FUNDAMENTALS OF WATER SYSTEM OPERATIONS - OPERATOR BASICS

OPERATOR BASICS

COURSE OBJECTIVE

To expose workshop participants to the basic knowledge that operators of water systems in the Caribbean should possess

OPERATOR BASICS

COURSE OUTCOMES

At the end of the course participants should be able to:

(i) Assess the regulatory environment within which a Water Utility operates and the duties and responsibilities of an operator

(ii) Determine the main sources of water and treatment options

(iii) Identify the main components of a water distribution system and the duties of an operator in its construction, operation and repair

OPERATOR BASICS
COURSE OUTLINE

- **1. Introduction to Public Water Supplies**
- **1.1** What is a Public Water Supply System?
- **1.2** Purpose of Public Water Supply Systems
- **1.3** Types of Public Water Supply Systems
- **1.4** Operator Certification Programme
- **2. Public Water Supply System Regulations**
- **2.1** Introduction to Regulations
- **2.2** Regulations Governing Public Water Systems
- **2.3** Plan & Specification Review & Approval
- **2.4** Monitoring and Reporting
- **2.4.1** Microbiological Quality
- **2.4.2** Chemical Contaminants
- **2.4.3** Chlorine Residual
- **2.4.4** Fluoridation
- **2.4.5** Lead and Copper / Corrosion Control
- **2.4.6** Secondary Contaminants & Concerns

OPERATOR BASICS
COURSE OUTLINE

- **3. Water Resources Basics**
- **3.1** The Hydrologic Cycle
- **3.2** Ground Water Movement
- **3.3** Stream Flow
- **3.4** Brief Chemistry of Water
- **4. Treatment of Water**
- **4.1** Overview of Disinfection
- **4.2** Chlorination
- **4.3** Ultra Violet Light (UV)
- **4.4** Other Disinfectants
- **4.5** Treatment for Common Chemical / Physical Contaminants
- **4.6** Treatment for Turbidity

OPERATOR BASICS

COURSE OUTLINE

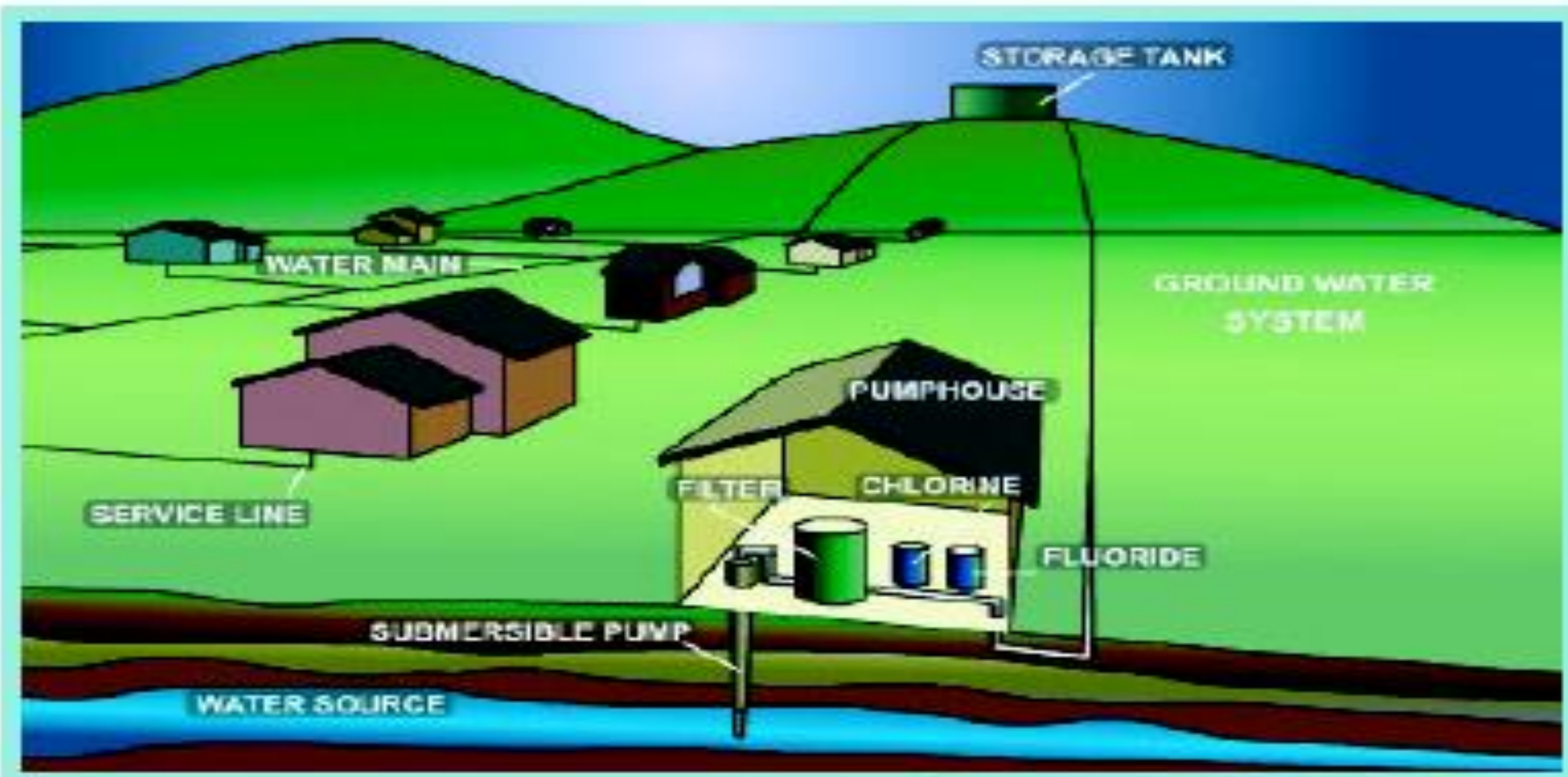
- **5. Distribution Systems**
- **5.1** System Components
- **5.1.1** Piping
- **5.1.2** Valves
- **5.1.3** Fire Hydrants
- **5.1.4** Storage Reservoirs
- 5.1.5 Booster Stations
- **5.2** Construction & Repair
- **5.2.1** Minimum Separation Distances
- **5.2.2** Looped Systems & Dead End Mains
- **5.2.3** Preventing Contamination
- **5.2.4** System Repairs
- **5.3** Record keeping

OPERATOR BASICS

- **1. Introduction to Public Water Supplies**
- This unit serves as an introduction to public water supply systems for participants to learn what they are by definition and by what basic criteria they are classified.
- There will be a brief discussion on what is required of operators and/or managers of these systems to maintain their skills and ensure that public health is protected.

OPERATOR BASICS

- **1. Introduction to Public Water Supplies**
- **1.1** What is a Public Water Supply System?



OPERATOR BASICS

MODULE 1

- **1. Introduction to Public Water Supplies**
- **1.1 What is a Public Water Supply System?**

A public water supply system provides piped water, **fit for human consumption**, to the public.

- Water **fit for human consumption** includes drinking water and water used for cooking, food preparation, hand washing, bathrooms and bathing.
- The system includes the source water intake (such as a well), treatment, storage, and distribution piping
- A private home served by its own well is not a public water supply system since it serves only a single service outlet.

OPERATOR BASICS

MODULE 1

- **1. Introduction to Public Water Supplies**
- **1.1 What is a Public Water Supply System?**

Fit for human consumption

Section …?….of regulations

- .

OPERATOR BASICS

- 1. Introduction to Public Water Supplies
- **1.2 Purpose of Public Water Supply Systems**
- The main purpose of public water supply systems is to provide water that is safe for human consumption.
- Other important purposes are to provide an adequate quantity of water of acceptable taste, odor and appearance; and often to meet limited irrigation needs and fire protection.
- Providing water service places **owners** and operators of water systems under an ethical and legal obligation to meet these needs.

OPERATOR BASICS

- 1. Introduction to Public Water Supplies
- **1.2 Purpose of Public Water Supply Systems**
- **Who or What are the OWNERS OF WATER SUPPLY SYSTEMS In Your Country?**

- 1. Introduction to Public Water Supplies

1.2 Purpose of Public Water Supply Systems

- Most people in the Caribbean take safe, inexpensive drinking water for granted. We assume all water that comes from a tap is okay to drink, whether in a restroom, at the office, a stand pipe or a friend's home.
- Few people realize the planning, monitoring, repair and maintenance required to obtain and protect adequate amounts of safe water.

OPERATOR BASICS

- 1. Introduction to Public Water Supplies

- **1.2 Purpose of Public Water Supply Systems**

  Operators must work towards the protection of the public from water contaminants that may cause acute or chronic health effects.

- Contaminants that may have an immediate impact on health after drinking small amounts of water must be dealt with in all public water systems. These are contaminants that cause acute health effects. Examples are disease causing organisms.

OPERATOR BASICS

- 1. Introduction to Public Water Supplies

- **1.2 Purpose of Public Water Supply Systems**

  Contaminants that cause health effects if consumed over long periods of time must also be dealt with in systems where the same residential or non-residential consumers have access to the water on a long-term basis. These are contaminants that cause chronic health effects. Examples include cancer-causing chemicals and chemicals affecting the nervous system or kidneys.

- 1. Introduction to Public Water Supplies

1.2 Purpose of Public Water Supply Systems

- The provision of an adequate quantity of water is addressed by properly sizing the source, pumping equipment, treatment, storage and piping to meet a reasonable demand for water created by all intended purposes.
- Taste, odor and color are addressed through recommended maximum levels of certain contaminants that may make water unappealing.

OPERATOR BASICS

- 1. Introduction to Public Water Supplies
- **1.2 Purpose of Public Water Supply Systems**
- A reasonable demand for water
- **About 150 litres a day per household, on average**
- **Bath: 80 litres**
- **Shower 30-60 litres**
- **Dishwasher wash: 16-25 litres**
- **Washing machine load 50-100 litres**
- **Toilet flushing: 30-40 litres per day**
- **Source: Environment Agency and South Staffordshire Water plc …..St. Lucia ?**

OPERATOR BASICS

- 1. Introduction to Public Water Supplies
- **1.3 Types of Public Water Supply Systems**

- **Gravity vs Pumped Systems**

- **Gravity system – Water flows under the influence of gravity from the source of production to the consumer**
- **St. Vincent and the Grenadines**

- **Pumped System – Pumps are used to raise the energy level of the water in abstraction, production and/or distribution of the water**
- **Most Caribbean Water Utilities**

OPERATOR BASICS

- **1. Introduction to Public Water Supplies**
- **1.4 Certification of Operators**

- In the USA, **All States** require community water systems to have a certified operator in charge.
- **Currently in the Caribbean no country has mandatory certification of operators**

OPERATOR BASICS

- 1. Introduction to Public Water Supplies
- 1.4 Certification of Operators
- Why Certification?

Public Safety

System Protection

OPERATOR BASICS

- 1. Introduction to Public Water Supplies
- **1.4 Certification of Operators**
- **Why Certification?**

Public Safety

- Certified operators play a crucial role in protecting the health and welfare of the public, which can be jeopardized if unqualified operators are allowed to operate water supply systems.
- There are many disease-causing organisms and chemicals that may enter a system through the source of water or through problems in the distribution system. Most contaminants cannot be seen or smelt, so proper system maintenance and monitoring is necessary to ensure the protection of public health.
- Water users expect a safe and adequate water supply and rely on the system operator to notify them if problems occur

OPERATOR BASICS

MODULE 1

- 1. Introduction to Public Water Supplies
- **1.4 Certification of Operators**
- **Why Certification**

System Protection

- Protection of the water system is an important job for the certified operator.
- Large amounts of money are required to design and install water system sources, treatment, distribution piping, valves and other components.
- Improper operation and maintenance of pumps, storage tanks and treatment systems can result in their early failure, and expensive repair or replacement.

OPERATOR BASICS

Estimated Useful Lives

Asset	Expected Useful Life (in years)
Intake Structures	35-45
Wells and Springs	25-35
Galleries and Tunnels	30-40
Chlorination Equipment	10-15
Other Treatment Equipment	10-15
Storage Tanks	30-60
Pumps	10-15
Buildings	30-60
Electrical Systems	7-10
Transmission Mains	35-40
Distribution Pipes	35-40
Valves	35-40
Blow-off Valves	35-40
Backflow Prevention	35-40
Meters	10-15
Service Lines	30-50
Hydrants	40-60
Lab/Monitoring Equipment	5-7
Tools and Shop Equipment	10-15
Landscaping/Grading	40-60
Office Furniture/Supplies	10
Computers	5
Transportation Equipment	10

Note: These numbers are ranges of expected useful lives drawn from a variety of sources. The ranges assume that assets have been properly maintained.

OPERATOR BASICS

- **1. Introduction to Public Water Supplies**
- **1.4 Certification of Operators**
- **Why Certification**
- Competent water system operations require someone with skill, knowledge and experience in operating, maintaining and troubleshooting water sources, treatment and distribution systems.
- Even if an operator does not repair or replace broken equipment, he/she must be able to recognize potential problems and take action to have problems corrected.

OPERATOR BASICS

- 1. Introduction to Public Water Supplies
- **1.4 Certification of Operators**
- **Why Certification?**
- This "Code of Ethics" is an example of the responsibilities that should be included in a certified operator's job specifications.
- "Using my best judgment and operating skills, I will always work to protect the public health, to ensure good service, to protect public property and the environment, by applying my skills in operating water and wastewater system equipment, by properly and accurately completing required records, following and complying with applicable rules and regulations, continuing my education in my field, and working with management to establish distinct and safe operating policies for the environmental systems for which I am entrusted."

OPERATOR BASICS

- 1. Introduction to Public Water Supplies
- **1.4 Certification of Operators**
- **Why Certification?**
- **The Operator should be backed up by Strong Regulations**

OPERATOR BASICS

2. **Public Water Supply Regulations**

In this section the following issues are addressed:

- The primary areas in which regulations affect drinking water:

  monitoring and reporting, operator certification, and system design standards.
- The importance in recognising how and why these are critical to public health protection and operator responsibilities.
- An overview of the national regulations applied in the Caribbean, USA and England.

MODULE 1

2. Public Water Supply Regulations

2.1 INTRODUCTION TO REGULATIONS

- The enabling Acts of Statutory Authorities contain specific water supply regulations
- Such Regulations normally govern *inter alia*:
  - The administering of rates and charges for water supply services;
  - The protection of waterworks catchment areas
  - Authorisation and the issuing of licenses to abstract water

Other regulations are also required

OPERATOR BASICS

2. **Public Water Supply Regulations**

- **2.2 Regulations Governing Public Water Systems**
- Regulations governing public water supply systems should serve two purposes.
- The primary purpose
- To ensure reasonable protection of the health of people who consume the water (referred to as "protection of the public health").
- The secondary Purpose
- To help ensure protection of the investment dollars spent on construction of the public water supply system.
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OPERATOR BASICS

2. **Public Water Supply Regulations**

- **2.2 Regulations Governing Public Water Systems**
- Public health protection is obtained by:
  - setting maximum contaminant level (MCL) for certain contaminants which may not be exceeded by a public water supply system;
  - ensuring monitoring for contaminants is done in a reasonable fashion, and;
  - requiring treatment be installed to remove contaminants to below levels specified by their MCL.
- The MCL for each contaminant is the enforceable drinking water standard, or primary standard. It is based on a maximum contaminant level goal (MCLG), a level below which no adverse health effects are expected to occur from drinking contaminated water. MCL's are set as close to the MCLG's as possible, taking costs and technology into consideration.

OPERATOR BASICS

2. **Public Water Supply Regulations**

- **2.2 Regulations Governing Public Water Systems**
- Some contaminants, for which analytical methods are poor or impractical, have minimum treatment requirements instead of MCL's.
- Examples of treatment technique requirements include filtration of surface water sources and corrosion control.

OPERATOR BASICS

2. **Public Water Supply Regulations**

- The "Multiple Barrier Concept" of public health protection incorporates several independent steps to provide public health protection.
- The theory behind this concept is:
- ‘The more barriers between a contaminant and the consumer, the more likely an isolated failure in one of the steps will not result in adverse public health effects’.

OPERATOR BASICS

2. Public Water Supply Regulations

For a public water supply system, **6 steps** in the multiple barrier concept include:

- **1. selecting the best source or source location;**
- **2. providing adequate treatment to remove or eliminate contaminants;**
- **3. developing and implementing a source water protection plan;**
- **monitoring water quality to check the effectiveness of treatment or the occurrence of contaminants (there are also often multiple barriers within treatment processes);**
- **4. ensuring the integrity of the transmission and distribution system**
- **5. providing sanitary surveys to identify deficiencies which might impact water quality or service; and**
- **6. reporting to the Regulator and public any contamination events, monitoring failures, or water treatment deficiencies.**

OPERATOR BASICS

2. **Public Water Supply Regulations**

DESIGN & CONSTRUCTION

- Proper design and construction of a public water supply system has a critical role in public health protection. It is also an expensive process regardless of the size of the system.

- Investment dollars are protected when the system is engineered, constructed, operated and managed so that it is able to provide safe water at all times for a long system lifespan.

OPERATOR BASICS

2. **Public Water Supply Regulations**

- **Unit 2: Public Water Supply System Regulations**
- **2.3 Plan and Specification Review and Approval**

- Public water supply systems should have any alterations or extensions of their water system approved by the regulatory agency prior to initiation of any construction.

- This includes addition of any treatment systems, main extensions, or replacing a pipe with a different size or type of pipe than was originally there.

- **Approval is not needed for repair or replacement of system components as long as the new parts are the same specification as the old parts and the work being performed is maintenance.**

OPERATOR BASICS

2. **Public Water Supply Regulations**

- **Unit 2: Public Water Supply System Regulations**
- **2.3 Drawings and Specification Review and Approval**

- Public water supply systems should have their drawings and specifications prepared and submitted by a professional engineer.

- **Drawings and Specifications for Projects done in-house must also be subjected to review and Approval**
- **(DISCUSS)**

OPERATOR BASICS

2. **Public Water Supply Regulations**

- **Unit 2: Public Water Supply System Regulations**
- **2.3 Drawings and Specification Review and Approval**

- Drawings and Specifications must be compared to minimum design standards that vary from country to country.

- Minimum standards ensure new sources of water are located properly to minimize the potential for contamination, that pipe used is adequately strong and will not easily leak, that treatment is adequate to address the problem for which it is needed, and that components are sized properly.

OPERATOR BASICS

2. **Public Water Supply Regulations**

- **Unit 2: Public Water Supply System Regulations**
- **2.3 Drawings and Specification Review and Approval**

- Systems which do not conform to the plan review and approval process may install inadequate or unnecessary treatment
- Others may install poor-quality pipes, which frequently break and leak

- What are some problems with inadequately designed water systems?

OPERATOR BASICS

2. Public Water Supply Regulations
- Unit 2: Public Water Supply System Regulations
- 2.3 Drawings and Specification Review and Approval

- Does your Utility have Standards for the design of Water Supply Systems

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2. **Public Water Supply Regulations**

- **Unit 2: Public Water Supply System Regulations**
- **2.4 Monitoring and Reporting**

- **Section ? Of enabling legislation**

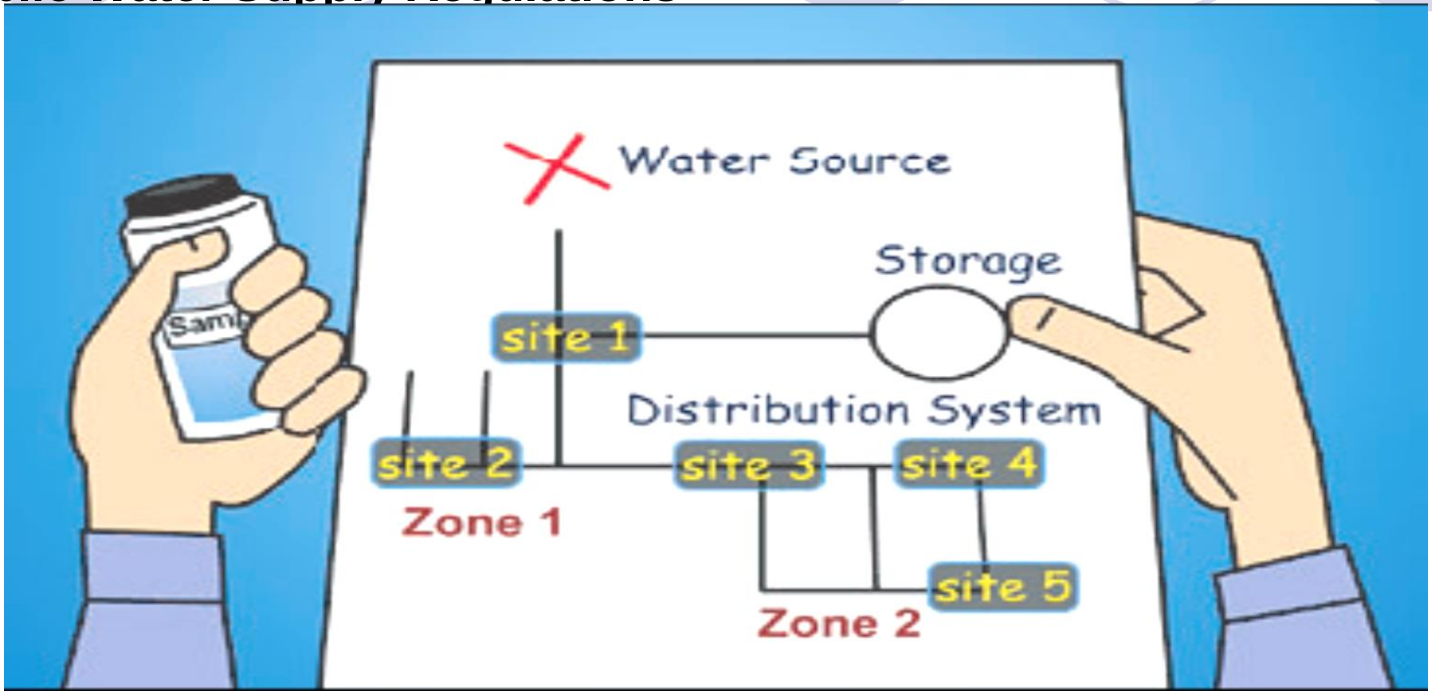
- **Following sections provide an overview of the major monitoring and reporting requirements for public water systems.**

2. **Public Water Supply Regulations**

- **Unit 2: Public Water Supply System Regulations**
- **2.4 Monitoring and Reporting**
- **Monitoring for possible contaminants is the process of sampling the water and submitting the samples to a laboratory for analysis.**
- **Reporting refers to either submitting results of analyses to the regulatory agency or submitting proof of other action, such as issuing a required public notice.**

OPERATOR BASICS

2. **Public Water Supply Regulations**



- Water quality monitoring is done to detect if part of the system has failed, is leaking, or is exposed to conditions that may shorten its useful life (FIGURE 1).
- Conditions that may affect the life of pipe include very hard water that might plug pipes, or corrosive water, which corrodes, or eats away at the interior of pipes and tanks.

OPERATOR BASICS

2. **Public Water Supply Regulations**

- **Unit 2: Public Water Supply System Regulations**
- **2.4 Monitoring and Reporting**
- **Monitoring requirements can be very complex. In the USA the EPA has developed a chart that identifies specific monitoring needs for individual systems.**
- **Caribbean has adopted WHO Standards**

2. Public Water Supply Regulations

- Unit 2: Public Water Supply System Regulations
- 2.4 Monitoring and Reporting
- Typical Monitoring covers microbiological monitoring, nitrate, lead and copper, other chemical contaminants and radionuclide requirements.

OPERATOR BASICS

2. Public Water Supply Regulations

- Unit 2: Public Water Supply System Regulations
- 2.4 Monitoring and Reporting
- Certified laboratories must be used for all microbiological and chemical contaminant monitoring.
- These laboratories are certified to have met minimum requirements for accuracy and performance of test methods.
- The Cayman Water Authority has the only Certified Laboratory in the Caribbean.

OPERATOR BASICS

2. Public Water Supply Regulations

- **Unit 2: Public Water Supply System Regulations**
- **2.4 Monitoring and Reporting**
- **Certified operators should collect all microbiological samples and if required for the system, they must also take all measurements for pH, temperature, turbidity, and residual disinfectant (chlorine) concentration.**

OPERATOR BASICS

2. **Public Water Supply Regulations**

- **Unit 2: Public Water Supply System Regulations**
- **2.4 Monitoring and Reporting**
- **In most Caribbean Countries the monitoring results are reported to the respective Ministries of Health.**

2. Public Water Supply Regulations

- **Unit 2: Public Water Supply System Regulations**
- **2.4.1 Monitoring and Reporting: Microbiological Quality**
- **Collectively the bacteria, protozoans and viruses are the most numerous organisms on Earth.**
- **Since they are very small and cannot be seen without a microscope, they are often referred to as microbes .**
- **Many microbes can cause disease if they are consumed in food or drinking water.**
- **"Microbiological quality" refers to the presence or absence of microbes in the water.**

2. Public Water Supply Regulations

- **Unit 2: Public Water Supply System**
- **Some common types of microbes you may be familiar with include organisms that cause cholera (a bacteria), hepatitis (a virus), and giardiasis (a protozoan)**
- **Analytical methods do not exist to allow monitoring for every individual disease-causing agent that might contaminate a public water supply system.**
- **Instead, we rely on monitoring for indicator bacteria which 'indicate' water may be contaminated.**
- **The indicator bacteria used for all water systems is a group called coliform bacteria.**

OPERATOR BASICS

2. **Public Water Supply Regulations**

- **Unit 2: Public Water Supply System**
- **Coliform bacteria, while not typically disease-producers**
- **themselves, are often associated with pathogenic (disease-producing) organisms. They are an index of the degree of microbiological safety of the water. They commonly come from soil or the fecal material (stools**
- **or manure) of warm-blooded animals. Coliforms survive longer in the environment than most disease causing organisms, making them useful in determinine if a contamination event might have occurred.**
- **Routine monitoring for coliform organisms is directed at looking for members of the total coliform group of bacteria. These bacteria have special characteristics when incubated (or 'grown') in the laboratory under specific conditions. If total coliforms are found in the water, the bacteria are further analyzed to determine if they are also fecal coliforms. Fecal coliforms are a specific subgroup of total coliforms, which grow only at body temperature of warm-blooded animals. They are used to indicate if fecal contamination of water has occurred.**

2. Public Water Supply Regulations

- Unit 2: Public Water Supply System
- **Microbiological quality monitoring has three important components:**
- **1) scheduled routine monitoring;**
- **2) repeat sample collection, and;**
- **3) use of a sample site plan to be sure the entire distribution system is being represented by the sampling process.**

OPERATOR BASICS

2. **Public Water Supply Regulations**

- **Unit 2: Public Water Supply System**
- **Coliform monitoring, or 'bacteriological' monitoring, is performed on a routine basis.**
- **Requirements for the number of samples to be collected each month are based on the population served by the public water supply system and whether the system operates seasonally (such as schools and recreational facilities).**
- **Every public water supply system must collect routine samples.**
- **The locations where routine samples are collected must be rotated each time so the entire distribution system is covered.**
- **Sample collection locations must be rotated to one of the places designated on a sample site plan.**

2. Public Water Supply Regulations

- **Unit 2: Public Water Supply System**
- **2.4.1 Monitoring and Reporting: Microbiological Quality**
- Repeat Samples, or "check samples", are collected if a routine sample comes back with an unsatisfactory result- this means coliform bacteria were detected. These samples are often referred to as "positive".
- The number of routine samples collected determines the number of repeat samples required. Repeat samples are intended to confirm the occurrence of a contamination event.
- The public water supply system must collect repeat samples within 24 hours of being notified the routine sample was unsatisfactory and before any adjustment is made to the treatment system. The intent is to determine if water already in the public water supply system is contaminated.
- **The intent is also to not mask a contamination problem by adding a disinfectant to the system before determining if contaminated water may already have reached consumers.**

OPERATOR BASICS

2. **Public Water Supply Regulations**

- **Unit 2: Public Water Supply System**
- **2.4.1 Monitoring and Reporting: Microbiological Quality**
- **Of course, if you find an obvious problem in the system, such as a dead bird in a storage tank or the well cap off a well casing, you should notify the regulator and correct the problem immediately.**
- **Repeat samples would still be required however.**
- **Public notice may still be necessary to inform consumers of the problem, depending on the outcome of the sample analysis.**

OPERATOR BASICS

- 2.4.2 Monitoring and Reporting: Chemical Contaminants
- Public water supply systems must monitor for over 100 different possible chemical contaminants.
- Chemical contaminants can be of two types: organic and inorganic.

OPERATOR BASICS

- 2.4.2 Monitoring and Reporting: Chemical Contaminants
- An organic chemical is one that is based on the chemistry of carbon. While humans and every other living thing are made of organic chemicals, the ones of concern as contaminants are mostly synthetic - herbicides, pesticides, plasticizers, solvents, petroleum components, disinfection byproducts.
- Examples of inorganic contaminants are metals, arsenic, asbestos and radionuclides (naturally radioactive atoms).

OPERATOR BASICS

- 2.4.2 Monitoring and Reporting: Chemical Contaminants
- Health effects caused by chemical contaminants include:
- kidney and liver effects,
- gastrointestinal disorders,
- cancer and
- nervous system disorders.

- 2.4.2 Monitoring and Reporting: Chemical Contaminants
- Two kinds of illness are of concern Acute and Chronic.
- Acute illness develops in a very short time, possibly even after one exposure to a contaminant.
- Chronic illness develops very gradually, requiring prolonged exposure to the contaminant. For example, an elevated concentration of copper in drinking water quickly causes acute gastrointestinal illness - nausea and vomiting. On the other hand consuming water with low levels of certain organic contaminants over the long term can cause various types of cancer.
- Chemical contaminants that cause acute health effects are generally monitored more frequently than Chemicals causing chronic health effects

- 2.4.2 Monitoring and Reporting: Chemical Contaminants
- All public water supply systems must monitor for nitrate and nitrite.
- These chemicals can cause a serious disorder called methemoglobinemia, or "blue baby syndrome". This is a condition in which blood is unable to transmit oxygen to the body, so the body appears to be blue. It is a serious threat to infants and pregnant mothers.
- Some areas have high levels of nitrate in ground water, and public water systems there must treat their source water to remove nitrates.

OPERATOR BASICS

- 2.4.3 Monitoring and Reporting: Chlorine Residual
- Public water supply systems using surface and ground water must disinfect the water and have a disinfectant residual remaining in the distribution system.
- Disinfection is usually done with chlorine.
- Operators must ensure the treatment system is running properly and is adding enough disinfectant to kill any disease-causing organisms that may be present. This is done through daily monitoring of the amount of disinfectant added and the disinfectant residual measured at representative taps in the distribution system.

OPERATOR BASICS

- 2.4.3 Monitoring and Reporting: Chlorine Residual
- A colorimetric test kit using the DPD method is commonly used for disinfectant residual determinations.
- For the vast majority of systems this means daily monitoring of the free chlorine residual at both the point of application and in the distribution system.
- The monitoring sites in the distribution system are rotated to cover the entire system each week.

OPERATOR BASICS

- 2.4.3 Monitoring and Reporting: Chlorine Residual
- The reason that residual (remaining disinfectant) must be monitored within the distribution system is that disinfectant reacts and is used up in the system. Only measuring the remaining concentration can assure that enough remains to do the job.
- The important message here is that if disinfection is required, the operator must monitor the performance of the disinfection system and report the results to the regulator.

OPERATOR BASICS

- 2.4.4 Monitoring and Reporting: Secondary Contaminants and Concerns
- Secondary contaminants have a recommended maximum contaminant level established. Since the levels are guidelines, they are not enforceable health limits.
- Secondary limits relate to the appearance and palatability of water - things like hardness, taste, odor, color, and iron and manganese levels.

OPERATOR BASICS

- 2.4.4 Monitoring and Reporting: Secondary Contaminants and Concerns
- Complaints about iron and manganese are common in many areas using ground water. They produce brown and black stains on fixtures porcelain plates and laundry when in levels higher than their recommended level.
- Hardness is another common complaint from consumers. Aside from concerns about soap use and the way it makes skin feel, hardness also can plug distribution piping. Home water softeners help with consumer needs, but centralized treatment is necessary to protect distribution pipes.
- Sulfide gas and other aesthetic concerns are also common.

- **2.5 Public Notification**
- The primary purpose of public notification is to inform consumers of any regulatory requirements that have not been met and steps they can take to minimize the impact.
- Public notification provides consumers with information that will educate them about the extent to which the water system is or is not meeting standards. It can also encourage them to support the expenditures necessary to provide safe water.
- Public notification must be provided when the system:

  - exceeds a maximum contaminant level (a primary standard);

  - fails to monitor for a contaminant as required, or;

  - is operating under a special allowance, termed variance or exemption.

OPERATOR BASICS

- **2.5 Public Notification**
- The method and timing of a public notice is determined by the severity of the problem. In some cases the problem must be announced on radio and TV within a few days of obtaining the test result.
- This is necessary when the contamination presents an immediate health threat to consumers. Specific language is required to be given with the notice.
- Consumer Confidence Reports are another means of keeping the public informed. They are annual reports to users regarding the source of drinking water, any treatment employed, monitoring performed and results of the monitoring - including any violations incurred by the system. They can be useful tools for educating users about system needs, as well as for instilling consumer confidence in water provided by the public water supply system.

3. WATER RESOURCES BASICS

3.1 The Hydrologic Cycle

- When rain reaches the land's surface some of the water renews surface waters such as rivers, lakes, streams, and oceans; some percolates into soils to be absorbed by plant roots; and some evaporates back into the atmosphere from the soil surface, from plant leaves (called evapotranspiration) and from surface water.
- Water in the atmosphere accumulates, eventually forming clouds and more precipitation.
- The rest of the water infiltrates the ground to become ground water.

3.1 The Hydrologic Cycle

- This cycle of water through precipitation and evaporation or evapotranspiration is called the hydrologic cycle

Figure 1: The hydrologic cycle (F-2)

- **3.1 The Hydrologic Cycle**

- It is an important concept because it shows:

- How the amount of ground water available to a water well is influenced by the amount of precipitation, percolation and underground water flow that occurs in a given area.

- It also shows how surface water is derived and made available for abstraction at intakes

- **3.2 Ground Water**
- Most ground water is simply water filling spaces between small grains of rock, or fractures and fissures in solid rock. It may also occur in solution channels, which have been formed in limestone deposits. Underground lakes or streams only occur in areas of cavernous limestone or in tunnels from lava flows.
- The speed at which ground water moves beneath the land surface depends on the nature of the underground rock layer the water must travel through. Most ground water eventually discharges into springs, rivers, the sea, or other surface waters. This discharge may occur within a few days of the water entering the ground or it may take several thousands of years.

3.2 Ground Water

- Water collects in the fractures, intergranular pores, and caverns in some of the rock layers (FIGURE 2).
- An aquifer is a layer that will yield ground water in useful quantities to a well or spring.
- In an aquifer, all of the voids or openings between the rocks are filled with water. Water in this phreatic zone (also known as the saturated zone) is called ground water.
- The top of the saturated zone is called the water table.
- The underground zone above the water table contains both air and water and is called the vadose or unsaturated zone.

- **3.2 Ground Water**
- Aquifers are composed of either **consolidated or unconsolidated** materials.
- **Unconsolidated** deposits are composed of loose rock or mineral particles of varying sizes. Examples include clay, silt, sand, and gravel. Alluvial deposits such as streambeds, glacial drifts, and lake deposits are examples of unconsolidated materials.
- **Consolidated** deposits are rocks formed by mineral particles combining from heat and pressure or chemical reactions. They include sedimentary (previously unconsolidated) rocks, such as limestone, dolomite, shale, and sandstone; igneous (formed from molten) rocks, such as granite and basalt; and metamorphic (highly compressed) rocks, such as quartzite and gneiss.

OPERATOR BASICS

- Some limestones and sandstones may be only partially cemented and are called semi-consolidated deposits.
- In some limestone areas, Ground water flows through solution channels and is collected in vast underground reservoirs (Are these aquifers?) or can exist in the semi-consolidated deposits.
- Many Caribbean countries obtain their fresh water supplies from limestone formations: eg Barbados and Bahamas

Types of Aquifers

- Aquifers can range from several acres to thousands of miles wide and from a few feet to hundreds of feet thick.
- In some areas, the ground water table is less than 10 feet (3m) below ground surface. In other areas, systems must rely on wells drilled more than 1,000 feet (300m) deep.
- Many wells serving community public water supply systems draw from alluvial aquifers less than 50 feet (17m) deep.
- Wells constructed in these relatively shallow aquifers have a greater potential for biological and chemical contamination than do wells constructed in deep or confined aquifers.

CBWMP

OPERATOR BASICS
MODULE 1

Types of Aquifers

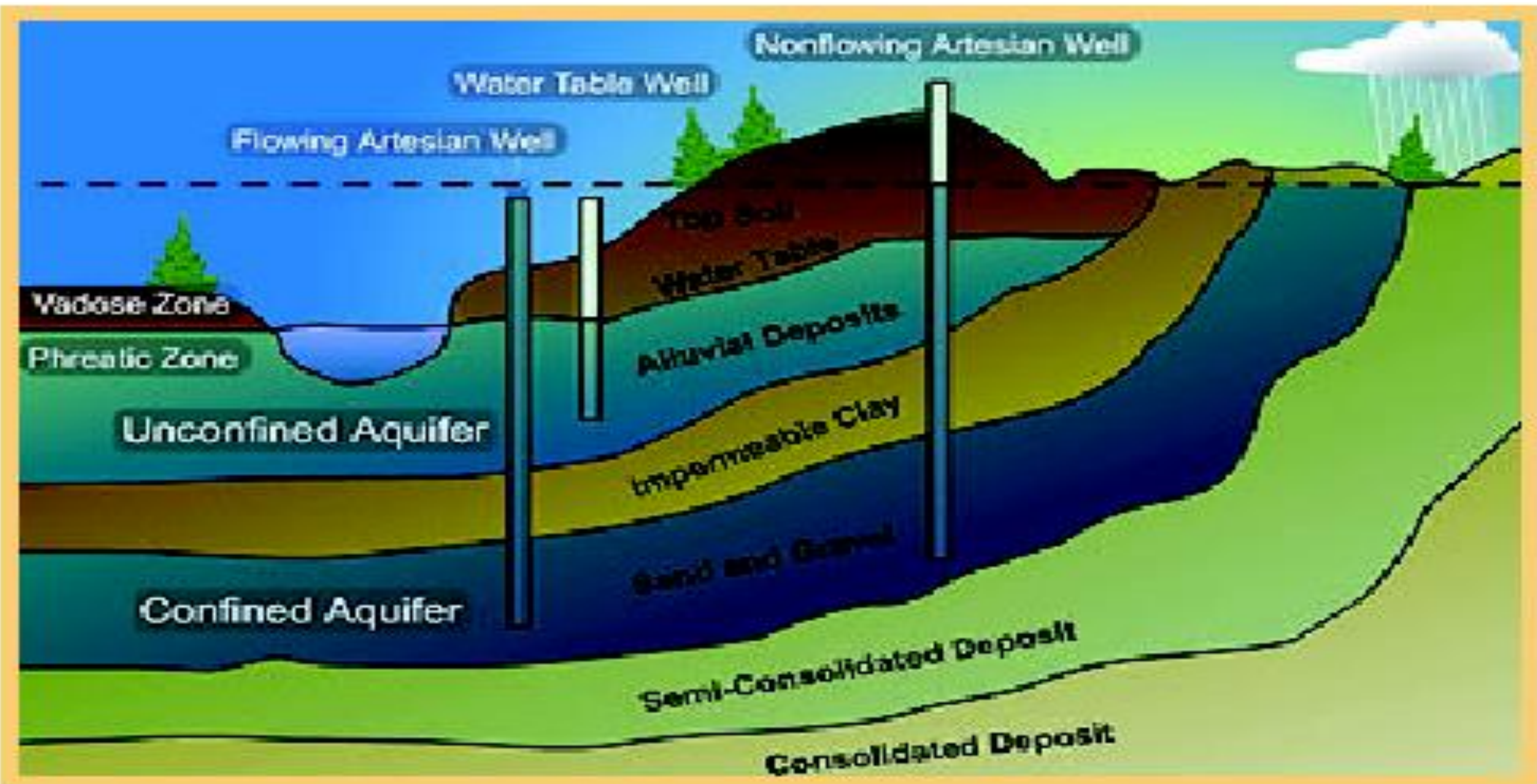


Figure 3: Confined and unconfined aquifers (F-3)

3.3 Surface Sources

- Surface sources include, springs, streams, rivers and impounding dams and reservoirs
- Most streams and rivers in the Caribbean are no longer perennial and dry-up during the dry season
- In the wet season at times of heavy rain fall the turbidity levels are high
- Many utilities have had to use alternative sources of water:
  - Impounding Dam and Reservoir (St. Lucia and Trinidad and Tobago)
  - Deep-well bed rock (Trinidad and Tobago)
  - Desalination (Barbados, Cayman Islands, Anguilla, Antigua, Trinidad and Tobago)

- **3.3 Surface Sources**
- The quantity of water available for abstraction at a surface abstraction point (portion of runoff) depends on:
  - Antecedent rainfall
  - Size of catchment area
  - Nature of the catchment (forest, grass land, cultivated area)
  - Infiltration
  - Down stream Riparian Rights

4. WATER TREATMENT

- **4.1 Overview of Disinfection**
- Some water sources may have bacterial or viral contamination and would not be safe for consumption without treatment. This would be evident by positive coliform tests that show the water system is periodically or continuously contaminated.
- Even if a source of water is not contaminated, water in the distribution system may be exposed to pathogenic organisms. This can occur through a break in a water line, a cross-connection, a flood or other disaster, or growth of organisms in a dead-end line
- Disinfection is a process that kills bacteria and viruses, which are harmful to people's health. Organisms that cause disease are referred to as pathogenic organisms.

4. WATER TREATMENT

4.1 Overview of Disinfection

- Another related term is sterilization. This is a process to kill all organisms.
- In water treatment, it is not necessary to kill all the organisms, just the ones that can affect health. Attempting to kill all organisms would generally be too costly and is not necessary to protect public health.
- Public water supply systems are vulnerable to a variety of organisms that can cause diseases such as amoebic dysentery, typhoid fever, cholera, giardiasis, and cryptosporidiosis. Most of these organisms are sensitive to disinfection, so disinfection is considered the single most important treatment step in the production of potable water.

4. WATER TREATMENT

4.1 Overview of Disinfection

- The effectiveness of all disinfectants is decreased by the presence of turbidity, some organic and inorganic chemicals and reducing agents such as hydrogen sulfide or certain forms of iron and manganese. If these materials are in the water, an additional disinfectant or a longer contact time may be necessary to kill pathogenic organisms.
- Although disinfectants, especially chlorine, have saved thousands of lives by providing safe water, there are some concerns about by-products formed when disinfectants combine with other chemicals in water.
- Disinfectants also have an upper limit of concentration that restricts the amount allowed in water routinely served to consumers.
- Disinfecting agents other than chlorine are available and each has advantages and disadvantages to their use.

4. WATER TREATMENT

4.1 Overview of Disinfection

- For most disinfectants, such as chlorine, the effectiveness of the disinfectant is increased with increasing water temperature. The temperature of the water affects the rate of the chemical reaction. Reactions occur slowly in cold water.
- Also, most disinfectants are affected by pH. Water with a pH above 8 reacts with chlorine to form a less effective disinfectant.
- Exceptions to these general rules are disinfection by ultraviolet light, which is not affected by temperature or pH, and ozone, which is not affected by pH.

OPERATOR BASICS
MODULE 1

- 4. WATER TREATMENT

- 4.1 Overview of Disinfection
- QUESTIONS?
- What is indicated by a positive coliform test?
- What are Distribution system contamination risks?
- What is the difference between disinfection and sterilization?
- Identify prominent waterborne diseases?
- What factors influence the effectiveness of chlorine as a disinfectant?

4. WATER TREATMENT

4.2 Chlorination

- The most common chemical used in the disinfection process is chlorine. Chlorine is usually preferred over other disinfectants because of cost, availability and effectiveness.
- The amount of chlorine that must be applied is dependent on how much it takes to obtain a free available chlorine residual. Chlorine in this form has the highest disinfection ability.
- To obtain a free chlorine residual enough chlorine must be added to satisfy the chlorine demand of the water. Iron, manganese, hydrogen sulfide, or other inorganic or organic materials in the water may cause chlorine demand.

4. WATER TREATMENT

- **4.2 Chlorination**
- The process of adding small amounts of chlorine to the water until the demand is satisfied and a free residual is obtained is called breakpoint chlorination. As shown in (FIGURE 2) Breakpoint chlorination curve, when chlorine is first added to water, it might not register a residual.
- The chlorine is used up by reacting with some materials such as iron, manganese or nitrite in the water. This is referred to as the chlorine demand.

OPERATOR BASICS
MODULE 1

- ## 4. WATER TREATMENT

- **4.2 Chlorination**
- Once the demand has been satisfied and as more chlorine is added, a chlorine residual will be able to be detected in the water. This chlorine residual is referred to as "combined" residual because it has combined with some of the organic compounds or ammonia in the water to form chlororganics and chloramines. The chlorine will not be a very effective disinfectant when combined with other chemicals and some of the compounds formed may cause taste and odor problems.
- As more chlorine is added, the chlororganics and chloramines are destroyed and the chlorine residual readings may actually drop.

4. WATER TREATMENT

4.2 Chlorination

- Finally, a point is reached where adding a certain amount of chlorine to the water results in a corresponding increase in the chlorine residual. This is called the breakpoint.
- This residual is "free available“ chlorine that is ready to react with and destroy contaminants. Free residual chlorine is the most effective disinfectant.
- Public water supplies should practice "breakpoint" chlorination, which means they are providing a free chlorine
- residual in their system.

4. WATER TREATMENT

4.2 Chlorination

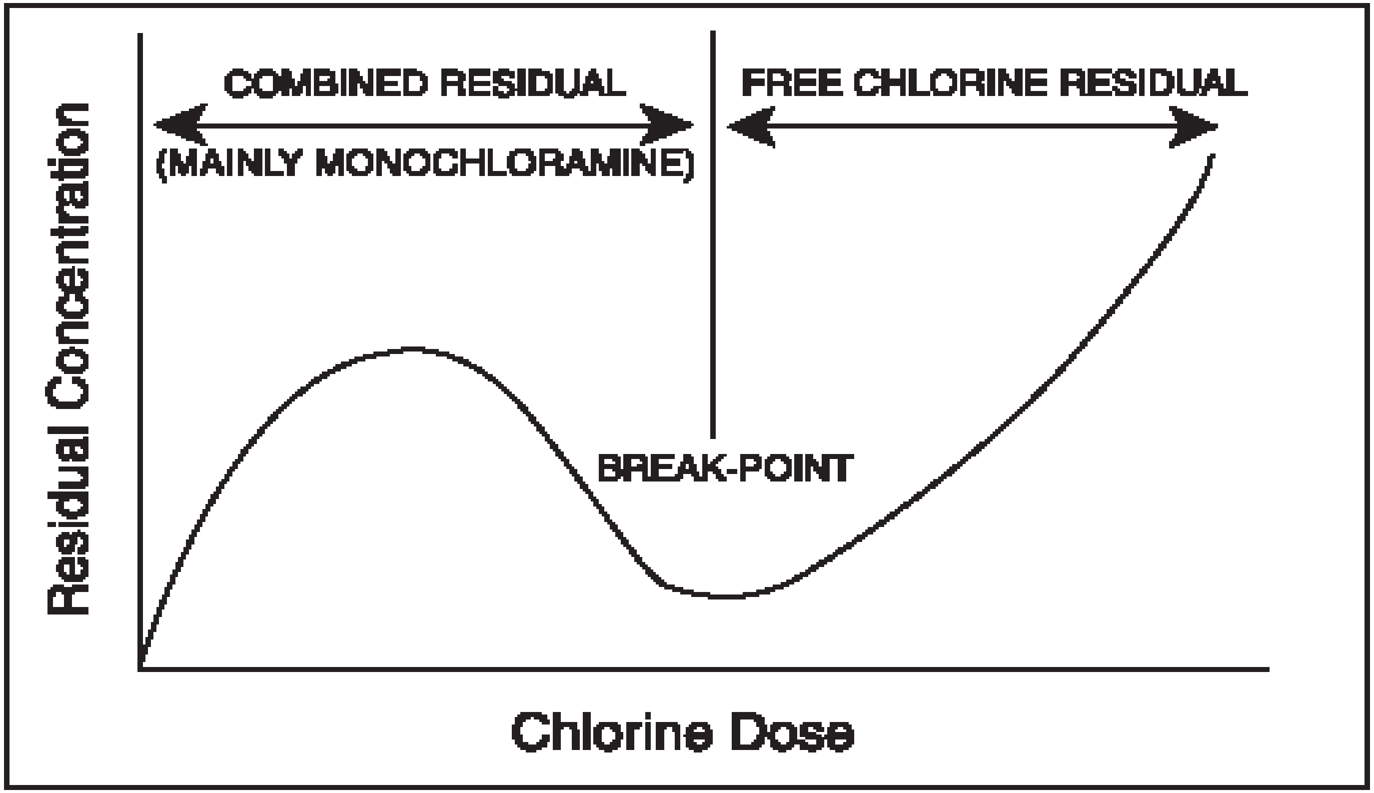


Figure 1.1: Typical Break-point Chlorination Curve

OPERATOR BASICS
MODULE 1

4. WATER TREATMENT

- ### 4.2 Chlorination

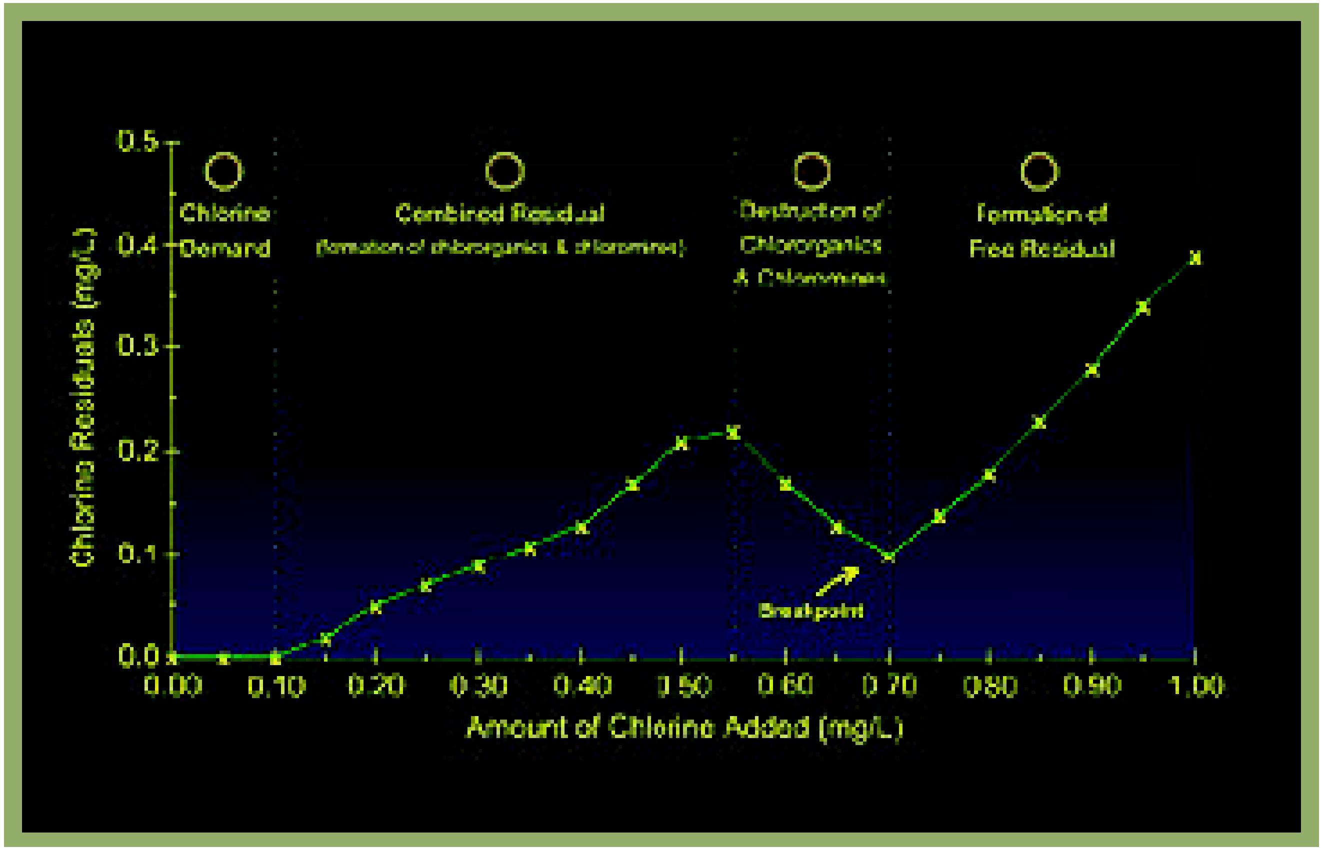


Figure 2: Breakpoint chlorination curve (F-24)

4. WATER TREATMENT

- **4.2 Chlorination**
- Chlorine residual determinations and reporting are an important responsibility of the operator.
- Chlorine residual is most commonly measured using a DPD
- colorimeter test kit . This kit indicates the chlorine residual level by comparing the color produced with the DPD chemical addition to the water with a standardized color residual indicator.
- The amount of chlorine to be added and the contact time that chlorine has with the water prior to reaching the first consumer will vary with the objectives of the disinfection procedure.
- For bacterial and virus disinfection of well waters, a chlorine residual in the distribution system of about 0.2 to 0.5 mg/L after a contact time of 30minutes is satisfactory.

4. WATER TREATMENT

4.2 Chlorination

- Chlorine is available in various forms.

The most used forms for small systems are:

- chlorine gas in 100 or 150-pound cylinders,
- chlorine as a liquid (sodium hypochlorite),and
- chlorine as a solid (calcium hypochlorite)
- Turks and Caicos Islands

4. WATER TREATMENT

4.2 Chlorination

- Chlorine gas:
  - is a greenish-yellow material with a penetrating and distinctive odor.
  - It is more than twice as heavy as air so will settle in low areas if it is released into the atmosphere
  - It can be purchased as a liquified gas in 100 or 150-pound steel cylinders for use by small systems.

4. WATER TREATMENT

- **4.2 Chlorination**
- **Chlorine** is a poisonous gas and must be handled with care. Chlorine gas is not corrosive unless it is in a moist atmosphere or in contact with any moisture. It then becomes highly corrosive and is especially destructive to electrical equipment.
- Liquified gas chlorine is the least expensive form of chlorine, but for safety and maintenance reasons it may also be the least desirable for small public water supply systems.

4. WATER TREATMENT

4.2 Chlorination

- Sodium hypochlorite, NaOCl, is a liquid containing 5% to 15% available chlorine. The 5.25%solution is sold in grocery stores under trade names such as Clorox, Purex, etc. This form can be used for emergency disinfection and then flushed away, but should not be used for continuous chlorination.

4. WATER TREATMENT

4.2 Chlorination

- Some swimming pool chlorination products contain cyanide and must not be used for continuous disinfection of drinking water.

- **Sodium hypochlorite** can be conveniently added to water using a small solution feed pump.
- Sodium hypochlorite can lose from two to four percent of its available chlorine content per month at room temperature; therefore, manufacturers recommend a maximum shelf life of 60 to 90 days.

4. WATER TREATMENT

4.3 Chlorination: Forms of Chlorine

- **Calcium hypochlorite** is a white solid which is available in powder, granular or tablet form at approximately 65% available chlorine. It may be sold under names such as HTH, Perchloron or Pitclor. It is normally dissolved in water and then injected into the drinking water using a solution feeder.
- Calcium hypochlorite:
  - It is a powerful oxidizing agent and must be handled with care, kept dry and away from combustible materials.
  - It may start a fire if the white solid material comes into contact with organic materials, such as an oily rag.
  - It has a shelf life of about 6 months after the container has been opened.

4. WATER TREATMENT

4.4 Disinfection Monitoring

- To demonstrate that continuous disinfection is being
- practiced, the public water supply system operator must
- monitor daily the amount of chlorine being added and
- the free chlorine residual obtained in the distribution
- system.
- Public water supply system regulations should specify
- details on this monitoring and reporting requirement.

4. WATER TREATMENT

4.5 Handling Chlorine

- For safety reasons, the chlorine is handled under vacuum so any leaks will leak air into the chlorinator instead of allowing chlorine to leak into the air. The vacuum is produced in an ejector in which a small stream of water is pressured through a nozzle orifice. This vacuum opens a check valve and an internal valve in the chlorinator, allowing chlorine to feed from
- the tank into the ejector where it is mixed with the water stream from the nozzle. The resulting chlorine solution is mixed with the main stream of water to be disinfected. A variable orifice flowmeter (rotometer) mounted on the chlorine gas cylinder indicates the chlorine flow rate with a small black ball suspended in a glass tube.

4. WATER TREATMENT

4.5 Handling Chlorine

- When using a gas chlorinator, the ejector water is usually controlled either by a solenoid valve or by starting and stopping a booster pump so the chlorination system operates while the pump is pumping and shuts down when the pump is off.

OPERATOR BASICS

4. WATER TREATMENT

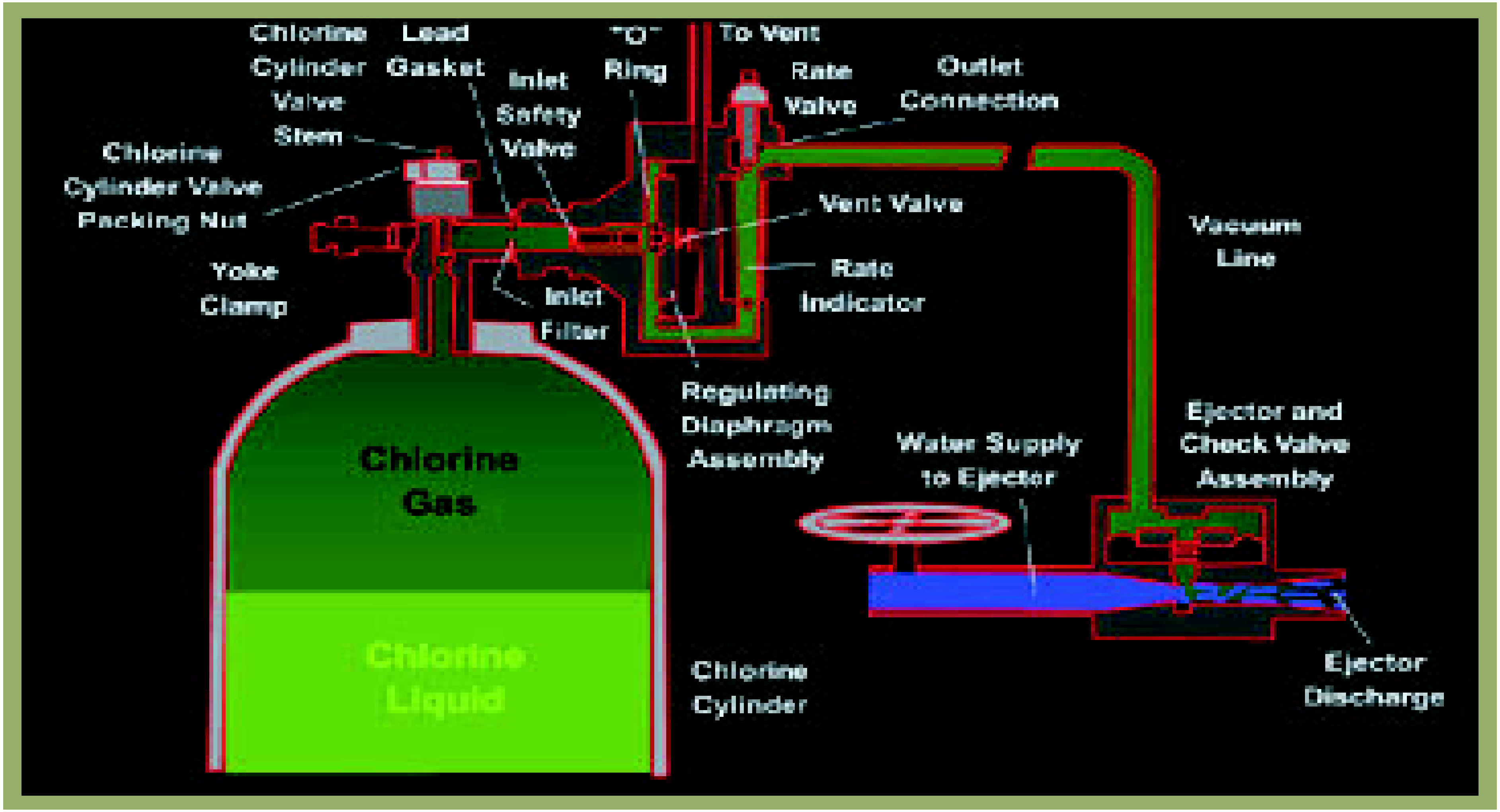


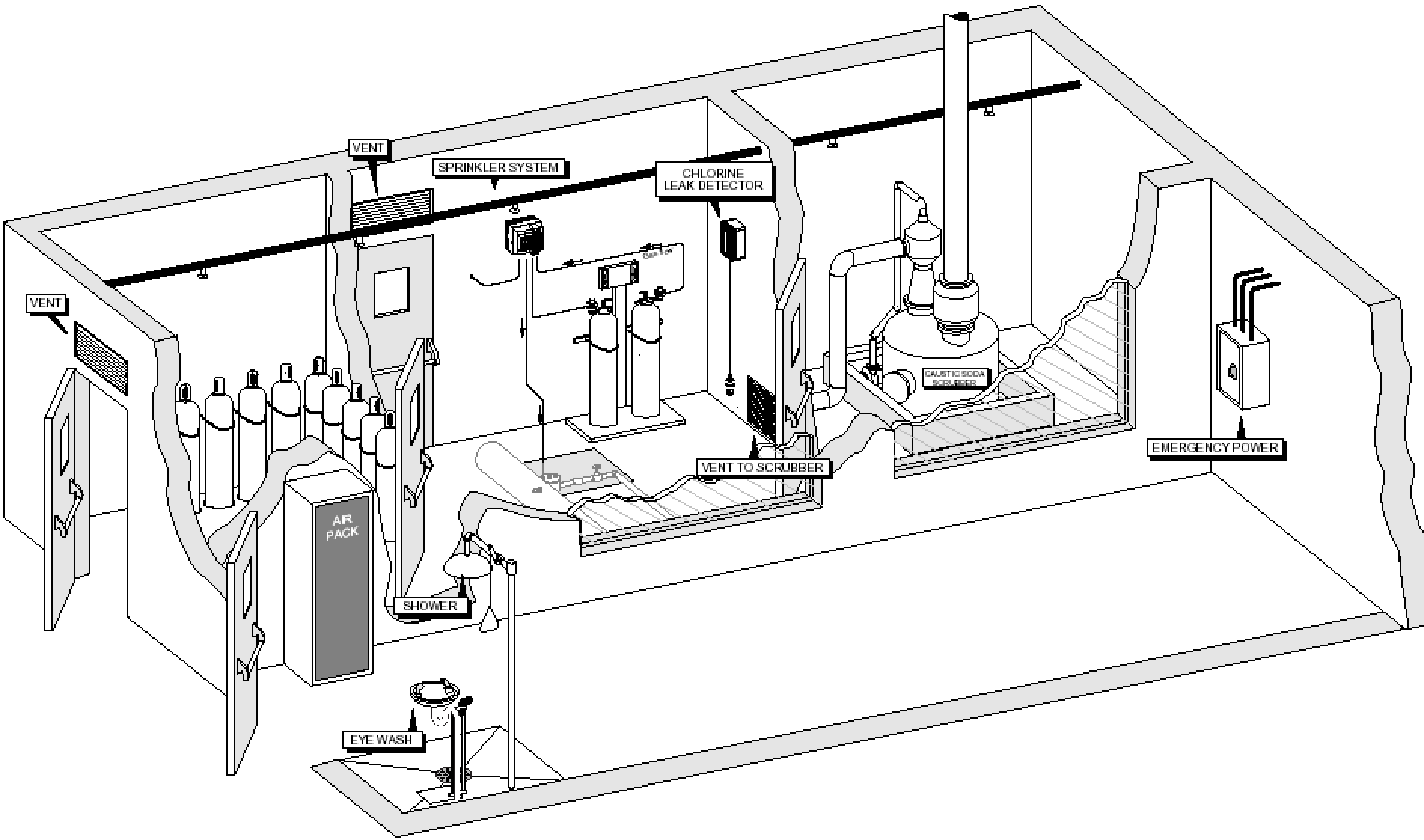
Figure 2: Gas chlorinator schematic (F-25)

4. WATER TREATMENT

4.5 Handling Chlorine

- Liquified gas chlorine is the least expensive form of
- chlorine, but is difficult to handle and therefore may not be applicable for some small systems.
- If you use a gas chlorination system, please refer to a more in-depth study than is provided here.

OPERATOR BASICS



4. WATER TREATMENT

4.5 Handling Chlorine

- Hypochlorination requires close attention by the
- operator as the pump and injection point often build
- Scale. The scale will prevent the pump poppet valves from sealing and the pump will not move
- the solution into the water to be disinfected.

4. WATER TREATMENT

4.5 Handling Chlorine

- Maintenance of the pump, and especially cleaning the pump valves, should be on a regular weekly schedule, or as often as experience indicates.
- A hypochlorinator pump should also be wired so it starts and stops in unison with the pumping system. This way,chlorine is only being added when the water is flowing
- Hypochlorination, using either calcium hypochlorite or sodium hypochlorite, is often the most practical method of disinfection for small water systems

4. WATER TREATMENT

4.5 Handling Chlorine

- Calcium hypochlorite is usually the less expensive of the two and is often selected for that reason.
- Typically, the hypochlorite is dissolved into a water solution and metered into the flowing water stream using a small diaphragm or plunger-type pump.
- Calcium hypochlorite tablets will not dissolve readily in water colder than 41 degrees F, so the availability and temperature of the mixing water must be considered.
- In hard water, calcium hypochlorite may form a calcium carbonate precipitate that will interfere with the solution feed pump unless the chlorine solution is prepared in a separate tank and allowed to settle. The clear liquid is then siphoned to a storage tank for use.

4. WATER TREATMENT

4.5 Handling Chlorine

- Sodium hypochlorite may also form some precipitate but may not need to be settled and siphoned.
- Sodium hypochlorite is often fed at full strength from the container, allowing for fewer problems in handling.

4. WATER TREATMENT

- **4.6 Other Disinfectants**
- **Ulta Violet Light**

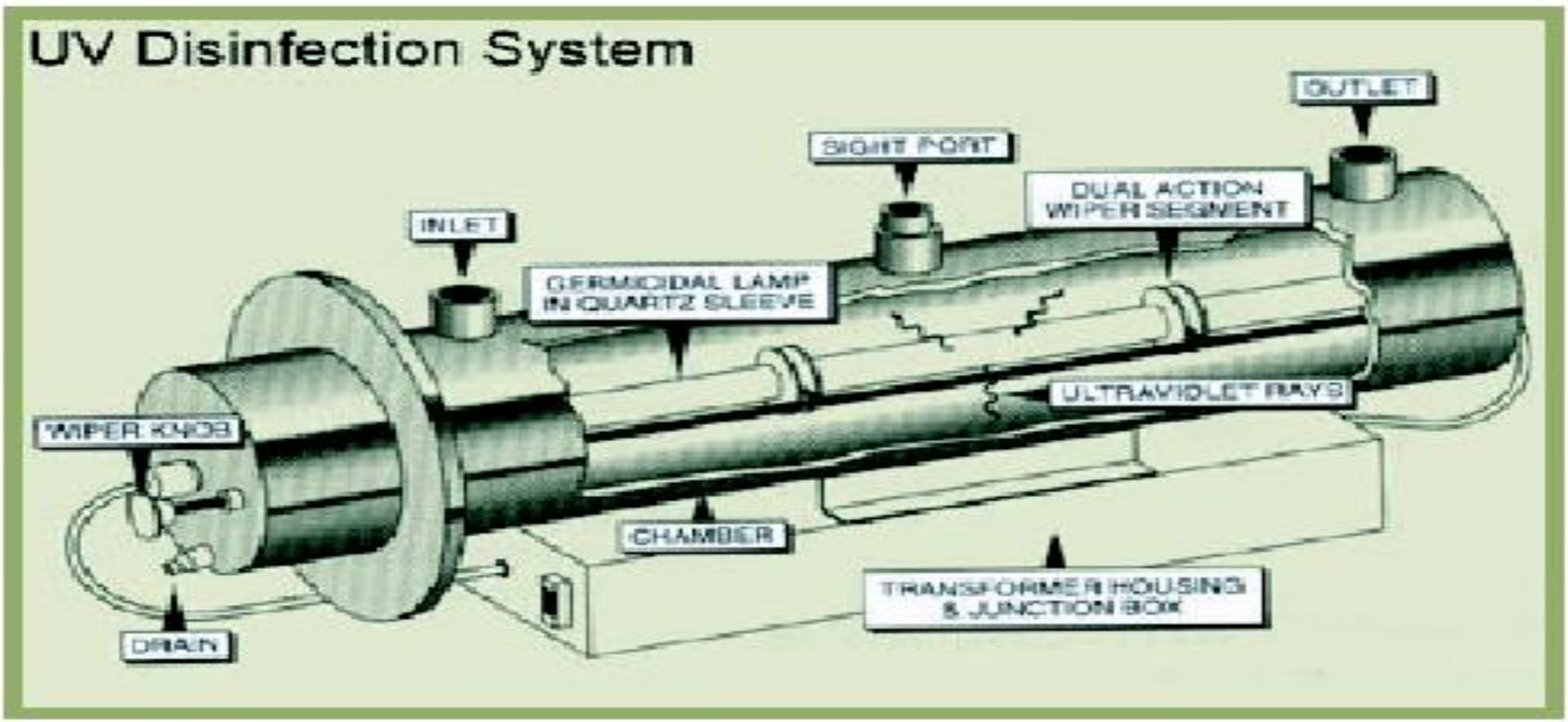


Figure 1: UV disinfection system (F-26)

4. WATER TREATMENT

- **4.6 Other Disinfectants**
- **Ozone – O_3**
- **New Form:** Passage of an electric current through a continuous flow of brine (salt) solution results in generation of a mixture of ozone, chlorine dioxide, hypochlorite ion, hypochlorous acid and elemental chlorine.

- **4.7 Treatment for Chemical / Physical Contaminants: Nitrate and Nitrite**
- Public water supply systems with total N concentrations over 0.5 mg/L must have their water checked for the concentration of nitrite. Levels of nitrate greater than 10 mg/L and levels of nitrite above 1 mg/L pose an acute health threat to infants under six months of age and unborn children. The health effect is caused by interference with the ability of blood cells to carry oxygen, which leads to a condition called methemoglobinemia (blue baby syndrome).
- Figure 1: Agriculture - a prime source of nitrates

4. WATER TREATMENT

- **4.7 Treatment for Chemical / Physical Contaminants: Nitrate and Nitrite**
- Nitrate is most commonly removed using either reverse-osmosis membrane filtration , electro-dialysis reversal, or an ion-exchange process, much like a water softener. In the softening process, water is passed through a tank containing resin, and the nitrate ions are adsorbed onto the resin and exchanged for another ion. The resin is usually a synthetic plastic and is specifically designed to remove nitrate. The treatment process usually consists of pre-filtration, ion exchange, and disinfection

4. WATER TREATMENT

- **4.7 Treatment for Chemical / Physical Contaminants: Iron and Manganese**
- Excessive amounts of iron and manganese in drinking water are objectionable because they stain clothes, fixtures, and encourage the growth of iron bacteria and other nuisance bacteria. For these reasons iron should not exceed 0.3 mg/L and manganese should not exceed 0.05 mg/L.

4. WATER TREATMENT

- **4.7 Treatment for Chemical / Physical Contaminants: Iron and Manganese**
- Excessive amounts of iron and manganese in drinking water are objectionable because they stain clothes, fixtures, and encourage the growth of iron bacteria and other nuisance bacteria. For these reasons iron should not exceed 0.3 mg/L and manganese should not exceed 0.05 mg/L.

- **4.7 Treatment for Chemical / Physical Contaminants: Iron and Manganese**
- Iron bacteria form slimes on pipe walls
- When the slime breaks away it causes red water (iron) and black particles (manganese), which also stains fixtures and clothes.

- **4.7 Treatment for Chemical / Physical Contaminants: Iron and Manganese**
- If the water contains less than 1.0 mg/L iron and less than 0.3 mg/L manganese, the use of phosphate, sequestering agents, followed by chlorination, can be an effective and relatively inexpensive treatment.

  Adding a sequestering agent will keep the iron and manganese in suspension so it will not precipitate and cause staining problems.

4. WATER TREATMENT

- **4.7 Treatment for Chemical / Physical Contaminants: Iron and Manganese**
- Iron and manganese can also be removed by oxidizing them to form insoluble precipitates and then filtering the precipitates out of the water.
- Chlorine is often used to oxidize these contaminants. However, potassium permanganate can also be used, but the dosage must be exact.
- An inadequate dosage of potassium permanganate will leave some of the iron or manganese unoxidized, and too much will cause a pink color in the water going to the distribution system.

- **4.7 Treatment for Chemical / Physical Contaminants: Iron and Manganese**
- Aeration (spraying or bubbling the water over trays) can also be used to oxidize iron. As the pH rises, the reaction rate increases. Some holding time must be provided for the reaction to take place and for the iron particles to settle out. A filtration process takes out the remaining particles.
- Iron and manganese can also be removed using an ion exchange process, but if the water contains much dissolved oxygen, it could foul the resin. Specific resins are available for iron and manganese removal.

4.7 Treatment for Chemical / Physical Contaminants: Taste and Odor

- People often get used to the taste of water they are exposed to every day. However, water operators will hear from their customers very quickly if these taste and odor characteristics change.
- Some tastes and odors make water undrinkable. Tastes and odors have been described as bitter, oily, dry, metallic, musty, earthy, fishy, grassy, or hay-like. Some water may even smell like rotten eggs - a result of having hydrogen sulfide gas in the water.

4.7 Treatment for Chemical / Physical Contaminants: Taste and Odor

- **Although bad taste and/or odor can be in safe drinking water, it may not be palatable (good tasting).**
- **It is the operator's job to make the water acceptable to customers' taste. When people don't like the taste they may not be supportive of needed changes in the water system, they may begin to buy bottled water or they may get water from a supply that is less safe, but tastes better.**

4.7 Treatment for Chemical / Physical Contaminants: Taste and Odor

- Tastes and odors go hand-in-hand. It is difficult for people to tell which of their senses is being affected.
- There are really only four true tastes - sour, sweet, salty, and bitter. Other variations on these are actually caused by odor.
- Surface water sources may be much more subject to tastes and odors because of exposure to algae, municipal wastewaters, agricultural runoff, vegetation die-off, and chemical spills.

4.7 Treatment for Chemical / Physical Contaminants: Taste and Odor

- Ground water tastes and odors may be caused by dissolved gases, biological growths, or by inorganic or organic contaminants.
- Organic contaminants most often are the result of a chemical spill or of unauthorized dumping, sometimes resulting in the abandonment of ground water supplies miles from where organic solvents were originally dumped.

4.7 Treatment for Chemical / Physical Contaminants: Taste and Odor

- **A variety of contaminants could also be introduced to drinking water through cross connections. Often the first warning the operator has of such a condition is the complaints about a "chemical" or "pesticide" taste or odor in the water.**
- **In the distribution system, microbiological growth in dead end lines or in sediment in the bottom of a storage tank could be a cause of taste and odor problems.**

4. WATER TREATMENT

4.7 Treatment for Chemical / Physical Contaminants: Taste and Odor

- A good preventive maintenance program of routine hydrant flushing and storage tank cleaning can prevent these problems from occurring.
- Sometimes the problem may be traceable to an individual customer's plumbing. Stale water in some of the lines, inadequate cleaning of faucet aerators, or bacterial growth in a faucet-mounted filter may all contribute to undesirable tastes and odors.

4. WATER TREATMENT

4.7 Treatment for Chemical / Physical Contaminants: Taste and Odor

- **Aeration is often used to remove a variety of volatile taste and odor contaminants. This process is known as degasification. Gases like hydrogen sulfide (rotten egg smell) are easily removed.**

4. WATER TREATMENT

4.7 Treatment for Chemical / Physical Contaminants: Taste and Odor

- The aeration process may take place by moving air through the water (bubbling air through a diffuser) or by passing the water through air (spray nozzles, aeration trays, etc.). A process called packed column aeration (PCA), or air stripping, combines both processes by flowing water over columns of support media (or packing) while forcing air up through these
- columns of media. This process improves the removal efficiency of the volatile substances.

4.7 Treatment for Chemical / Physical Contaminants: Taste and Odor

- Granular activated carbon (GAC) is also one of the best available treatments for volatile organics. Water is run through a stationary bed of GAC and the contaminant particles are adsorbed onto the surface of the carbon.
- Although GAC is quite useful in removing volatile organics, its removal efficiency varies for other types of organic compounds. The process would be rather expensive for very small water systems, as it requires monitoring the performance of the filter and periodic replacement of the filter media.
- Both chlorine and potassium permanganate can be used to oxidize odor-producing compounds. These are often more useful in water systems dealing with surface water taste and odor problems.

FUNDAMENTALS OF WATER SYSTEM OPERATIONS - OPERATOR BASICS

WATER AND SEWERAGE COMPANY

ST. LUCIA

WELCOME TO

WORKSHOP

DAY 2

DATE: APRIL 20 & 21 2006

OPERATOR BASICS

4. WATER TREATMENT

- **4.8 Treatment for Chemical / Physical Contaminants: Suspended Matter (Turbidity)**
- Water will sometimes contain Suspended Matter.
- This material could not only cause cloudy unappealing water, but it could also settle at low points in the distribution system or cause clogging problems in customer's plumbing systems. Consequently, some small water systems use filtration systems to trap this material before it enters the distribution system.

4. WATER TREATMENT

- 4.8 Treatment for Chemical / Physical Contaminants: COLOUR
- Natural colour exists in water primarily as negatively charged colloidal particles.
- Colour caused by suspended matter is referred to as apparent colour and is differentiated from colour due to vegetable or organic extracts that are colloidal and which is called true colour.
- Waters containing colouring matter derived from natural substances undergoing decay in swamps and forests are not considered to possess harmful or toxic properties.

4. WATER TREATMENT

- **4.8 Treatment for Chemical / Physical Contaminants: COLOUR**
- **Not aesthetically pleasing – consumers will shun coloured water and prefer unsafe but clear supplies**
- **MCL for colour is 15 units**
- **Treatment is readily accomplished by coagulation with the aid of a trivalent metallic ion such as alum**

4. WATER TREATMENT

- **4.8 Treatment for Chemical / Physical Contaminants: Hardness**
- Some consumers use hardness as a measure of the
- quality of the water they receive. Hardness is a characteristic of water caused mainly by the presence of calcium and magnesium.
- Excessive concentrations of these chemicals tend to inhibit the cleaning action of soap, cause deposits in boilers and hot water heaters, and interfere with many industrial processes. Customers often complain about the difficulties in doing the laundry and washing dishes.

4. WATER TREATMENT

- **4.8 Treatment for Chemical / Physical contaminants: Hardness**
- Excessively hard water can coat the insides of pipes and distribution mains and eventually restrict
- flow.
- Hardness is often expressed in terms of mg/L as calcium carbonate. There are different opinions on where the dividing line is between soft and hard water, but some textbooks define hard water as water with hardness greater than 100 mg/L as calcium carbonate.

4. WATER TREATMENT

- **4.8 Treatment for Chemical / Physical contaminants: Hardness**
- The most popular method of hardness removal is the ion exchange process. Many customers might have one of these units in their home and refer to it as a "water softener". This process also has some other benefits such as removal of small amounts of iron and manganese, and radioactivity that might be in the water.
- On the negative side, soft water can increase the rate of corrosion of metal pipes.

4. WATER TREATMENT

- **4.8 Treatment for Chemical / Physical contaminants: Hardness**
- An ion exchange process can be used centrally by a public water supply to soften all the water for their customers. In the ion exchange process, water is passed through the resin in the treatment unit and the resin exchanges sodium ions for calcium and magnesium. The calcium and magnesium remain trapped on the resin until the system is back flushed with a high concentration of salt (sodium chloride) and the resin is again recharged with sodium ions. The brine solution is then flushed out of the unit and the ion exchanger is again ready to begin trapping calcium and magnesium and exchanging it for sodium.

OPERATOR BASICS

4. WATER TREATMENT

- **4.8 Treatment for Chemical / Physical contaminants: Hardness**
- Fluoridation is an optional process. Many community water systems and some schools add fluoride to the drinking water to help prevent tooth decay.
- A small amount of fluoride in the diet is essential to the health of teeth and bones. Fluoride levels between 0.9 and 1.5 parts per million (ppm) are considered optimal for drinking water.
- Some water supplies have naturally occurring fluoride at or near optimal levels, but many do not.
- **At levels above 2.0 ppm, fluoride is known to cause brown mottling (discoloration) of teeth.**
- **At levels above 4.0 ppm it is suspected of causing brittle bones.**
- **Fluoride is toxic, and has been shown to be fatal, if the concentration in drinking water is too high.**
- These incidents of acute toxicity have been attributed to improper fluoride addition to a water system, not naturally occurring levels in water.

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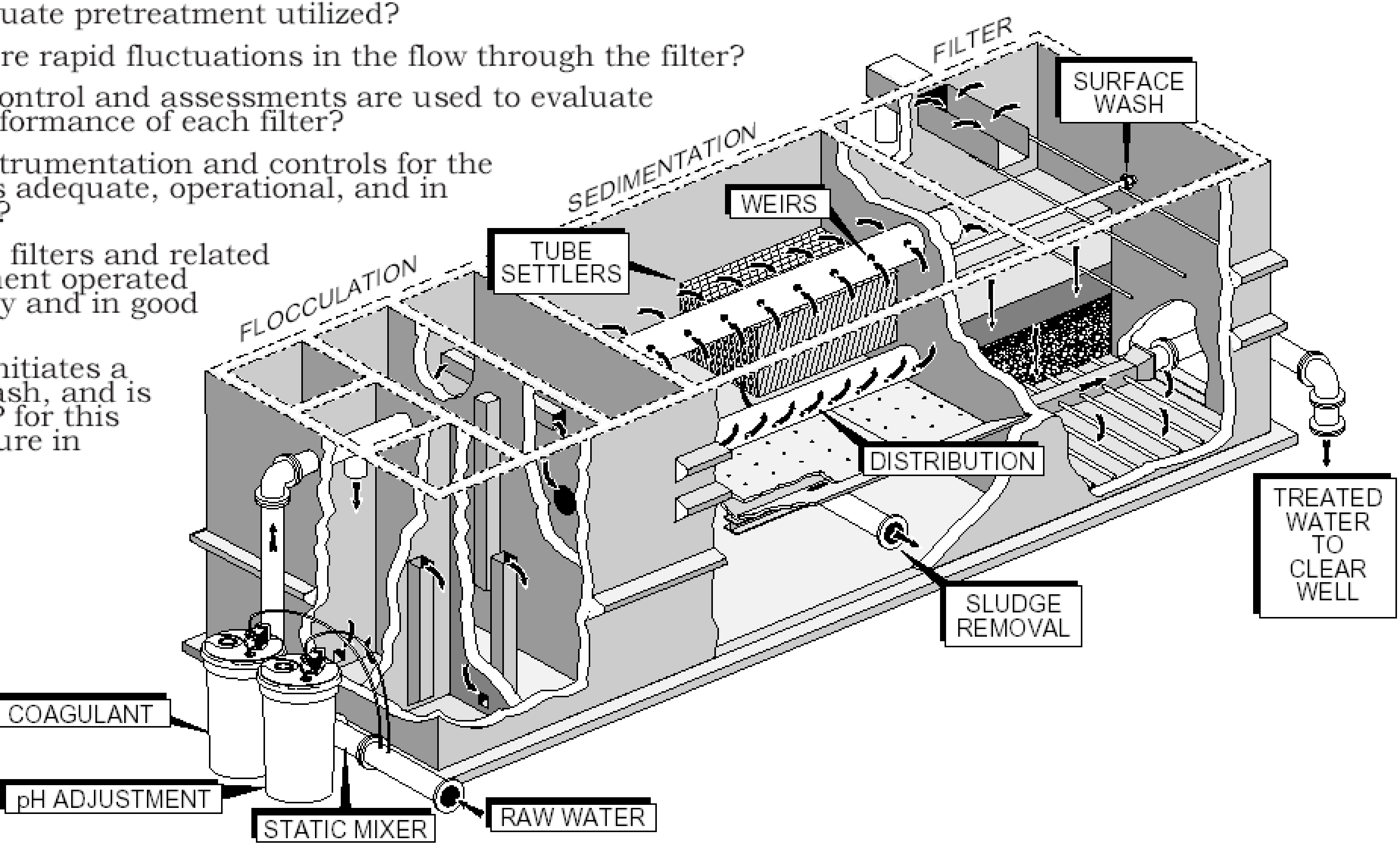
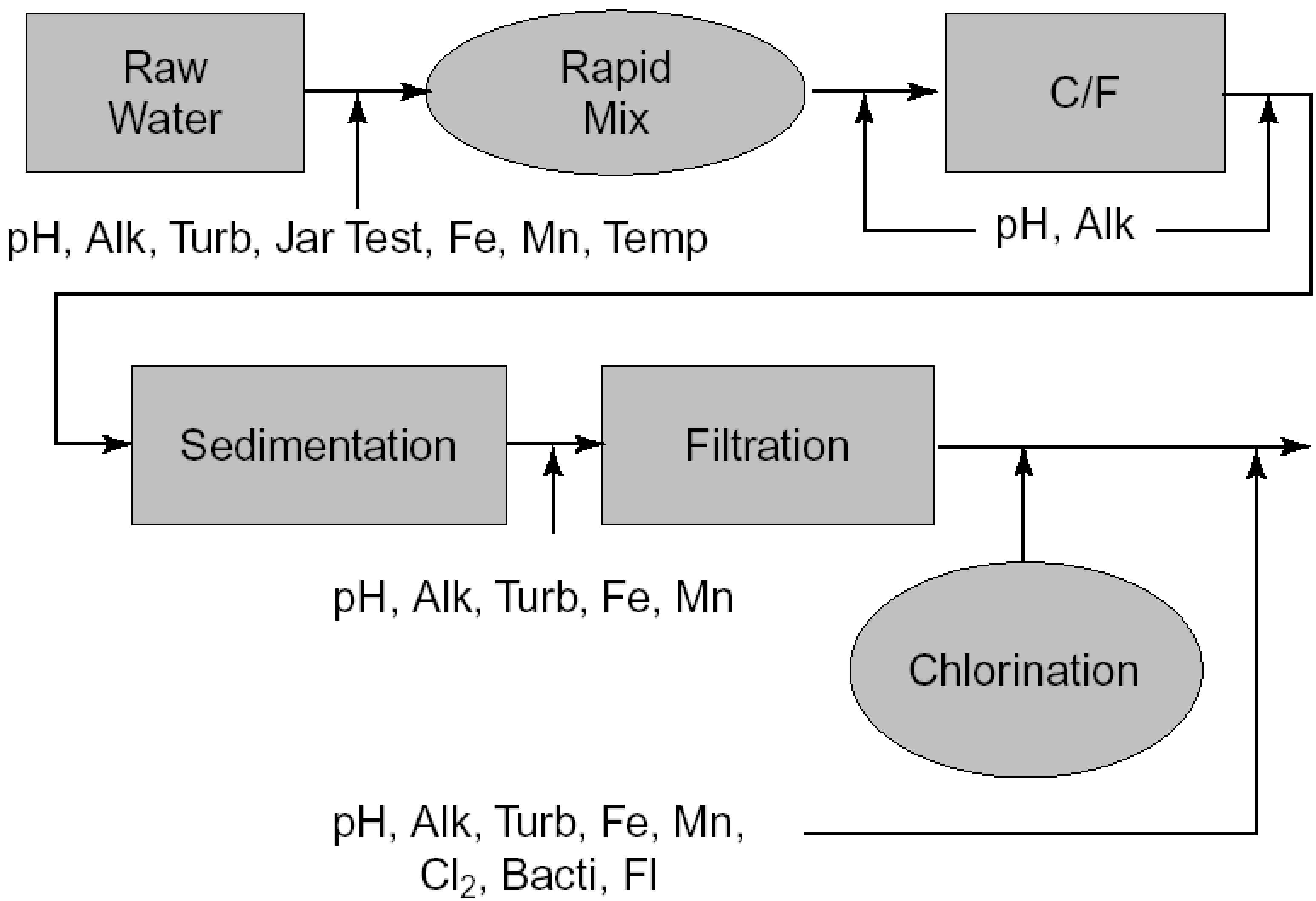


OPERATOR BASICS



OPERATOR BASICS

- **5. Distribution Systems**
- **Topics to be Reviewed:**
- **Basic water distribution system components**
- **Unaccounted-for water in a distribution system**

- **5. Distribution Systems**
- **5.1 System Components**
- This unit provides a basic explanation of the following
- water distribution system components :
- - piping;
- - valves;
- - hydrants;
- - meters;
- - storage reservoirs; and
- - booster stations.

- **5. Distribution Systems**
- **5.1 System Components**
- An adequate distribution system is able to provide a sufficient amount of safe water to all users at a pressure that will satisfy normal needs. It also provides water without undue water loss.
- Even in a metered system, not all water coming from the treatment plant can be accounted for. Some is lost because of theft, leaks in the system, some may be discharged through hydrants as part of a flushing program, under-registration of meters and some may evaporate from storage tanks or be used fighting fires or watering city parks. This portion is usually referred to as unaccounted-for water or non-revenue water

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1 System Components – Leak Detection**

Rergulation ?

- **5. Distribution Systems**
- **5.1 System Components**
- Leak detection programs can be employed to minimize water loss, thereby reducing maintenance and operating costs. When a water system is completely metered, the comparison between the amount of water produced and the amount billed to customers can sometimes indicate the magnitude of water losses in the system.
- To properly maintain the system it is important that operators be familiar with all parts of the system and the effects they may have on the quality of the water served to customers.

OPERATOR BASICS

- 5. Distribution Systems
- 5.1.1 System Components: Piping
- There are four general types of piping systems used by water utilities:
- Transmission Lines
- In-plant piping systems
- Distribution Mains
- Service Lines

OPERATOR BASICS

- 5. Distribution Systems
- 5.1.1 System Components: Piping
- Transmission Lines:
- Transmission lines carry large quantities of water from a source of supply (raw water) to a treatment plant or from a treatment plant or pumping station to a distribution system.
- They generally from one location to another without service connections

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.1 System Components: Piping**
- **In-plant piping systems**
- **In-plant piping systems are the pipes located in pumping stations and treatment plants. The piping is generally exposed and has many valves, outlets and bends that must be secured against movement.**

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.1 System Components: Piping**
- **Distribution Mains**
- **Distribution mains are the pipelines that carry water from transmission lines and distribute it throughout a community.**
- **They have many side connections and are frequently tapped for customer connections**

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.1 System Components: Piping**
- **Service Lines**
- **Service lines or services are small-diameter pipes that run from the distribution mains to the customer premises**

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.1 System Components: Piping Materials**
- A variety of pipe materials are available for use in a public water supply system to carry water under pressure. They include:

plastic,

Gray cast iron/ductile iron,

steel,

Fibreglass

concrete and

asbestos-cement.

Service pipes (those running from the distribution system to a customer) may be made of copper, plastic, iron, steel, or brass. In the Caribbean what is the most common material?

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.1 System Components: Piping Materials**
- Standards organizations have established standards to ensure that materials used in distribution systems will not leach contaminants into the drinking water and will meet minimum strength criteria.

- **5. Distribution Systems**
- **5.1.1 System Components: Piping Materials**

Figure 1: Advantages and drawbacks of pipe materials

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.1 System Components: Piping Materials**
- The following are brief summaries of the various types of pipe commonly found in water systems:

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.1 System Components: Piping**
- Ductile Iron Pipe / Gray cast iron:
- A system might include two types of cast iron pipe - gray cast iron and ductile iron.
- Although it is no longer manufactured, gray cast iron pipe over one hundred years old is still in use in some systems. It is tough and easily tapped.
- Ductile iron is similar but stronger, less rigid, lighter, and offers better corrosion resistance. Ductile iron is lined on the inside to prevent corrosion, and to provide a smooth pipe interior that offers little frictional resistance to flow. On the exterior, bituminous coatings or a polyethylene wrap may be used to reduce corrosion caused by aggressive soils.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.1 System Components: Piping**
- Steel Pipe:
- Steel pipe is lighter than ductile iron and has a high tensile (pulling or stretching) strength, some flexibility, is easily installed and joined, low in cost, readily welded together, and easily assembled, handled and transported.
- However, it is more subject to corrosion and therefore must be lined or coated inside and out. Coatings or linings might be a cement or epoxy material and the exterior could be coated with epoxy or mastic or with a protective plastic wrap. Galvanized pipe is steel pipe that has been coated with zinc.

- **5. Distribution Systems**
- **5.1.1 System Components: Piping**
- Concrete Pipe:
- Concrete pipe is durable, has good internal corrosion resistance, requires little maintenance and is easily
- installed. Prestressed concrete (also called reinforced concrete) is the most common type and has reinforcement
- with wire strands to provide more resistance to loads and pressure. The disadvantages of concrete pipe are that it
- is heavy, difficult to tap, needs special fittings, and may deteriorate in aggressive soils. It is available in sizes
- 12-inch diameter and larger.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.1 System Components: Piping**
- Asbestos-Cement (AC) Pipe:
- Asbestos-cement pipe was quite popular until it was found, under certain conditions, to release asbestos fibers that can be harmful to human health.
- Health concerns are mainly with airborne asbestos, but researchers are still investigating the effects of ingestion.
- Airborne asbestos affects those in the pipe manufacturing business and those involved in pipe replacement, repair, or tapping.

- **5. Distribution Systems**
- **5.1.1 System Components: Piping**
- Asbestos-Cement (AC) Pipe:
- AC pipe will not burn, deteriorate, or corrode, and has a high tensile strength. It is light (about half the weight of ductile iron pipe); very smooth inside so it offers little frictional resistance to flowing water, and it is easily tapped, cut and machined in the field.
- The disadvantages of AC pipe include easy breakage when bent and vulnerability to impact damage. It is also difficult to locate when buried and can't be thawed using electrical methods because it doesn't conduct electricity. Asbestos fibers can leach out of the pipe when it is transporting very soft water. Respirators should be worn when there is the possibility of asbestos fibers becoming airborne during placement or repair.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.1 System Components: Piping**
- Plastic Pipe:
- Plastic pipe has become very popular in many parts of the country.
- The types of pipe in general use are PVC (polyvinyl chloride), PE (polyethylene), and PB (polybutylene). Plastic pipe has very low frictional flow resistance because it has such a smooth interior surface.
- It is light and easy to handle and join.
- The pipe materials are not subject to corrosion, and are generally less expensive than other types of pipe.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.1 System Components: Piping**
- Service Lines:
- A wide variety of materials have been used for service lines but the most common in the Caribbean are polyvinyl Chloride (PVC), polyethylene and copper.
- Lead service lines were once popular……**no longer used**
- Where the potable water is soft, lead service lines may have to be replaced by the water utility to eliminate the leaching of lead from the lines into customers' drinking water.
- Corrosion control treatment can also be an effective remedy for lead leaching.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.2 System Components: Valves**
- Valves are a very important part of the distribution system because they regulate the flow of water, reduce pressure, provide air and vacuum relief, blow off or drain water from parts of the system and prevent backflow.
- The operator should know the locations of all system valves so they can be used when necessary.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.2 System Components: Valves**
- Each water system should have a current map with the locations of all the valves clearly marked.
- It is important that access to the valves not be compromised by other facilities.
- For example, access to a valve can unknowingly be covered during street repair if its location is not known to the repair crew.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.2 System Components: Valves**
- Valves of any size need to be operated slowly. Closing a valve too quickly causes water hammer. When flowing water is suddenly stopped, shock waves are generated, which cause large pressure increases throughout the system. These shock waves travel quickly and can cause extensive damage, sometimes splitting pipes or blowing fittings completely off the system.

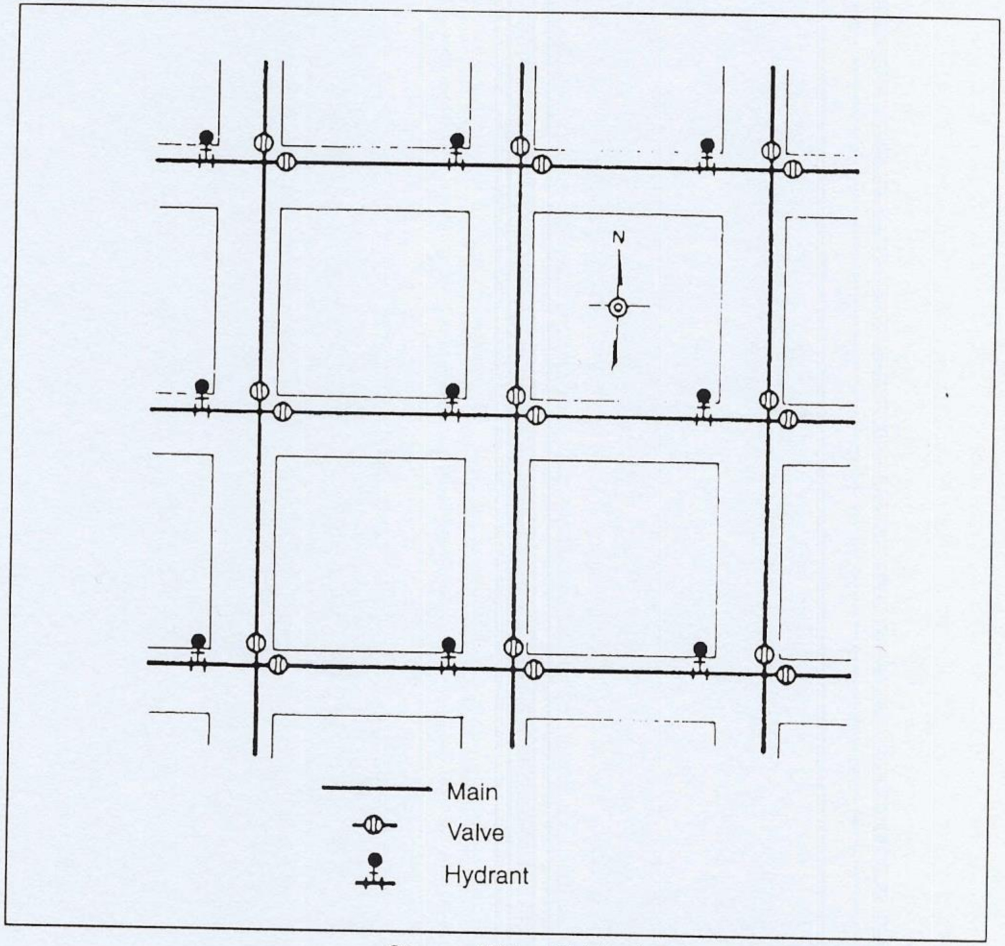
OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.2 System Components: Valves**
- The operation of a valve frequently creates a partial vacuum or void on the downstream side of the valve.
- These voids fill with low-pressure vapors from the water. When these pockets collapse, they create a mechanical shock causing flakes of metal to break away from the valve surface.
- A noisy or vibrating valve may be an indication that cavitation is occurring. This will eventually result in leaks and a valve unsuitable for service.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.2 System Components: Valves**
- Gate valves are used to isolate sections of the distribution system to permit emergency repairs without interrupting service to large numbers of customers.
- In the gate valve, a sliding flat metal disc is moved at right angles to the direction of flow by a screw-operated stem. The disc can be taken completely out of the flow chamber so that the valve provides very little resistance to flow when it is open.

FIGURE 2-1
Valves installed at intersection of mains in a grid pattern



Source: Water Distribution Operator Training Handbook.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.2 System Components: Valves**
- Various types of rotary valves are available, including the ball, butterfly, and plug valves. Usually a 90-degree rotational movement opens the valve, with a notch, arrow or other indicator to show valve positions.
- In a ball valve, the movable part is a ball with a cylindrical hole bored through it. When the ball is in the open position there is a straight passage through the valve, but when it is rotated 90 degrees the flow is blocked. Ball valves should be operated either closed or opened all the way.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.2 System Components: Valves**
- The butterfly valve is a disc that fills the full diameter of the pipe.
- The disc rotates on a shaft to permit or block the flow of water.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.2 System Components: Valves**
- Plug valves are most often used as corporation stops on service lines. They may have a tapered or cylindrical plug with an opening through the side that can be turned to open, restrict, or close the flow.
- Globe valves are very efficient in either flow or pressure regulation. In these valves, a disc is raised or lowered onto a seat, and the flow of water is blocked when the disc contacts the seat. This is the principal of operation of the common home faucet.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.2 System Components: Valves**
- In a diaphragm valve, a flexible piece (usually rubber or leather) inside the valve's body can be adjusted up or down using an attached stem to block or regulate the flow of water.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.2 System Components: Valves**
- Pressure-reducing valves reduce the water pressure by restricting the flow. Pressure on the downstream side of the valve regulates the amount of flow permitted through it. This type of valve is usually of the globe design with a spring-loaded diaphragm that sets the size of the opening. As downstream pressure is exerted against the diaphragm, the spring is compressed, moving the valve element toward the seal, thereby limiting the flow. If the downstream pressure drops, the spring opens the valve element and provides more flow.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.2 System Components: Valves**
- Pressure Reducing Valves allow distribution systems to maintain pressures to the customers in the desirable 50 to 80 psi range. Pressure regulators are especially valuable in hilly areas where elevation differences produce high differentials in pressure within the distribution system.
- Backflow prevention or cross-connection control can be accomplished using valves specifically designed for that purpose.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.2 System Components: Valves**
- Most valves do not provide an absolute stoppage of water. Most leak under some circumstances, many just because of age and deterioration. Leaking valves have been responsible for contamination of public water supply systems when they were the only barrier between the water system and a non-potable supply.

OPERATOR BASICS

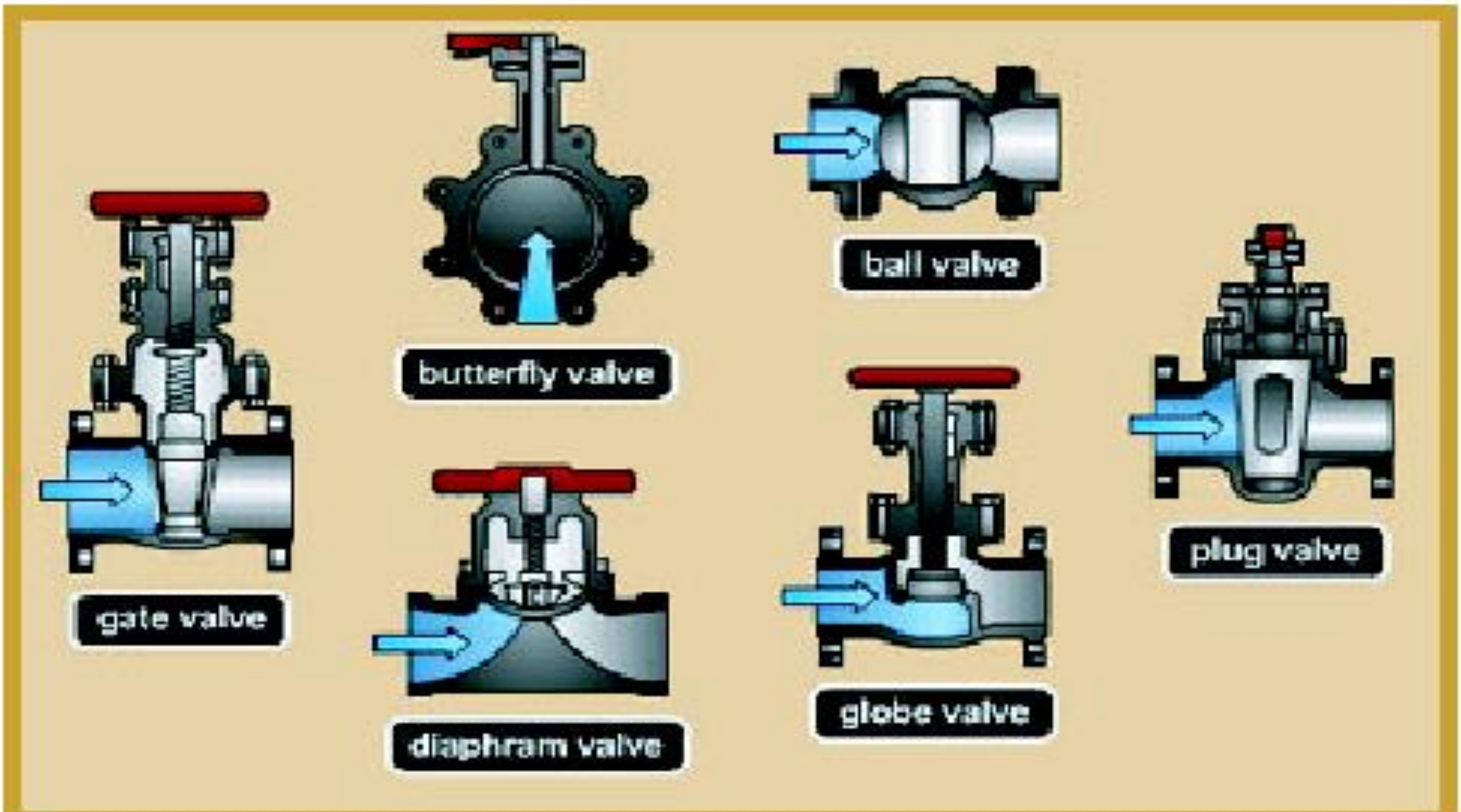
- **5. Distribution Systems**
- **5.1.2 System Components: Valves**
- Preventive Maintenance:
- Valves should be inspected and operated annually. Valves are more apt to suffer from lack of use than from overuse. Annual exercise of valves will keep them in operable condition. Otherwise, they may become stuck and will be inoperable when really needed. This valve-exercising process should be geared into a routine maintenance plan.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.2 System Components: Valves**
- Valves should be exercised full open to full closed. Records should indicate whether the valve is right or left hand and whether the valve is normally closed or open. The condition of the packing and nut should be noted. A follow-up program of correction of valve deficiencies should be carried out and these corrections or replacements noted in the valve file and on maintenance maps.
- Valve boxes are often located beneath streets and they should be checked annually to see that they are not damaged, filled with debris, or paved over.

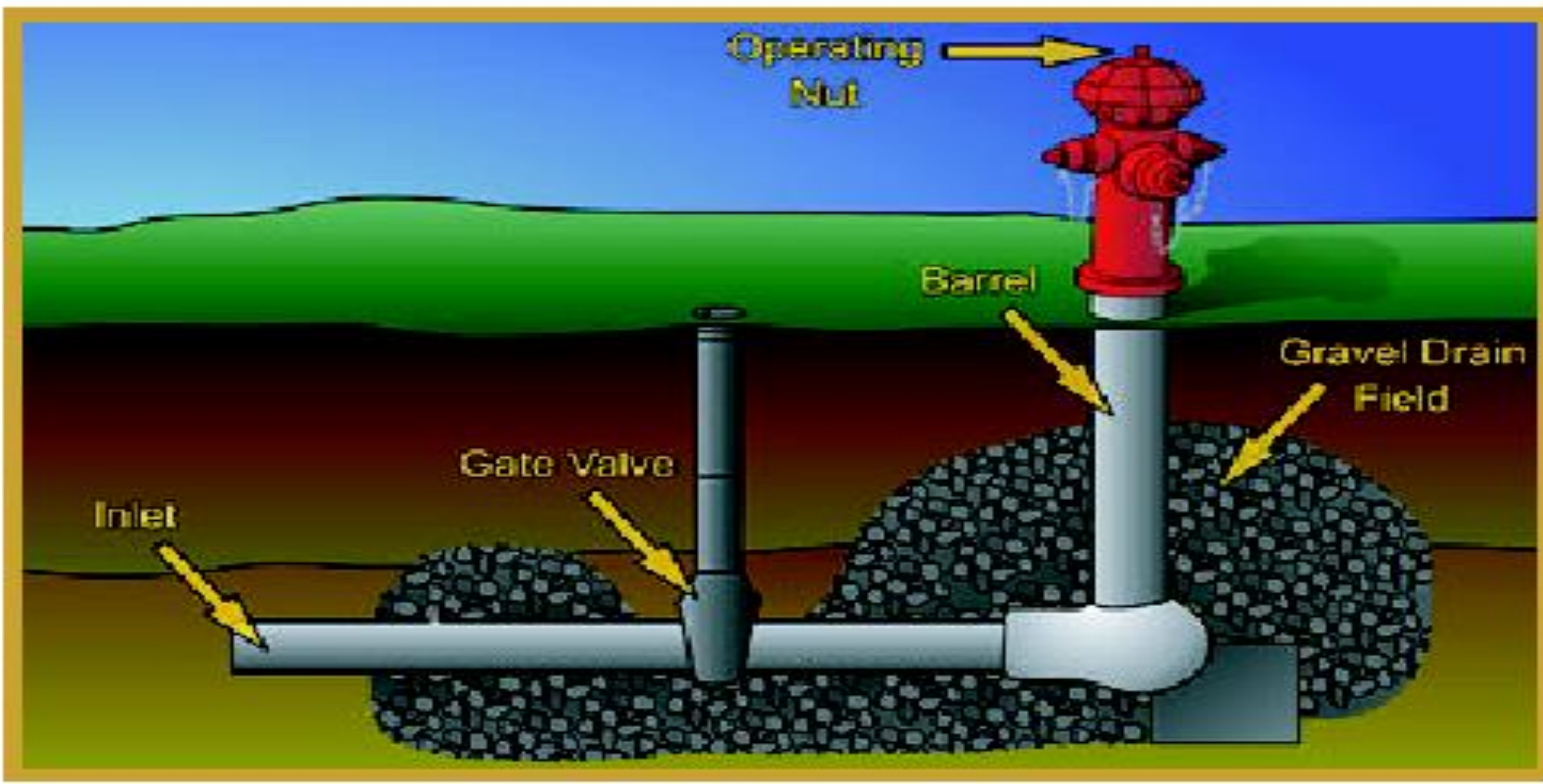
OPERATOR BASICS

- **5. Distribution Systems Valves**



OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.2 System Components: Fire Hydrants**



OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.3 System Components: Fire Hydrants**
- If the water system is designed to provide fire protection, it will include fire hydrants.
- The water lines and the hydrant connections to the distribution system must be a minimum of 100 mm in diameter.
- The location and spacing of hydrants is specified in Utility's design standards. Generally, in residential areas they should be at every street intersection.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.3 System Components: Fire Hydrants**
- Preventive Maintenance:
- A program of distribution system flushing should be
- established.
- Flushing is usually done at fire hydrants or at special flushing hydrants on dead end lines.
- Larger systems should develop a flushing protocol whereby hydrants nearest the source are flushed first, and subsequent hydrants are flushed sequentially outward toward the end of the distribution system. This prevents suspended sediment from being inadvertently flushed back into the distribution system through interconnections and looped mains. The hydrant flushing exercise can be combined with an inspection of the hydrants

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.3 System Components: Fire Hydrants**
- Preventive Maintenance:
- Hydrants require an annual inspection, maintenance, and repair routine for the following items:
- - pressure and flow;
- - loose or missing caps and cap chains;
- - damaged nuts or cracked barrels;
- - lost or damaged gaskets;
- - peeling or wearing paint;
- - leakage, using a listening device;
- - lubrication of threads and the operating nut;
- - adequate clearance above ground and from poles,
- posts, buildings;
- - gate valve condition and that valve is in ON position; and
- - complete barrel drainage after use.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.3 System Components: Fire Hydrants**
- Preventive Maintenance:
- The barrel of the hydrant must be drained after use to prevent backflow. Hydrants have a drain hole and if it is plugged, it may be necessary to remove the inside assembly of the hydrant and clean it out.
- If the gravel drain zone has failed, it is necessary to excavate and replace the gravel bed.
- Remember that hydrants should be kept fully open or fully closed. Either way will allow any remaining water in the hydrant to drain from the drain hole
- Partially closing the hydrant will not allow this drainage.
- Hydrants must also be opened and closed slowly to prevent breakage of the connecting pipe or joint.

OPERATOR BASICS

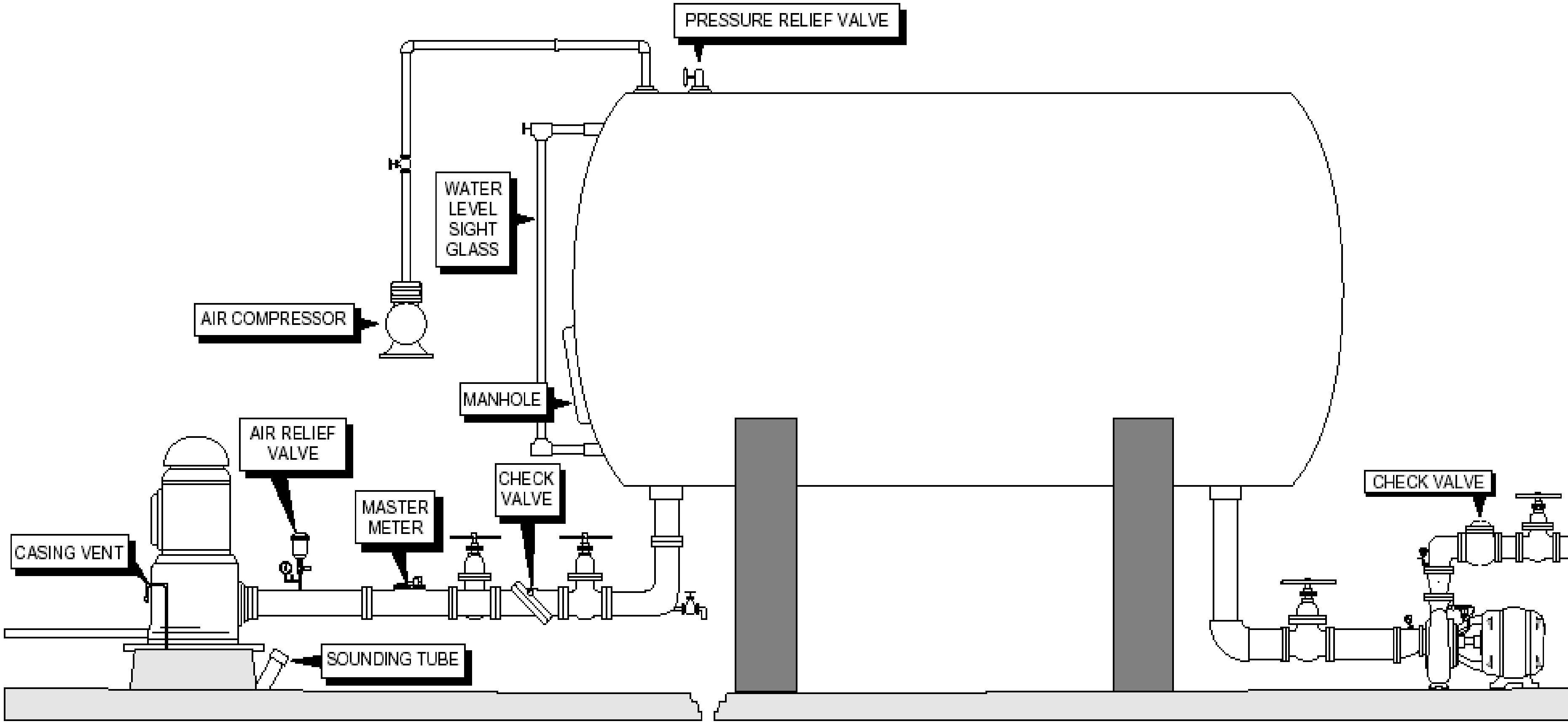
- **5. Distribution Systems**
- **5.1.4 System Components: Storage Reservoirs**
- Small water systems may have a small amount of storage in the form of a hydropneumatic tank - either a standard pressure tank with an air/water interface, or a captive-air tank.
- Other systems might have ground level concrete or steel storage tanks or elevated steel tanks that serve the system by gravity.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.4 System Components: Storage Reservoirs**
- Small hydropneumatic pressure tanks are used to maintain pressure within the distribution system and to prevent well pumps from cycling too frequently. These tanks are captive-air tanks.
- Larger hydropneumatic tanks use on-site, permanent air-charging devices to maintain the needed air pressure within the vessel. The tank should have a sight glass so the air/water ratio in the tank can be observed and adjustments made.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.4 System Components: Storage Reservoirs**



OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.4 System Components: Storage Reservoirs**

- Many small water systems have elevated steel tanks or ground level concrete or steel tanks.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.4 System Components: Storage Reservoirs**
- Concrete or steel storage tanks provide a greater amount of storage capacity than hydropneumatic tanks and may provide sufficient fire flows. They also continue to operate for a period of time during a power outage.
- These storage facilities have several openings, and it is vital that they are maintained to keep contamination out.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.4 System Components: Storage Reservoirs**
- All water distribution storage tanks should be covered to protect against contamination.
- All storage tanks should be equipped with vents, an access hatch, overflow outlets and drains.
- The vents should be turned downward and screened or covered to prevent the entrance of dust, birds, insects and other vermin.

OPERATOR BASICS

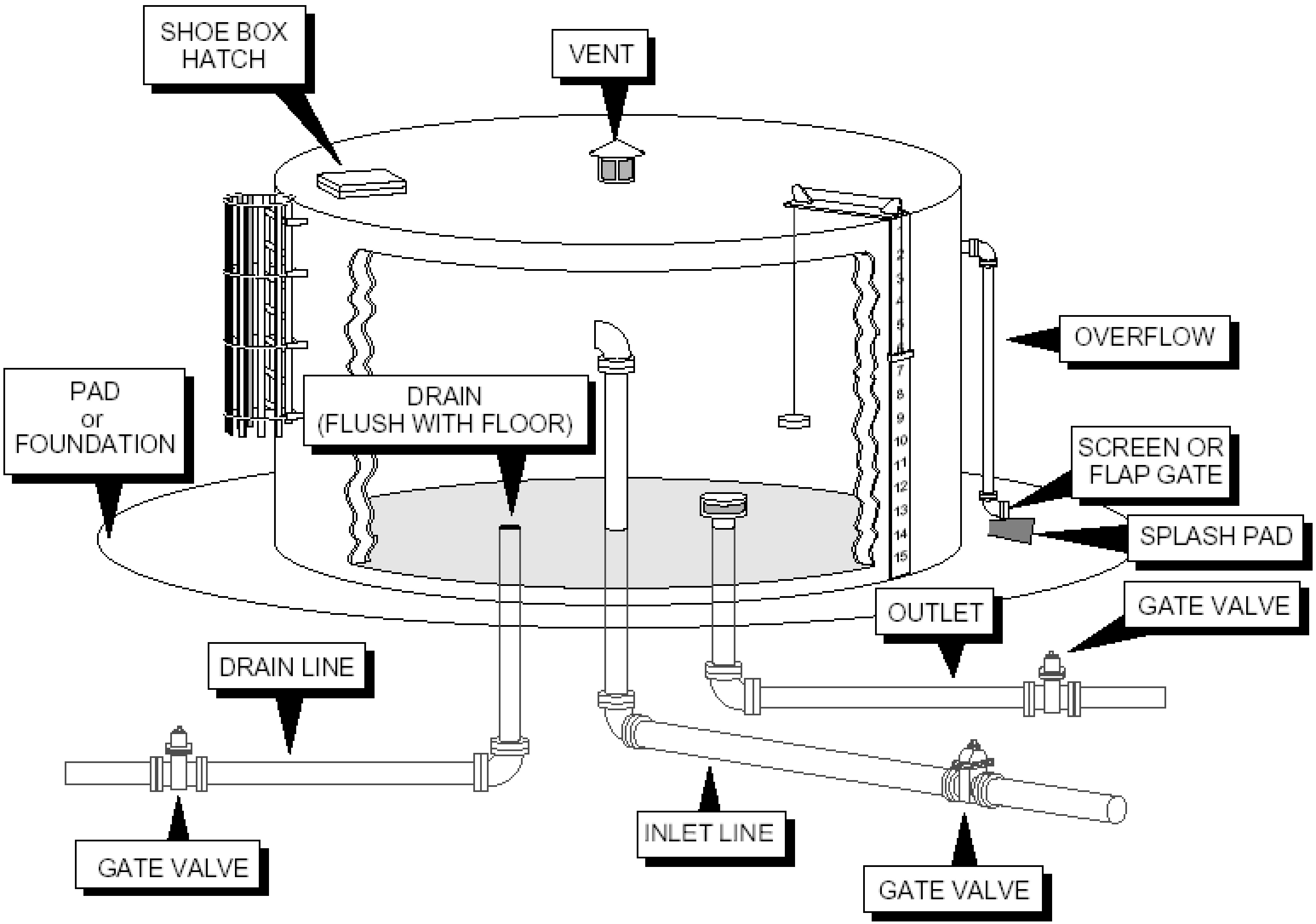
- **5. Distribution Systems**
- **5.1.4 System Components: Storage Reservoirs**

Figure 2: Storage reservoir with shoebox lid and vent

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.4 System Components: Storage Reservoirs**
- The drain and the overflow pipe should also be screened and designed with a splash pad or other means to prevent erosion when overflow or drainage occurs.
- The access hatch should have an overlapping, gasketed, locking, shoebox-type lid

OPERATOR BASICS



OPERATOR BASICS

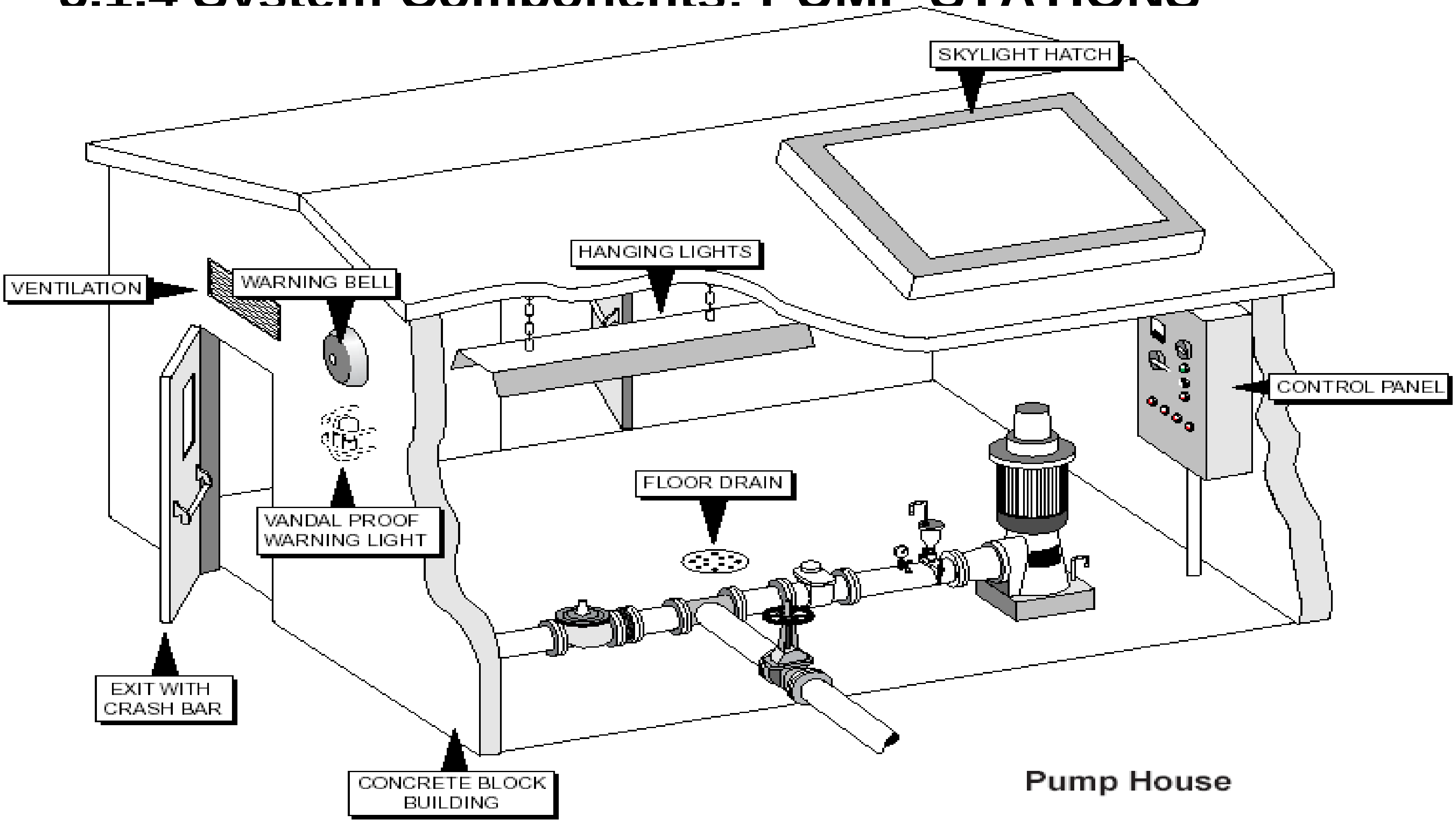
- **5. Distribution Systems**
- **5.1.4 System Components: Storage Reservoirs**
- Preventive Maintenance:
- Storage tanks should be drawn down at least once a year for a complete inspection, inside and out. Inspection should include ensuring that the access hatch lock is operable and the lid is in condition to prevent contaminant entry.
- Also inspect the vent to be certain that the screen is in good condition and will prevent animals of all sizes from entering the tank.
- The inside of a storage tank is an enclosed space, so it's essential that anyone entering the tank for any purpose follow the safety guidelines.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.4 System Components: Storage Reservoirs**
- Interior paint must be properly applied and cured, so no tastes, odors or toxic materials are leached into the water.
- After interior inspection or maintenance the tank should be thoroughly disinfected standard procedure, before being placed back on line.
- It may be necessary to undertake special measures to maintain system pressure and service while the tank is off-line.

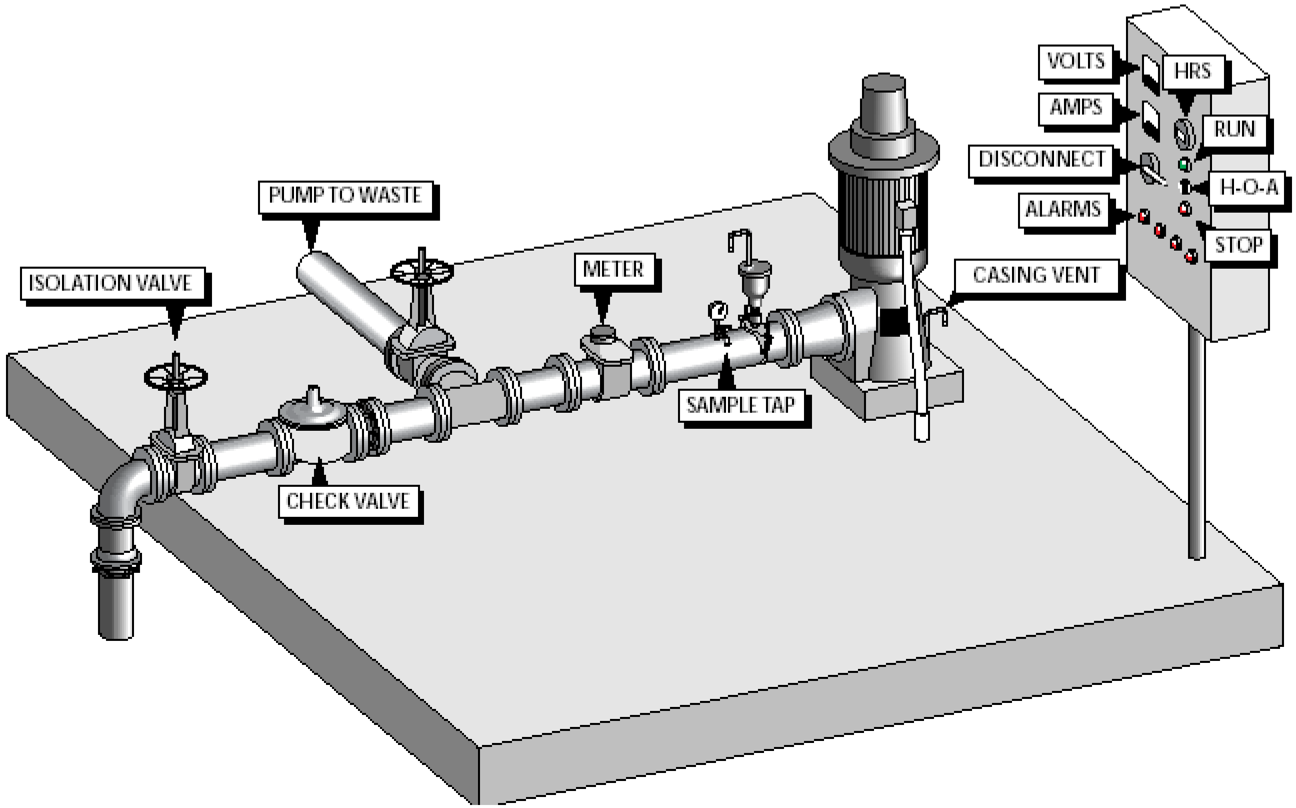
OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.4 System Components: PUMP STATIONS**



OPERATOR BASICS

- **5. Distribution Systems**
- **5.1.4 System Components: PUMP STATIONS**



OPERATOR BASICS

- **5. Distribution Systems**
- **System Components:Pump Station**
- Pump Inspection and Preventive Maintenance Procedures:
- 1. Observe and record pump pressures and flow along with the pump's electricity demands.
- 2. Check for abnormal noise or vibration from all pumps and heat or odor from non-submersible pumps.
- 3. Provide proper lubrication of pump bearings using water or food-grade lubricants specified by the pump manufacturer. Over-greasing and under-greasing are both problematic for pump operation.
- 4. Look for soapy or foamy appearance of the lubricant which could indicate water infiltrating the bearing shaft seals.
- 5. Listen for any bearing noise.
- 6. Tighten packing glands to permit only a small amount of leakage. Do not over-tighten to prevent all leakage. Check the leakage rate daily.
- 7. Inspect the pump priming system for performance and leakage.
- 8. Check automatic pump controls and exercise standby generators each week.
- 9. Check pump alignment on cold pumps and after they have run long enough to reach the proper operating temperature.

- **5. Distribution Systems**
- **System Components:Distribution Systems**

5.2 Construction and Repair

- Providing clean water on a reliable basis requires that water lines be appropriately located and carefully installed in the first place.
- Small-system operators are not usually system designers, but they often have opportunity to comment on proposed designs and oversee new construction.
- They are responsible for line repair - a situation where a careful sequence of actions is needed to prevent water contamination within the system
- So operators should be familiar with the principals of water line layout, as well as good sanitary procedures during repair

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components:Distribution Systems**
- **5.2 Construction and Repair**
- Although the small system operator may not be involved in the design and construction of the water system, it is important to understand a few basic facts about this process. Being aware of some of these fundamental concerns will also assist in making sound decisions when system repairs are needed.

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components: Construction and Repair**
- **Minimum Separation Distances**
- Parallel Installation with Sewer Pipes:
- Water mains should never be laid in the same trench with sewer pipes. The potential for contamination is too great. Most regulations require at least a 10 foot (3m) separation between these two systems.
- Water Main Crossing Sewer Lines:
- When it is necessary for the water line to cross a sewer line, there should be at least 18 inches (450 mm) of vertical separation between the water main and sewer line. Also, one full length of water pipe should be laid so that the joints are as far as possible from the sewer.

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components:**

5.2 Construction and Repair

- Depth of Burial:
- All water mains should be covered with sufficient earth to prevent accidental damage.

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components: Construction and Repair**
- Pipe Bedding:
- A continuous and uniform bedding material (gravel, sand) must be provided in the trench for all buried pipe.
- This will help to prevent future punctures and breakage by large rocks putting excessive pressure on portions of the pipe.
- Backfill material should be tamped in layers around the pipe to provide adequate support and protection for the pipe. This will prevent undue settling and breakage.

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components:**

5.2 Construction and Repair

- Thrust Blocks:
- Flowing water can exert enormous force on portions of the distribution system, especially at pipe bends.
- Therefore, it is important to be certain thrust blocks are placed to support the pipes and other components at all points where the flow of water changes direction (FIGURE 2).

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components: Construction and Repair**
- Thrust Blocks:

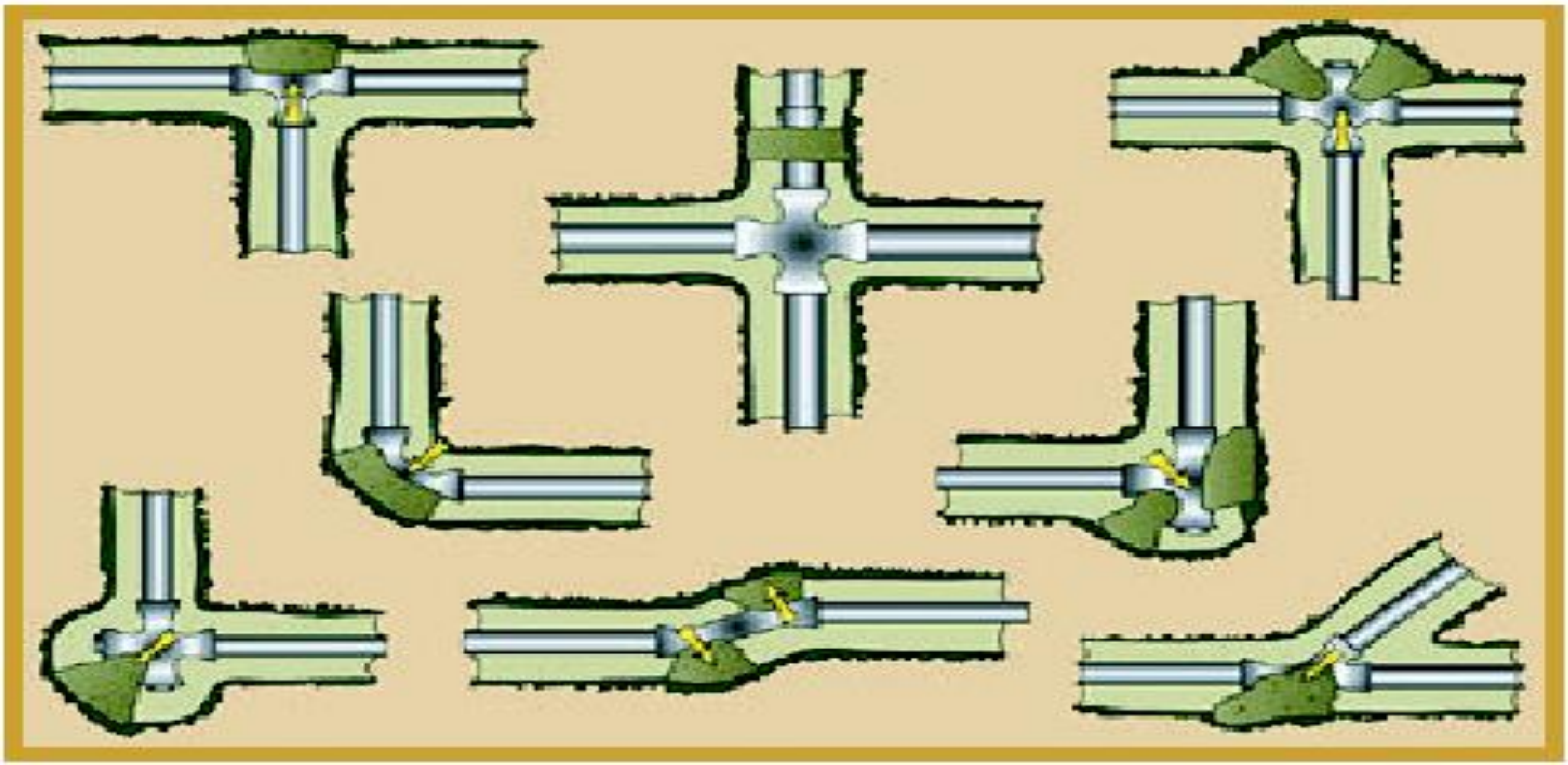


Figure 2: Thrust block examples (F-36)

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components:Construction and Repair**
- **Looped Systems and Dead End Mains**
- Whenever practical, water lines should be installed to loop back into another part of the distribution system.
- This allows circulation of water to all users, and gives a backup source of supply should part of the line be shut off for repair.
- Dead ends should be avoided. The lack of movement of the water in these lines will cause stagnation and result in the growth of slimes and bacteria, and development of taste and odor problems.

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components:Construction and Repair**
- **Looped Systems and Dead End Mains**
- If it is necessary to have a dead end line, a fire hydrant or a flushing hydrant should be installed on the end of the line so stagnant water can be routinely discharged.
- The hydrant should be large enough to generate a flow of 2.5 feet per second (0.7 m/s) in the line for thorough flushing.

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components: Construction and Repair**
- **Looped Systems and Dead End Mains**
- **Preventing Contamination**
- During the construction process it is almost impossible to prevent some contaminating materials from entering the pipe system.
- It is extremely important to keep this contamination to a minimum, so the system can easily be flushed and disinfected before being put back into service.
- All pipes should be carefully stored and handled to prevent damage and the possibility of contamination.

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components:Construction and Repair**
- **Looped Systems and Dead End Mains**
- **Preventing Contamination**
- After it is in the trench, the end of the pipe should be securely plugged each evening before the crew leaves the site.
- This will prevent small animals from entering and will also be a safety measure to protect children who may play in the area.
- When the construction is finished, the contractor must be certain the new portion of the distribution system is thoroughly disinfected before allowing it to be joined with the existing system.

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components: Construction and Repair**
- **Looped Systems and Dead End Mains**
- **Preventing Contamination**
- The new portion should be flushed and disinfected and a coliform test must be taken and the water shown to be of potable quality before it can again become part of the system.
- After the disinfection process, heavily chlorinated water should be disposed of according to regulatory requirements. The water should never be discharged directly to a stream or lake, because chlorine is highly toxic to fish in small amounts.

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components:Construction and Repair**
- **Looped Systems and Dead End Mains**
- **Preventing Contamination**
- **System Repairs**
- Care must be taken when making repairs to avoid contamination if possible.
- The section of the distribution system to be repaired should be isolated as quickly as possible.
- This is especially necessary if extensive damage is occurring because of washouts or flooding.

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components:Construction and Repair**
- **Looped Systems and Dead End Mains**
- **Preventing Contamination**
- **System Repairs**
- Some water system personnel leave a small positive pressure on the line to be repaired so all water will flow out of the pipe and the contaminated water will not flow back in. This generally requires sufficient pumps to keep the water out of the hole and keep it from surrounding the pipe while the repair is being made.

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components:Construction and Repair**
- **Looped Systems and Dead End Mains**
- **Preventing Contamination**
- **System Repairs**
- Customers in the area which will be without water should be notified as quickly as possible and requested to not open their taps until notified by the system operator.
- Notification before the water is shut off is best so the customers can make sufficient preparations.

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components: Construction and Repair**
- **Looped Systems and Dead End Mains**
- **Preventing Contamination**
- **System Repairs**
- It is important to dig out the trench from under the pipe so the pipe is exposed and the repair clamp can be installed freely. This will also allow for clean replacement pieces to be installed. Some water system personnel disinfect the clamp and/or the piece of pipe to be inserted. This is especially important if these pieces of equipment have been sitting around in a storage yard, exposed to the elements.
- Before the repair is made, calcium hypochlorite granules should be placed into the pipe in sufficient quantities to disinfect the portion being repaired. This should result in a chlorine concentration of 100 to 300 mg/l in the pipe.

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components:Construction and Repair**
- **Looped Systems and Dead End Mains**
- **Preventing Contamination**
- **System Repairs**
- In wet excavations, large quantities of hypochlorite should be applied to open trench area to lessen the danger of contamination.
- The interior of all pipes and fittings used in making the repair must be swabbed or sprayed with a one percent hypochlorite solution before they are installed.

OPERATOR BASICS

- **5. Distribution Systems**
- **System Components: Construction and Repair**
- **Looped Systems and Dead End Mains**
- **Preventing Contamination**
- **System Repairs**
- Once the repair has been completed, water should be held in the line as long as possible to give the opportunity for the chlorine to kill the bacteria. In most cases, the operator will be asked to get the system back into service as quickly as possible. The system should then be flushed and the nearby customers should be notified and asked to flush their lines.
- Coliform samples should be taken on both sides of the main break after pipe repair. If positive results are found, the system should again be flushed.
- Samples should be taken and the main taken out of service if contamination is observed. After satisfactory coliform results are obtained the water main may be returned to normal service.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.3Record Keeping**
- The operator should keep a file with a distribution system map showing the location of all valves and valve boxes, hydrants, and pipe with pipe diameter indicated.
- The map and related files should include notations of repair work.
- Piping needing frequent repair may be due for replacement.
- Additional records should be kept to provide information on equipment, complaints, monitoring and maintenance

OPERATOR BASICS

- **5. Distribution Systems**
- **5.3 Record Keeping**
- Records kept should include:
- - water taste and odor complaint locations
- - repair and leak locations
- - valve and hydrant locations and condition
- - coliform sample locations and sites of unsatisfactory results
- - meter totalizer readings
- - amount of water produced
- - tank inspection dates and findings
- - tank maintenance dates and details
- - pump maintenance and repair dates and details
- - water quality monitoring dates, locations and results
- - water treatment records and chlorine residuals maintained, if applicable- spare parts inventory
- - operator and owner's manuals for all equipment.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.3 Record Keeping**
- This information is essential for tracking performance and problem areas of the water system. It is also needed to document water quality provided to customers and to indicate the need for improvement projects.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.3 Record Keeping**

- Each system also needs to maintain financial records of various types.

OPERATOR BASICS

- **5. Distribution Systems**
- **5.3 Record Keeping**
- **Asset management** is a planning process that ensures the utility has the most value from each asset and has the financial resources to rehabilitate and replace them when necessary.
- Asset management also includes developing a plan to reduce costs while increasing the efficiency and the reliability of assets.
- Successful asset management depends on knowing about system’s assets and regularly communicating with management and customers about system’s future needs.

OPERATOR BASICS

- **5. Distribution Systems**

5.4

- **Cross-Connection and Backflow Defined**

- A cross-connection is a **direct or indirect** connection between a potable water system and any other liquid, gas, or other substance.

- 5. Distribution Systems

5.4

- **Cross-Connection and Backflow Defined**
- A **direct connection** is a physical link between the piping arrangements of a potable and non-potable system.

Figure 1: A common cross-connection (the hose)

- 5. Distribution Systems

5.4

- **Cross-Connection and Backflow Defined**
- An **indirect connection** is where the water itself makes the connection such as a hose from a potable supply submerged in contaminated water, or a leaking pipe that "pools" water around the break.

- 5. Distribution Systems

5.4

- **Cross-Connection and Backflow Defined**
- Backflow is the unwanted reverse flow of water, gases or other substances into a potable water supply distribution system. It can potentially occur at any time there is a cross connection between the potable supply and any source of pollution or contamination
- Backflow occurs when conditions in the system cause back-siphonage or back-pressure.

- **5. Distribution Systems**

5.4 Cross-Connection and Backflow Defined

- Back-siphonage backflow can occur when a negative pressure (below atmospheric pressure, or a vacuum) develops in the distribution system. This can allow pollutants or contaminants to be siphoned into the water system.
- Negative pressure can be caused by undersized pipes, pipeline breaks, or high withdrawal rates, as when fire hydrants are used. Small systems on hilly terrain are particularly vulnerable to negative pressure, because heavy water use at the lower elevations can literally siphon the water away from the higher-elevation portion of the distribution system.

- 5. Distribution Systems

5.4 Cross-Connection and Backflow Defined

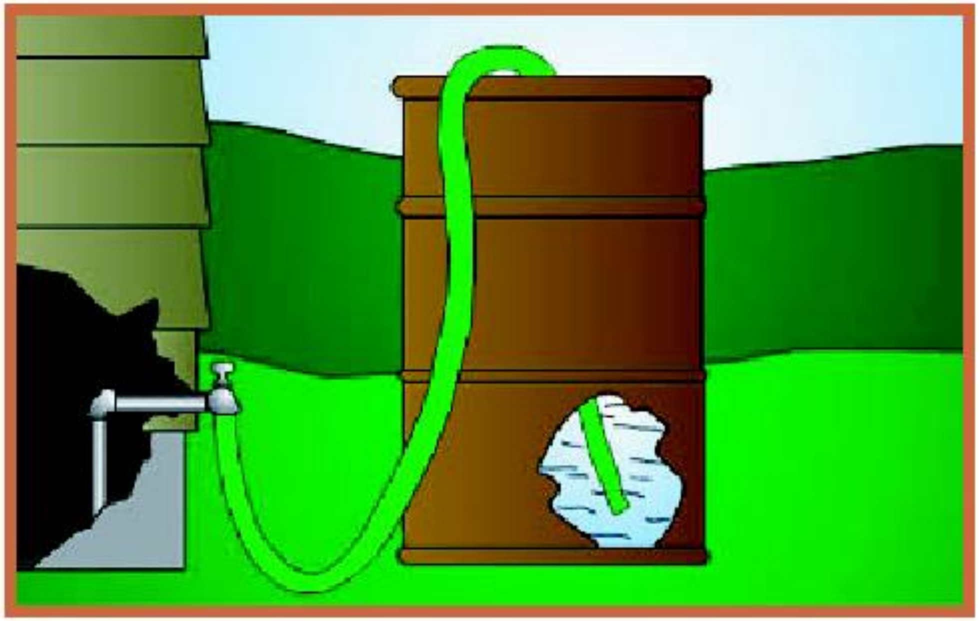


Figure 2: Common situations can lead to back-siphonage

- **5. Distribution Systems**

5.4 Cross-Connection and Backflow Problems

- Cross connections and unwanted backflow have serious health implications.
- Many cases have been documented tracing serious disease outbreaks directly to a specific cross-connection and backflow condition in a potable system

- 5. Distribution Systems

5.4 Cross-Connection and Backflow Problems

- Although major disease outbreaks get plenty of publicity, it is likely many backflow events occur in systems and go unnoticed. This is because too few people may be affected to create a public stir, or persons who become ill may just think they have the flu.
- A backflow event may also be of a short duration. Monthly bacteriological testing may not catch the localized and short-term contamination event. Even if contamination is widespread, contaminants can be flushed out of the system before the next sample is collected

- **5. Distribution Systems**

5.4 Cross-Connection and Backflow Problems

- An occasional unsatisfactory bacteriological test result may be an indication of cross-connection problems and should not be dismissed as sample collection error or a problem with the analytical laboratory.
- The conditions that caused the contamination event may already have passed before check-samples are collected.
- Field Conditions (Next Slide)

5.4 Cross-Connection and Backflow Field Conditions

- Operators should be alert to operational conditions that could cause a cross- connection and backflow situation.
- Was power to the pump off? Was the pump out of service for repairs? Was there a line break that caused an unusually high amount of water loss in one area?

- **5. Distribution Systems**

5.4 Cross-Connection and Backflow Controls

- There are two types of Controls:
- containment and
- isolation

- **5. Distribution Systems**

5.4 Cross-Connection and Backflow Controls

- Containment is the primary protection for a water system. It is the responsibility of the water purveyor.
- The intent of this type of control is to restrict the backflow of pollutants or contaminants from the consumer facility back into the water system.
- An example is a requirement by a municipality that an appropriate backflow preventer be placed between a municipal water main and a hospital or industrial site.
- A small subdivision might require a backflow preventer on every service line to every residence.

- **5. Distribution Systems**

5.4 Cross-Connection and Backflow Controls

- Isolation is secondary protection provided by the consumer to protect the on-site portion of a water
- system.
- Typically construction of this part of the water system should be governed by local plumbing codes.

- 5. Distribution Systems

5.4 Cross-Connection and Backflow Devices

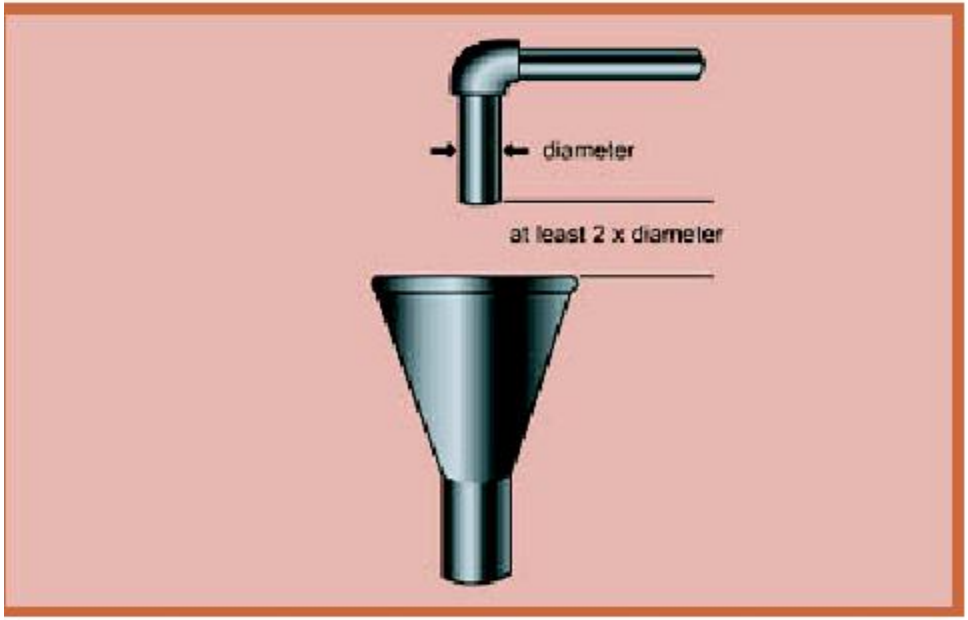


Figure 1: Air gap (F.40)

- 5. Distribution Systems

5.4 Cross-Connection and Backflow Devices

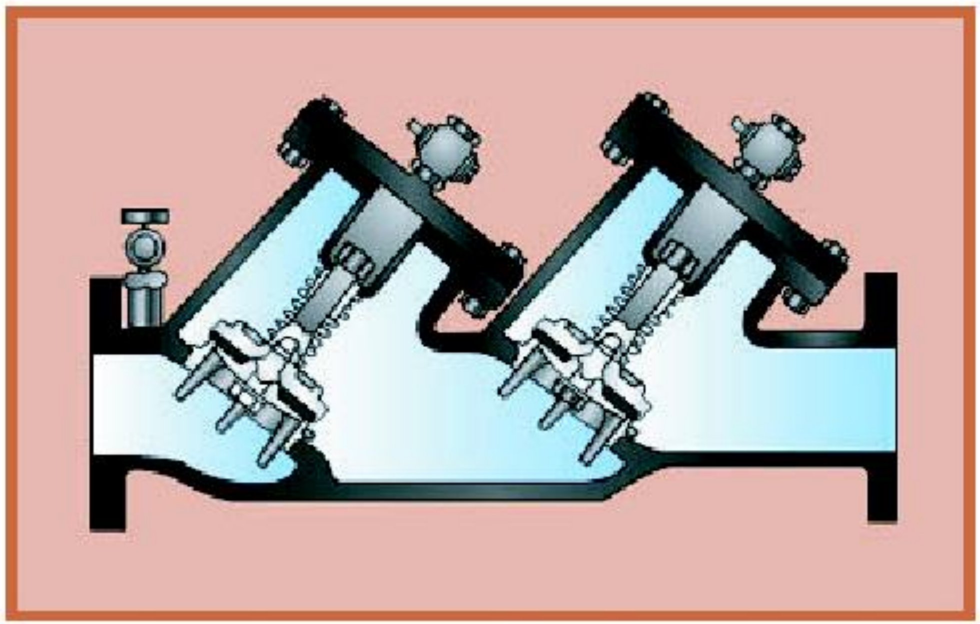


Figure 1: Double check valve assembly (DC) (F-42)

- **5. Distribution Systems**

5.4 Cross-Connection and Backflow Devices

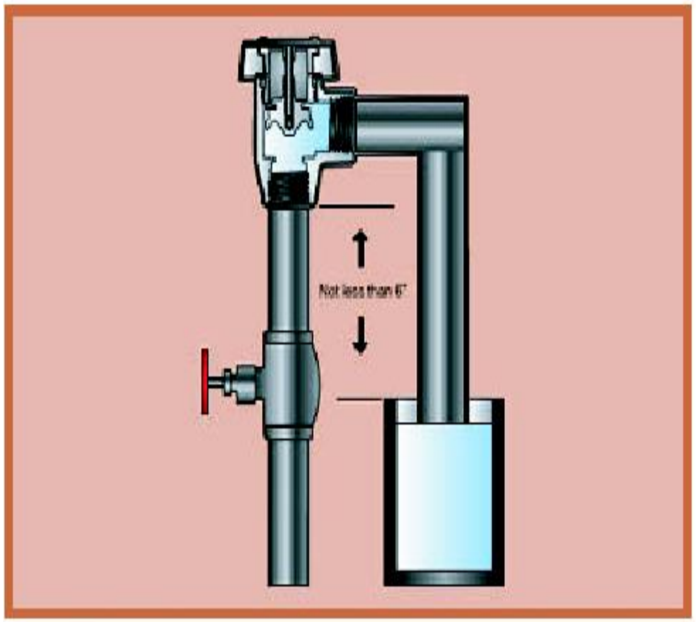
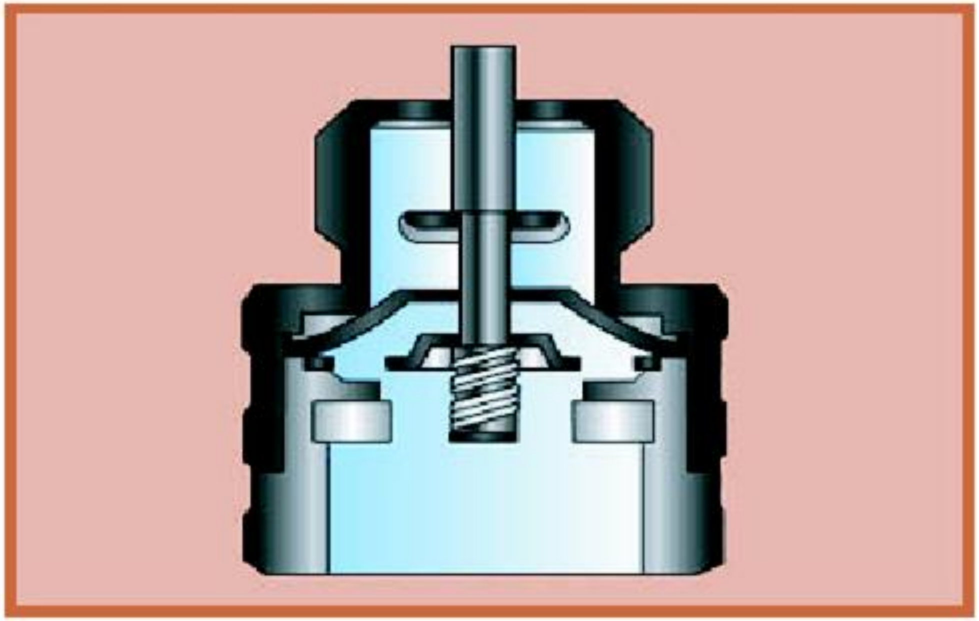


Figure 1: Atmospheric vacuum breaker (AVB) (F-10)



OPERATOR BASICS - Acknowledgements