injury unless neutralized before removing the toilet. If chemicals must be used, the specific instructions on the container must be followed. Water must be allowed to flow through the drain for a considerable length of time to flush out any remaining traces of the chemical.

CAUTION

When using chemicals to unclog a toilet:

- Consult the manufacturer's MSDS
- Follow the chemical manufacturer's procedures, and
- Use all required PPE.

Noises In Plumbing Systems

Plumbing systems can make unusual noises that often cause undue concern. Some causes of noise and remedies for each are described here.

Faucet Noises

Faucet noises can be caused by a worn washer, which allows water to leak or drip. These noises can also be caused by a defective internal assembly, which results in “chattering” or “whistling.” Often a loose washer causes chattering by alternately stopping and then freeing the water supply when the faucet is not shut completely off.

The remedy is to disassemble the faucet and tighten the small screw holding the washer on the end of the spindle. If the washer is worn, replace it. Chattering and whistling can also occur in faucets due to poor design (a small, restricted waterway).

Water Hammer

This type of noise is a pounding or banging of pipes and shuddering of fixtures. It is caused by a shock wave that results when water flow in a pipe is suddenly stopped, perhaps by the rapid closing of a faucet. If allowed to continue, it can cause serious damage to a plumbing system, and can result in costly repairs.

However, other water hammer causes are very difficult to locate. If necessary, “**water hammer arrestors**” may be installed. These devices act as a cushion to absorb the excessive pressure caused in the system when a flow of water is suddenly stopped. Older systems may have short lengths of closed pipe installed to form air chambers which serve the same purpose. If the system already has these short lengths of pipe, it may be that the air has leaked out. In that case, the water system must be drained and the air chamber restored.

All exposed water pipes should be checked to ensure all lengths of pipe are securely fastened to joists or beams with a pipe strap, clamp, or hanger. Providing support for these pipes might also prevent noise caused by vibration.

Other Noises

The normal functioning of the plumbing system can cause other water system noises, one of which can be described as a “hissing” sound. Most of these noises are not usually objectionable. However, sometimes a ceiling or a wall can amplify the sounds to a level where they can become bothersome. Wrapping the pipes, or using sound-insulating material, will help if these “normal” noises are annoying.

Chapter Summary

In this chapter, a variety of potable water supply systems were identified and explained. These included upfeed and downfeed systems that may or may not have storage tanks.

Potable water heaters were described for direct-fired heating, indirect heating, and instantaneous heating methods. Recirculation systems for hot water were also covered.

The next objectives covered safety devices, their installation, and correct operation. These devices prevent scalding, pressure vessel failure, or potable water contamination. They include temperature limits, mixing valves, safety valves, and backflow preventers.

Finally, this chapter covered the maintenance required for hot water storage tanks, faucets, water closets, and flush valves. Emphasis was placed on how to minimize water consumption by identifying when flush valves do not function properly, and the steps to troubleshoot and repair them.

Ultimately, the safety of the building occupants is of greatest importance. Of secondary importance is to operate a facility with maximum energy efficiency. With the information in this chapter, a Power Engineer can identify and resolve inefficient or unsafe conditions pertaining to water distribution systems.

CHAPTER 3

Drainage Systems

LEARNING OUTCOME

When you complete this chapter you should be able to:

Describe the design and components of various drainage systems used in facilities.

LEARNING OBJECTIVES

Here is what you should be able to do when you complete each objective:

1. *Describe the overall layout of building drainage systems.*
2. *Describe storm water drainage systems for buildings.*
3. *Describe how surface runoff is managed in order to minimize environmental impact.*

Chapter Introduction

All Power Engineers must know what effluent leaves their facilities, and how these effluents are handled. From a basic facility operator standpoint, these effluents are soil, waste, and storm water. Facility operators need to know how to address operational problems such as plugged drains and dry traps. To do this, they need to understand the operating principles of these systems.

In addition, larger industrial facilities must manage surface runoff, in order to meet environmental regulations. The mismanagement of surface water has both financial and environmental costs. The Power Engineer must know the legal requirements and the correct procedures to follow so that hazardous materials are not released to the environment.

This chapter, then, addresses soil and waste, storm water, and surface water drainage systems and procedures.

Objective 1

Describe the overall layout of building drainage systems.

Drainage Systems

Water is used to move waste material in building piping. Waste flow, consisting of water and waste material, is conveyed downward in a building by gravity to a central disposal point. Pumps are used in locations where sewage must be "lifted" to a higher elevation.

Quite often, the terms "**soil**" and "**waste**" are used to describe the type of material conveyed in a pipe. Soil pipes carry waste liquids and solids, while waste pipes convey material from any building fixture other than a toilet.

Wastes from fixtures such as sinks are discharged through the drain into a trap located in the discharge pipe. The wastes then pass into a horizontal branch that leads to a vertical **waste stack**, in which they flow downward by gravity. The base of the stack becomes the building sanitary drain. Since most large buildings have several waste stacks, they are all connected to the building or house sewer leading to a municipal sewage system.

An adequate number of branch lines are provided on each floor of a building to remove the waste. Each branch line may serve several types of fixtures.

Horizontal Branch Piping

Horizontal branch piping is used to convey wastes from fixtures throughout a building to a waste or discharge stack. This piping must be designed so that flow will not be interrupted.

Each branch connection to the discharge stack should have a **long turn elbow** that meets the vertical stack at an angle of 45°. All horizontal piping should have an adequate slope and size to maintain a minimum flow velocity of 0.6 m/s. This ensures that the solids are always kept in suspension, and prevents pipe blockage.

All branch lines must be of sufficient size so that they are only partially filled with waste material and water. This precaution prevents the formation of a hydrostatic head (pressure) near the stack that could hinder the flow of waste from a fixture.

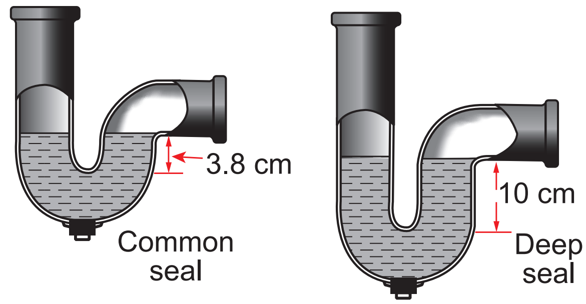
The slope or gradient of branch piping, expressed in millimetres per metre, depends on the size of horizontal piping. Piping 76 mm or less in diameter should have a minimum gradient of 21 mm/m toward the stack. Larger horizontal piping should be installed with a slope of not less than 11 mm/m.

All piping arrangements or designs in a building sanitary system must comply with the requirements of local regulations and building codes.

Traps

The purpose of a **trap** is to seal the outlet of a fixture from the drainage piping so that sewer gases do not enter the building. In toilets and some urinals, the trap is an integral part of the fixture. However, traps are installed externally in the discharge piping of other fixtures, such as sinks. When externally located, the trap should be within 610 mm of the fixture and should be accessible for cleaning. Figure 1 illustrates two trap seals of different depths.

Figure 1 – Traps



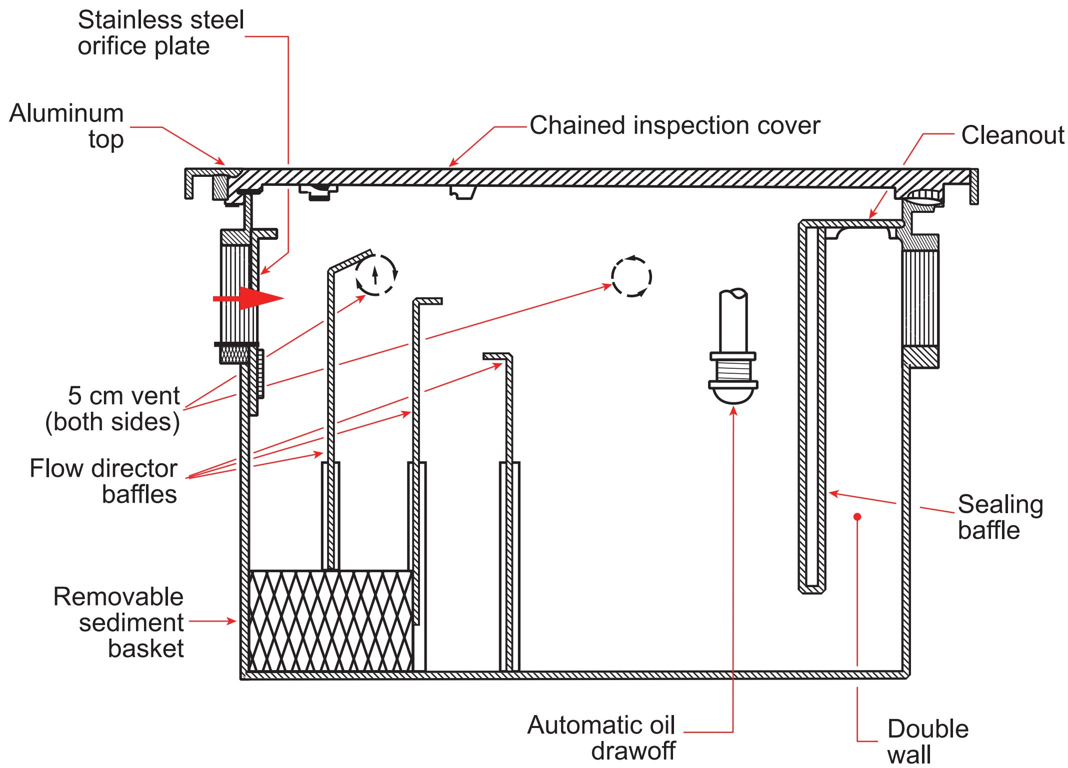
Traps should have enough water flowing through them so that the residual water is clean. Traps are available in depth from 3.8 cm to 10 cm. The normal movement of waste and soil in a stack can siphon or blow out the trap seal, unless the waste removal system is designed with adequate venting. Deeper traps provide greater resistance to siphoning, but are fouled or plugged more easily. A **cleanout** plug is usually located at the bottom of the trap to clean it out.

Traps are often installed at the end of a long length of horizontal piping before a floor drain. If fixtures are used infrequently, the water in the trap evaporates, allowing sewer gases to enter the building. Water must be added periodically to maintain a water seal. As an alternative, the trap may be sealed with trap oil, which will not evaporate. Floor drains in washrooms where floors are not washed regularly can often dry out. This condition is indicated by a sewer smell in the washroom. To remedy this problem, it is necessary to pour a pail of water down the drain to re-seal the trap.

When grease, oil or cooking fats are discharged as waste from fixtures, such as kitchen sinks, they must be removed before they cool and clog the drainage lines. To do this, the waste liquid first passes into a **grease trap** or **grease interceptor.**

Referring to Figure 2, wastes from a sink pass through a flow control device into a grease trap. The oil or grease mixture is deflected downward by the first flow director baffle, so that the mixture passes through the sediment basket. Oil and grease rise to the surface and are removed by the automatic oil draw off. A sealing baffle, extending below the oil level, traps the water in a separate compartment, so it can be withdrawn from the trap.

Figure 2 – Grease Trap or Interceptor



Grease traps require regular cleaning at frequent intervals. Failure to do so may permit fats, oil, and grease to enter the drainage system, where it congeals and creates blockage. Blocked sewer lines can and will cause costly damage to the facility, and may require several days of closure to clean and sanitize the affected areas. It is recommended that grease traps be placed on a scheduled preventative maintenance schedule, and cleaned by a reputable plumbing firm.

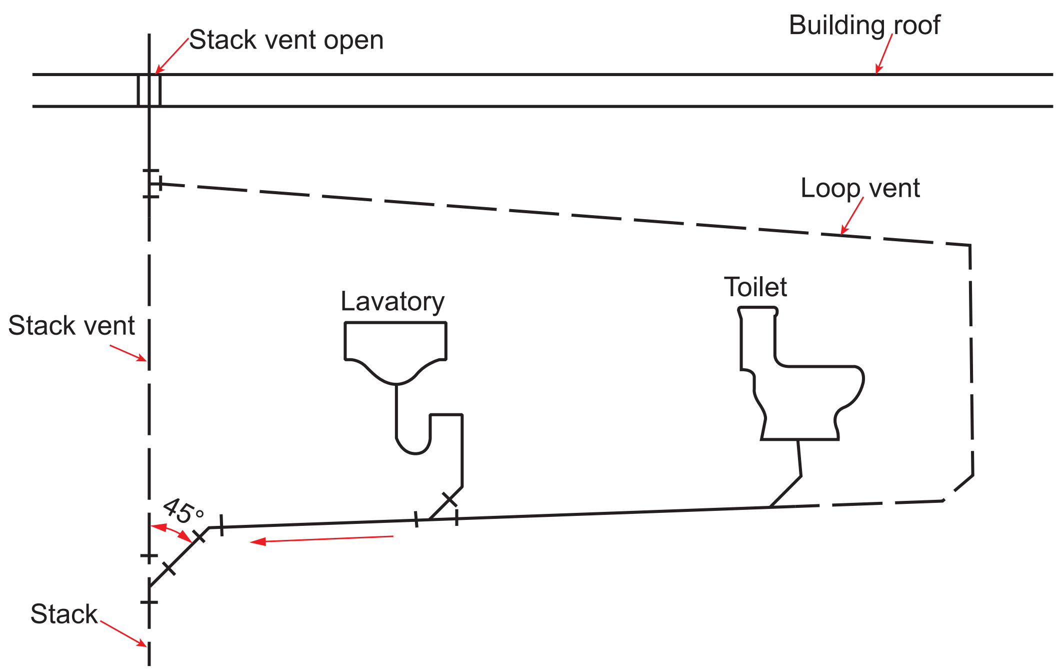
If drains become clogged, it will be necessary to use a **snake** to clear the lines. Blockage can be caused by grease accumulations, rags, sanitary products, tree roots, or collapsed sections of pipe. Plumbers can determine the cause and location of the blockage using fibre optic drain cameras. Once the cause of blockage is discovered, the correct snake attachment can be selected to clear the drain line.

Air Venting

It is very important to displace the air in the drainage system when wastes are being discharged. Positive pressure in the drainage system can force sewer gases back through the traps into the building. Negative pressure (partial vacuum) in the drainage system can allow the sealing liquid to be drawn out of the traps, thus breaking the seal between the drainage system and the building. A proper venting system prevents both of these undesirable conditions. The design of the venting system and the distance from the fixtures to the vent are very important.

Figure 3, a type of installation used for a one-storey building, consists of a vertical pipe or stack extending from the building sanitary house drain to an open end above the roof of the building. The part of the stack above the horizontal point of sewage discharge is referred to as the stack vent. Since the whole system is enclosed, the only discharge route for air and sewer gas is through the vent above the roof.

Figure 3 – One-Storey Venting System



In extremely cold climates, ice can accumulate inside the stack vent where it exits through the roof. As a result, stack vents are usually oversized in buildings located in colder climates. During periods of cold weather, building operators should check for the build-up of ice in the venting system where it exits through the roof. If the vent is blocked with ice, the ice should be carefully removed.

On Track

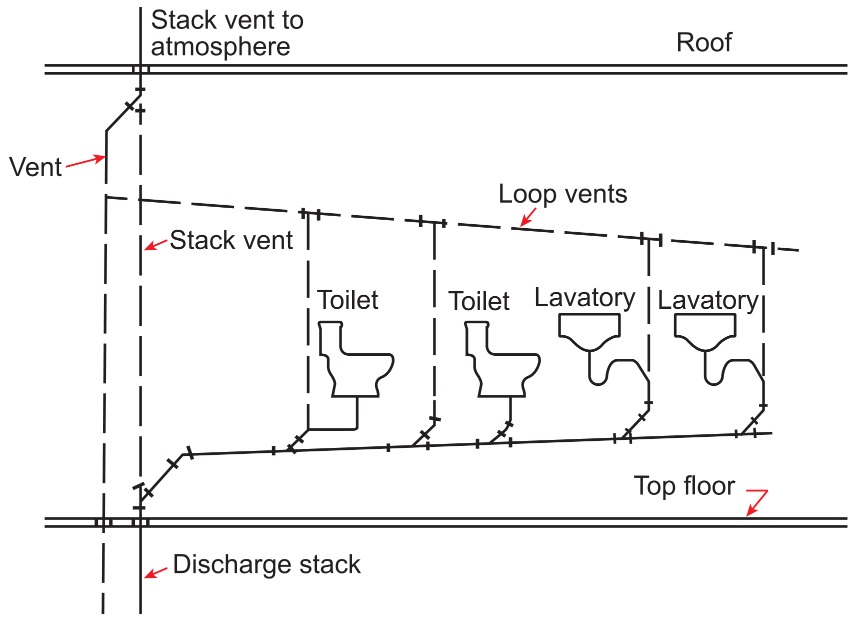
A loop, connected to the stack above the point of waste discharge, provides a continuous supply of air to the horizontal branch line. This air prevents siphoning of the sealing liquid out of upstream traps when downstream fixtures are used.

All loop vent piping should be sloped, as shown in Figure 3, so that material such as scale will not accumulate in the pipe. Branch line connections to the stack and fixture drain connections to the branch lines should not meet at an angle greater than 45°.

Figure 4 illustrates a venting system that is suitable for multi-storey buildings. In Figure 4, only the top storey is shown.

Two stacks are provided, one for venting purposes only and the other for discharging wastes. The **vent stack** may be connected to the waste stack above the highest horizontal branch in the building, so the pressures in the two columns are equalized. Each fixture discharging into a horizontal branch is vented individually in this system design. Normally, the vent stack is connected to the waste stack at the house drain and at least every ten floors in a multi storey building to equalize pressures and prevent negative or positive pressures from developing. Most buildings have several waste and soil stacks, with each waste stack providing drainage for only one section of the building.

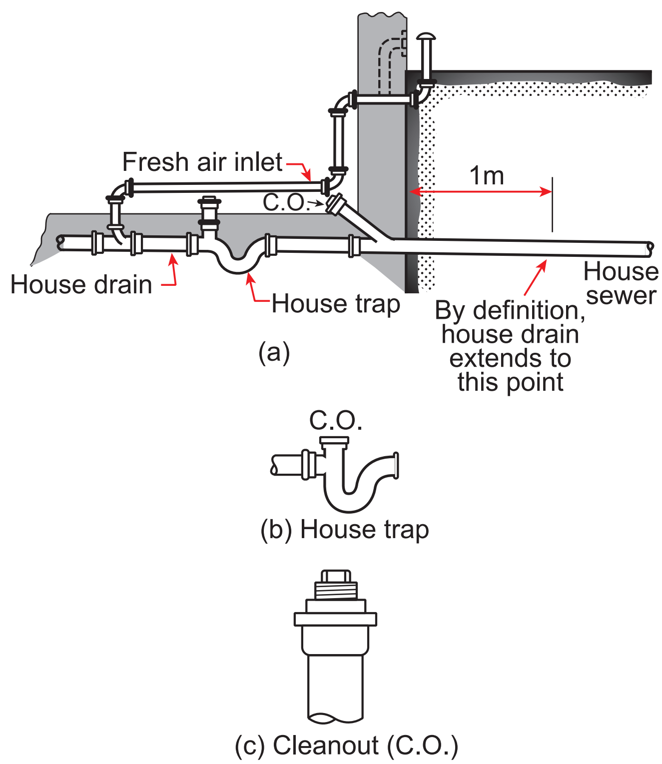
Figure 4 – Multi-Storey Building Venting System



Before the building or house sewer is connected to a municipal sewage disposal system, the sewage must pass through a vented trap which prevents sewer gas from flowing into the building. The vent must be on the upstream side and extend above ground, terminating with an open cover. Figure 5(a) illustrates the method of connecting a **house drain** to a sewer system.

Cleanouts are provided before and after the traps, so any obstructions can be removed. The cleanout, shown in Figure 5(b) and Figure 5(c), contains a plug in a short piece of straight pipe which can be removed to clean out blockage in the drainage system.

Figure 5 – House Drain Connection to Sewer



Drainage Pipe Material

Materials often used for indoor sanitary drainage piping are cast iron, galvanized steel, and copper. Other materials, such as plastic and borosilicate glass, may be used in chemical waste systems.

Cast iron soil pipe joints may be caulked with **oakum** to be semi-rigid, but still capable of being water and gas tight. Copper and plastic materials are mainly used for drainage, venting, and waste discharge from a fixture.

Plumbing codes permit the use of plastic pipe in private home sanitary systems, but prohibit or restrict their use in commercial buildings. Always consult local codes to ensure correct materials are selected.

Sumps

When the lowest drain in a building (such as in a sub-basement) is below the level of the municipal sewers, an arrangement must be provided to "lift" liquid sewage, so it can be discharged into the sewage system. This "lifting" is usually accomplished by constructing a **sump** below the lowest floor level and using a pump to convey the sewage.

The sump is usually provided with a manhole to permit cleaning and provide access to the submerged pumps or ejectors. Large sumps are provided with ladders built into the concrete.

All sumps should have a vent leading to the roof of the building, so toxic gases can be vented. This venting maintains air circulation in the sump, so gases do not accumulate in the mechanical spaces.

CAUTION

Sumps are confined spaces. They:

a) Have difficult access and egress.

b) Are not designed for human habitation.

c) May have atmospheres containing highly toxic H_2S gas.

A confined space entry permit must be obtained and all confined space procedures must be followed prior to entering a sump pit. As part of the confined space entry, lockout and tagout procedures must be followed.

Submersible centrifugal pumps are often used for lifting sewage to a higher level. These pumps are located near the bottom of the sump with sufficient space beneath them to accommodate solids that may settle at the bottom. Usually two pumps are used, so maintenance can be performed on one pump while the other is in operation. Float-controlled switches are used to start and stop one pump while the other is on standby. If, for some reason, the in-service pump cannot remove the liquid sewage, the standby pump will start. The level of sewage must always be below the bottom of the vent line, so there is never any obstruction in the venting system.

Sometimes, air-operated **sewage ejectors** may be used in sumps. A float-controlled switch starts an air compressor when the sewage reaches the maximum desired level. The air gives the sewage sufficient velocity to lift it to the desired level. Air pressure is used to close the inlet check valve to the sump and open the outlet check valve.

Objective 2

Describe storm water drainage systems for buildings.

Storm Water Drainage

The main function of a storm water drainage system is to remove storm water and provide sub surface drainage (from sources such as weeping tiles) into a storm sewer. Most jurisdictions require separate storm and sewage systems in a building.

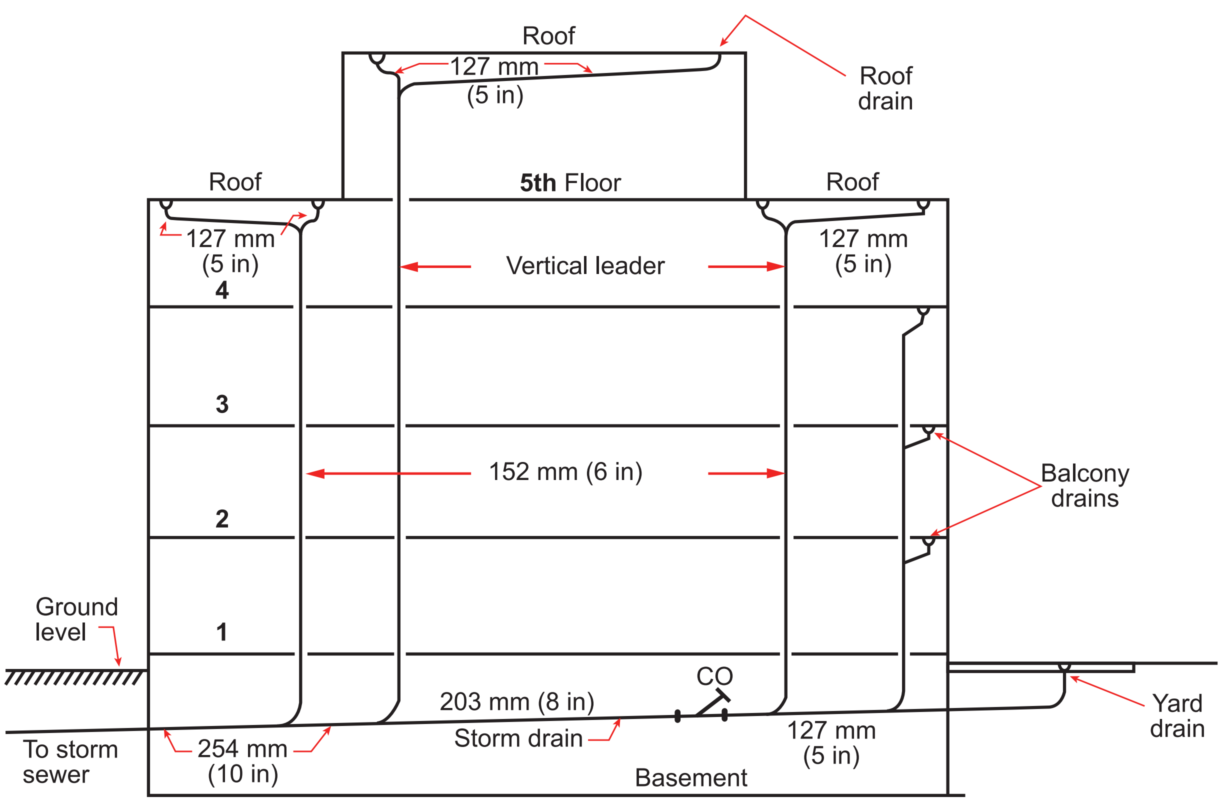
Gutters

Gutters are used to convey rainwater from a horizontal or sloping roof to a vertical pipe, called a **leader** or **downspout** that is connected to a **storm drain.** Gutters may be constructed as an integral part of the roof or as a separate attachment to the roof.

Roof Drainage

Figure 6 shows a storm drainage system for a five-storey building, indicating the areas drained and the corresponding sizes of the vertical leaders and horizontal drains. The roof drainage system is divided into sections, each with a vertical leader. These roof sections are sloped slightly so the rainwater will collect at certain points where drainage inlets are installed. Storm water flows directly into the leaders and collects in the storm drain to be discharged into a storm sewer.

Figure 6 – Building Storm Drainage System



The diameter of the vertical leader depends on the roof area it serves. The size of the storm drain is increased gradually as additional leaders are added. All the leader drains meet the storm drain at an angle of approximately 45°. Cleanouts are provided to allow for the clearing of blockages from the storm drain.

Some communities permit drainage with controlled flow. The size of drainage pipes is reduced so total drainage will take place during average storms. However, during severe rainfalls, water will be allowed to accumulate on the roof. With this system, the weight of the water must be considered when the roof is designed.

When storm drain piping is installed within a building, an insulating cover should be put on the pipes to prevent condensation on the outside surfaces of the piping during cold weather.

Roof drains are mounted level with the roof surface. Removable strainers should be provided to prevent foreign material from entering the system.

Piping Materials

The materials used for storm piping located inside a building may be cast iron, galvanized steel, or copper. Pipe joints may be packed, screwed, or flanged. When placed outside the building, the leaders may be made of pipe or sheet metal. Pipe material may be copper or galvanized steel, while sheet metal conductors are usually aluminum, with corrugations to permit expansion. Plastic pipes can be used, but compensation must be allowed for their high expansion coefficients. When a sheet metal leader discharges below grade level, it is connected to a cast iron drain or boot that protrudes above the finished grade.

Cast iron soil pipe is commonly used for underground storm drains inside a building. Concrete or **vitrified clay** may be used outside the building if permitted by local regulations or codes.

Allowance for pipe expansion is very important, especially if large variations in outside temperature occur during the year. Expansion joints or sleeves are usually provided to accommodate expansion.

Subsoil Drainage

Footing drains are usually installed to prevent an accumulation of ground water around the building foundations. In this way, they reduce hydrostatic pressure on the walls below ground level. This pressure can cause cracking and buckling of the walls below ground level. Perforated or porous pipe is used to collect the water near the footings and to drain it to a sump or a more remote area.

Objective 3

Describe how surface runoff is managed in order to minimize environmental impact.

Facilities such as SAGD sites, refineries, pulp and paper plants, and mines cover large areas of land, and produce or store environmentally hazardous materials. The potentially hazardous materials are produced or stored in areas where they can be contained, thus preventing them from entering the surrounding environment. Typically, earthen **berms** and ditches that surround the plant site serve this purpose. The water contained behind the berms and in the ditches can be released either directly or via storm water collection ponds or tanks. The method of release must be that mandated by the facility's **environmental license.**

Heavy rainfall and snowmelt can fill the areas surrounded by berms or ditches with water. This water, if permitted to accumulate, will:

a) Enter production buildings,

b) Damage equipment, and

c) Negatively affect the safe operation of the plant.

Therefore, the water must be occasionally released.

The surface water that accumulates may be contaminated from the specific hazardous materials at the plant site. Before any water is released, it must be tested according to site-specific environmental licensing requirements. If the water has tested at acceptable levels for release, it may be released into a special run-off pond or directly to the environment, depending on the environmental licensing requirements.

Water is released by temporarily opening sluice gates or with portable pumps. The company must record and report the time and date of release, the released water quantities, and the water test results.

On Track

Every plant has an environmental license, issued by the local jurisdiction, which in part covers releases of effluent. The license may address:

a) Contaminant limits

b) Contaminant types

c) Contaminant concentrations

d) Liquid volumes

e) Release frequency and release duration

Site specific procedures are developed to meet the licensing requirements. Always follow the site-specific procedures whenever surface water is released to ensure compliance with environmental regulations.

If water tests indicate excessive contaminant levels, the water must be directed to a special containment where it can be disposed of in an environmentally responsible manner. This often involves the use of specialized vacuum trucks that convey the contaminated water to special processing facilities.

Any release of contaminated surface water from a site must be in accordance with strict environmental guidelines established by the local Jurisdiction. Severe penalties may be issued for non-compliance.

Chapter Summary

All Power Engineers must know what effluent leaves their facilities, and how these effluents are handled. This chapter discussed the designs and principles of operation for sanitary waste systems, storm water systems, and surface runoff management systems.

Soil and waste are collected from plumbing fixtures and directed to the main waste stack. From here, the soil and waste is directed to a municipal or plant treatment facility.

Traps keep sewer gas from entering the building. Venting permits the flow of soil and waste, and keeps drain traps from losing their seal.

Roof drains, gutters, and footing drains direct storm and melt water from areas where water accumulates, and directs this water to a storm sewer system.

Surface runoff in large plant sites may require specialized management, including berms, dykes, and run-off ponds to successfully operate within their environmental license.

This chapter also showed how to:

a) Identify plant drainage systems
b) Identify operational problems related to these systems, and
c) Select ways of addressing these operational problems.

Unit Summary

This concludes the Plant Auxiliary Systems unit. This unit covered:

a) Various lighting, water supply and drainage systems
b) Components of these systems, and
c) Design considerations of these systems.

This unit focused on the proper maintenance of the lighting, water supply, and drainage systems to ensure the health and safety of building and power plant workers and occupants. These are also the fundamental requirements for safe and efficient power plant operation.

Key points were emphasized, where necessary, so the Power Engineers can work safely, promote efficiency, and adhere to legal requirements.

A self-assessment tool is available on MyPower LMS. Login using the unique user ID and password found on the inside front cover of Unit 1.

Notes

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UNIT B-8

KNOWLEDGE EXERCISES AND UNIT GLOSSARY

Knowledge Exercises – Chapter 1

Name: ______________________ Date: ______________________

Instructor: ______________________ Course: ______________________

Objective 1

1. What is a luminaire? Describe four types mentioned in this chapter.

2. Compare and contrast uniform and a non-uniform types of illumination.

Objective 2

3. Name five advantages of low-voltage switching.

Chapter 1 (Cont.)

4. With the aid of a sketch, explain how a photocell works.

5. Name two types of occupancy sensors, and explain how they work.

Objective 3

6. An emergency lighting system must provide the required illumination automatically in the event of any interruption of normal lighting due to (list three situations):

7. Emergency lighting systems are typically required to turn on within ____________ seconds, and must typically remain on for ___________ minutes.

8. Emergency lighting systems are powered by ____________ or ____________.

Chapter 1 (Cont.)

Objective 4

9. Specify six methods for reducing the energy consumed by lighting systems.

10. What is the lamp type with the least efficacy? What lamp type has the greatest efficacy?

Knowledge Exercises – Chapter 2

Name: ______________________ Date: ______________________

Instructor: ______________________ Course: ______________________

Objective 1

1. Describe an upfeed and a downfeed cold water distribution system.

Objective 2

2. Explain the circumstances where hot water recirculating systems are used.

Chapter 2 (Cont.)

3. Sketch a domestic hot water circulating system.

Objective 3

4. Why are mixing valves used in potable hot water systems? Describe how a mixing valve operates.

Chapter 2 (Cont.)

5. Make a simple sketch of an indirect heater with a storage tank. Include all necessary fittings.

Objective 4

6. Why is it necessary to protect potable hot water heaters from both over-pressurization and over-temperature?

7. Describe the operation of a T&P valve.

Chapter 2 (Cont.)

Objective 5

8. Why are backflow preventers installed in potable water systems?

9. An __________ ___________ is a physical separation between the free flowing discharge end of a potable water pipe and an open or non-pressure receiving vessel such as a sink or bathtub.

10. Describe the construction of RP and DCVA backflow preventers, and explain how each one works.

Objective 6

11. Describe the regular maintenance tasks performed on a hot water storage tank.

Chapter 2 (Cont.)

12. What causes water hammer in a potable water system? How can the effects of water hammer be reduced?

13. A flushometer runs for too long. What may be the cause?

14. A flushometer passes flush water for too short a period. What may be the cause?

Knowledge Exercises – Chapter 3

Name: ______________________ Date: ______________________

Instructor: ______________________ Course: ______________________

Objective 1

1. Make a simple sketch of a grease trap. Explain why grease traps are necessary, and how they work.

2. What is the purpose of a p-trap in a sanitary sewer piping system?

3. Explain why soil and waste systems must have appropriately located vents.

4. Why do some soil and waste systems use pumps?

5. What precautions must be taken before people are permitted to work in sump pits?

Chapter 3 (Cont.)

Objective 2

6. Why are storm water drains insulated when they pass inside buildings?

7. Why is it important to drain water that builds up at a building's footing?

Objective 3

8. Why are berms and ditches used to control surface runoff at large facilities?

9. Name three things companies must record when releasing water from behind a berm to the environment.

   a)

   b)

   c)

Unit B-8 Glossary

Term	Definition
Air gap	A physical separation between the discharge end of a potable water pipe and an open, non-pressurized vessel (such as a sink); used to prevent backflow.
Aqua-stat	A hot water boiler fitting that starts and stops the burner by sensing the temperature of the water. The term “AQUASTAT™” is a trademark of Honeywell International, Inc., originally filed in 1923.
Atmospheric vacuum breaker	A type of backflow preventer that has a moving element inside that prevents water from spilling from the device during flow. If the flow should stop, the device drops down to provide a vent opening.
Back pressure	A condition that may result in backflow, created when the potable water supply pressure is below the discharge pressure.
Back syphonage	A condition that may cause backflow, created when the potable water supply pressure falls below atmospheric pressure.
Backflow	A backwards flow of water (or other liquid, gas, mixture, or other substance) into the distributing pipes of a potable water supply from any source.
Ball cock	A float-operated valve that admits water into a container to maintain a preset level.
Berm	An artificial ridge or embankment, constructed of earth. It surrounds an area that needs to be contained.
Circulating hot water system	A potable hot water system found in larger buildings. It has both hot water supply and return lines, so that hot water is always available near the plumbing fixtures.
City water	Potable water that is provided by a municipal distribution system.
Cleanout	A capped pipe which provides access to a sewer line, allowing sewer blockages to be removed.
Coefficient of utilization (CU)	The percentage of light delivered to a work surface by a luminaire.
Cross connection	A permanent or temporary piping connection between a potable water source and a contaminant.
CU	See *coefficient of utilization*.
Direct lighting	A lighting system designed to deliver light from a luminaire without reflection.
Double check valve	A backflow preventer, it has two check valves which act independently of each other. The check valves close if the water pressure upstream of the device is less than the pressure downstream.
Downfeed (gravity) system	A potable water distribution system with a storage tank that is located on the roof of the building. It distributes water vertically, in a downward direction, via gravity.
Downspout	A pipe to carry rainwater from a roof to a drain or to ground level.
Environmental license	A permit to conduct industrial activities as long as stipulated environmental requirements are met.
Flush valve	A valve that admits water into a urinal or toilet.
Flushometer	A valve for flushing toilets or urinals by operation of a handle that discharges water under pressure directly into the fixture and automatically shuts off the flow after the flushing period is over.

Term	Definition
Footing drain	An exterior foundation drainage system placed outside the foundation wall near the wall footing. Its purpose is to alleviate hydrostatic pressure on foundation walls.
Grease interceptor	A plumbing device designed to prevent greases and solids from entering a wastewater disposal system.
Grease trap	A grease interceptor.
Gutter	A shallow trough located beneath the edge of a roof for carrying off rainwater.
HID	See *high intensity discharge*.
High intensity discharge (HID)	An electrical lamp that produces light by means of an electric arc between tungsten electrodes housed inside a transparent fused quartz or fused alumina tube. The tube is filled with gas and metal salts. These lamps include mercury vapour, metal-halide, high pressure sodium, and low pressure sodium types.
House drain	A horizontal pipe that receives the contents of soil and waste pipes, and extends a few feet outside the foundation.
House tank	A storage tank that is located above the highest plumbing fixture of a downfeed potable water supply system.
Hush tube	A tube that adds water below the water surface into a toilet flush tank, to reduce noise.
Incandescent	Producing light by means of high temperature, as in incandescent lighting.
Indirect hot water heater	A potable water heater that uses steam or hot water heat from a boiler to heat potable water, via a heat exchanger located in the potable water storage tank.
Indirect lighting	A lighting system designed to deliver light by first reflecting it off a surface such as a ceiling or a wall.
Infrared	Invisible electromagnetic radiation of a frequency longer than that of visible red light.
Instantaneous water heater	A water heater that heats water on demand as it flows through the heater. It has no internal water storage other than what is in the heat exchanger coil.
Lamp efficacy	Comparison of a lamp's light output, in lumens, to the power it consumes in Watts.
Leader	A vertical drain line on multi-story buildings employed to drain storm water into the storm sewer system.
Long turn elbow	An elbow pipe fitting with a long radius of curvature.
Lumen	An SI unit of light intensity.
Luminaire	A device used to control the distribution of light from a lamp. Luminaires consist of lamps, sockets, ballasts and diffusers or reflectors.
Luminous efficiency	Comparison of a lamp's light output, in Watts, to the power it consumes, in Watts.
Mixing valve	In a plumbing system, a valve used to mix a stream of hot water with a stream of cold water to maintain a constant mixed water temperature stream.
Non-circulating hot water system	A hot water system used for smaller buildings. Hot water is delivered directly to the fixtures without provisions for recirculation back to the water heater.
Oakum	Tarred fibre used for caulking or packing the connecting joints of cast iron drain and waste piping.

Term	Definition
Photocell	A device that generates an electric current, an electric voltage, or varies in resistance dependent on the degree of illumination.
Potable	Water that is safe to drink.
Pressure vacuum breaker	A type of backflow preventer; it consists of a single body with a spring loaded check valve that opens to admit air whenever the pressure within the body approaches atmospheric pressure.
Reduced pressure device	A type of backflow preventer; it has two independently acting check valves and an automatic operating pressure differential relief valve located between them.
Refill tube	A small tube that directs water into the overflow tube of a toilet flush mechanism. It refills the toilet's internal trap.
Riser	A vertical section of piping that delivers fluids to locations at multiple elevations.
Roof drain	A storm water or melt water drain that removes water from a flat roof.
Sewage ejector	A container that, when full of sewage or waste, uses compressed air to displace the contents up to a higher discharge line.
Snake	A manual or powered device that turns a long flexible shaft having various attachments, used to clean drain and waste lines.
Soil	In plumbing systems, a combination of liquid and solid waste.
Storm drain	A drainage system used to direct rain and melt water away from surfaces such as rooftops, paved areas, and sidewalks.
Sump	A sewage tank installed below the level of the lowest floor, with a submersible-type centrifugal pump that is used to pump the sewage into the public sewer main.
Temperature and pressure (T&P) relief valve	A safety valve installed on potable hot water tanks and heaters.
Thermowell	Tubular fittings installed to protect temperature sensors from the action of process materials. It also permits easy replacement of temperature sensors.
Trap	A plumbing device, shaped as an "s" or "p", which contains a liquid seal to prevent sewer gas from entering occupied places.
Troffer	A recessed rectangular fluorescent light fixture that fits into a modular dropped ceiling grid.
Ultrasonic	Refers to sound energy of a frequency greater than that of audible sound.
Ultrasound	Sound energy of a frequency greater than that of audible sound.
Upfeed system	A water distribution system; distributes water vertically, in an upward direction, with the use of pumps or municipal water supply pressure.
Vacuum breaker	A device placed on a toilet or urinal flush valve. It prevents water from being siphoned backward into the potable water system.
Vent stack	A vertical pipe parallel to a building's waste stack to which each floor's vents are connected.
Vitreous china	An impervious porcelain coating. It is applied to the surface of ceramic plumbing fixtures, such as sinks, urinals, and toilets.
Vitrified clay	A hard ceramic blend of clay and shale, used in the manufacture of drainage and waste pipe.
Volatile fluid	A liquid that vapourizes at low temperatures and pressures.
Waste	In plumbing systems, liquid waste.

Term	Definition
Waste stack	A vertical pipe used in a building to convey soil and waste, by gravity, to the building sanitary drain.
Water closet auger	Also known as a “Toilet Auger”. It is a tool made specifically to unplug a toilet. Generally, it consists of a flexible metal cable with a small bob at the end. On the other end is fitted with a hand crank used to feed and turn the flexible cable to dislodge clogs in the toilet.
Water hammer arrestor	A device used to control the pressure pulse generated by the sudden interruption of water in a potable water distribution system.
Water main	A principal pipe, in a system of pipes, for conveying water, especially one that is installed horizontally.
Wraparound	A fluorescent light fixture that is surface-mounted. It has a clear prismatic lens that surrounds the lamps.

Additional Workspace

Additional Workspace

Additional Workspace

Additional Workspace

Additional Workspace

Additional Workspace